THE ECOLOGY OF NON-NATIVE RED-EARED SLIDERS AND THEIR POTENTIAL IMPACTS ON THE NATIVE FAUNA OF SINGAPORE

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“Slow but steady wins the race”,

said the turtle as he crossed the finish line.

- Aesop’s fables

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Summary

The red-eared sliders (*Trachemys scripta elegans*), originally from North America, has been considered an invasive species and has established populations outside of its natural range. The possible impact of this species has not been well studied despite being imported to many countries as pets and having been considered a pest in many countries. Furthermore, nothing is known of this species' ability to adapt to a tropical equatorial climate. This study examines various aspects of the red-eared slider's ecology in Singapore and it was found that populations were denser at ponds than at reservoirs. The red-eared slider is an opportunistic omnivore and exhibits diurnal activity which is typical of this species. However it appears to be capable of modifying its reproductive strategy to produce smaller clutches of eggs at a higher frequency throughout the year, an adaptation to the aseasonality of this region. Local attitudes and opinions towards the introduction of the red-eared slider were also examined and despite being educated on the origin of this species, release of red-eared sliders is widely accepted and practiced among Singaporeans. The results of these studies indicate that the red-eared slider fulfills many criteria that characterise a successful invasive species. These information were used to create a set of recommendations as a framework for the control and management of populations of red-eared sliders in Singapore and other countries within the region.

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Introduction to the Order Testudines

The class Reptilia represents the earliest group of animals adapted to life on dry land by laying eggs with a calcareous or parchment-like shell complete with yolk sac and embryonic membranes (although some are able to give birth to live young). The presence of scaly skin also minimises cutaneous water loss. All reptiles are ectotherms, unable to maintain body temperature by physiological means but rather through behaviour modification.

There are four extant orders within the class Reptilia — Squamata (lizards and snakes), Sphenodontida (tuatara), Crocodylia (crocodilians) and Testudines (turtles). All of these orders, with the exception of Testudines, belong to the subclass Diapsida. Testudines is the single surviving branch of the subclass Anapsida, from the superorder Chelonia, hence their common moniker 'chelonians'. Members of this group are characterized by the possession of a primitive skull with a solid cranium with no temporal openings (figure 1.1). The single most distinguishing feature of Testudines is the fact that all members possess a special bony or cartilaginous shell developed from their ribs and spine. The upper half of the shell, the carapace, typically consists of 50 bones and is joined to the plastron (the lower half) via a bridge and the bones are typically covered with horny scutes (figure 1.2) (Ernst and Barbour, 1989). Some families of testudines do not have the covering of horny scutes but have a thick layer of leather skin instead. These are referred to as leatherbacks or softshells.

(a) (b)

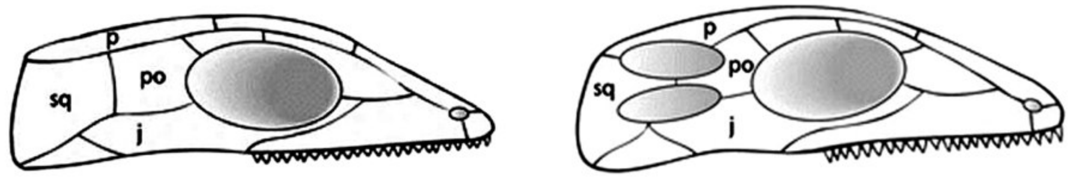
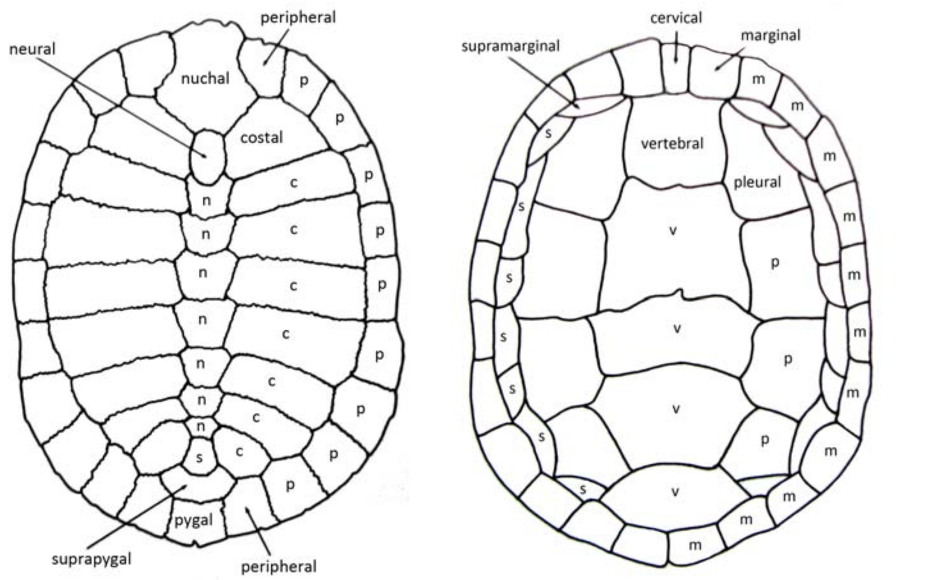


Figure 1.1 Skull designs seen in reptiles: a) anapsid skull with no temporal openings behind the eye socket (turtles); b) diapsid skull with two openings behind the eye socket (crocodylians, lizards and snakes). Adapted from Benton (1993).

(a)



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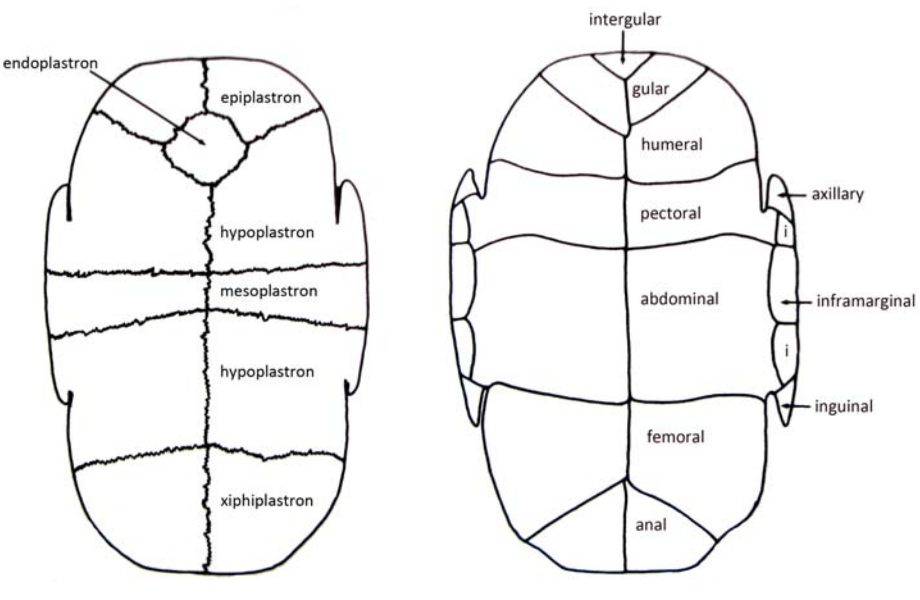


Figure 1.2 A) Caparacial bones (left) and scutes (right) and b) plastral bones (left) and (scutes). Adapted from Ernst and Barbour (1989).

Testudines are generally referred to as turtles, but the terms terrapins and tortoises are used to describe freshwater semi-aquatic species and terrestrial species respectively In some cases, the term "turtle" is used to refer to marine turtles exclusively. For the purpose of this dissertation, the term turtle will be used to refer to all chelonians.

There exists 458 extant species (in 14 families) of turtles worldwide (Fritz and Havaš, 2006). Of these 14 families, two consist of marine species, one consists of purely terrestrial species and the rest are aquatic or semi-aquatic freshwater species. The family Geomydidae includes old world pond turtles (91 species and sub-species) and the family Emydidae includes new world pond turtles (96 species and sub-species).

Turtles occur in various habitat types, ranging from marine to freshwater to terrestrial areas and they are major biodiversity components of the ecosystems that they inhabit, often serving as keystone species (Moll and Moll, 2004b) As with many other organisms, turtles are highly affected by anthropogenic threats. Unprecedented habitat destruction and alteration, physical, chemical and hormonal pollution of habitats, alteration of ecosystem dynamics by invasive species, exploitation as a food source, global warming (affecting temperature-dependent sex determination and habitat stability) and introduced pathogens (Moll and Moll, 2004a) are just some of the threats facing this diverse group. For example, marine turtles fall prey as by-catches of several large-scale fishing methods. They are also plagued by physical pollution such as the consumption of jellyfish-looking plastic bags and being entangled by drift nets. Indiscriminate alteration of natal beaches where these turtles nest also result in a significant decrease in the numbers of nesting sites around the world. In South East

Asia, turtles such as *Cuora trifasciata* and *Batagur baska* are considered critically endangered, having being exploited for food and medicinal purposes.

Currently, of the 458 extant species of turtles, 148 are considered endangered or vulnerable (Turtle Conservation Fund, 2002). One famous example of the plight of turtles includes the Galapagos Tortoise, *Geochelone nigra abingdoni,* currently extinct in the wild and represented by a single male. Thus, there is an urgent need for national parks and other protected areas to consider turtle conservation in their designs, and to apply existing research results and field survey data to the management of this group of animals. Studies documenting habitat, diet, reproduction, density, ecology, and other life history characteristics of native terrapins in the wild are important to increase our understanding of their biology and to help manage populations (Turtle Conservation Fund, 2002).

1.2 The red-eared slider

1.2.1 Taxonomy and natural ranges

The species of interest in this dissertation, *Trachemys scripta elegans*, belongs to the speciose and diverse family Emydidae. The Emydid turtles were previously separated into two distinct subfamilies, the Batagurinae (old world pond turtles) and the Emydinae (new world pond turtles) (Ernst and Barbour, 1989). However, the family Emydidae now consists of new world turtles, found from Canada to central South America and the West Indies, with the exception of *Emys*, which ranges from Europe and northern Africa into the Middle East (Fritz and Havaš, 2006).

The genus *Trachemys* Agassiz 1857 is one of the 10 genera placed under the subfamily Emydinae, and commonly known as sliders. There had been much taxonomic confusion surrounding this genus and had in some historical literature, been included under *Chrysemys* and *Pseudemys*. However, a revision of this group, evidenced by several characters, distinguished the *Trachemys* as distinct (Seidel and Smith, 1986). To date, *Trachemys* comprises six species, one of which is *Trachemys scripta* (Schoepff, 1792). This species is notoriously variable throughout its native range and currently comprises of 14 subspecies that have been described and named.

Trachemys scripta elegans (Wied, 1839) is the subspecies imported into Singapore for the pet trade. This particular subspecies ranges from Illinois to the Mexican Gulf (figure 1.3), and can be distinguished from conspecifics by a suite of characters; the presence of a wide red postorbital stripe, narrow chin, one transverse yellow stripe on each plural, and the presence of one large dark ocellus on each plastral scute (figure 1.4). The bright red postorbital stripe lends this subspecies the common name "red-eared slider".

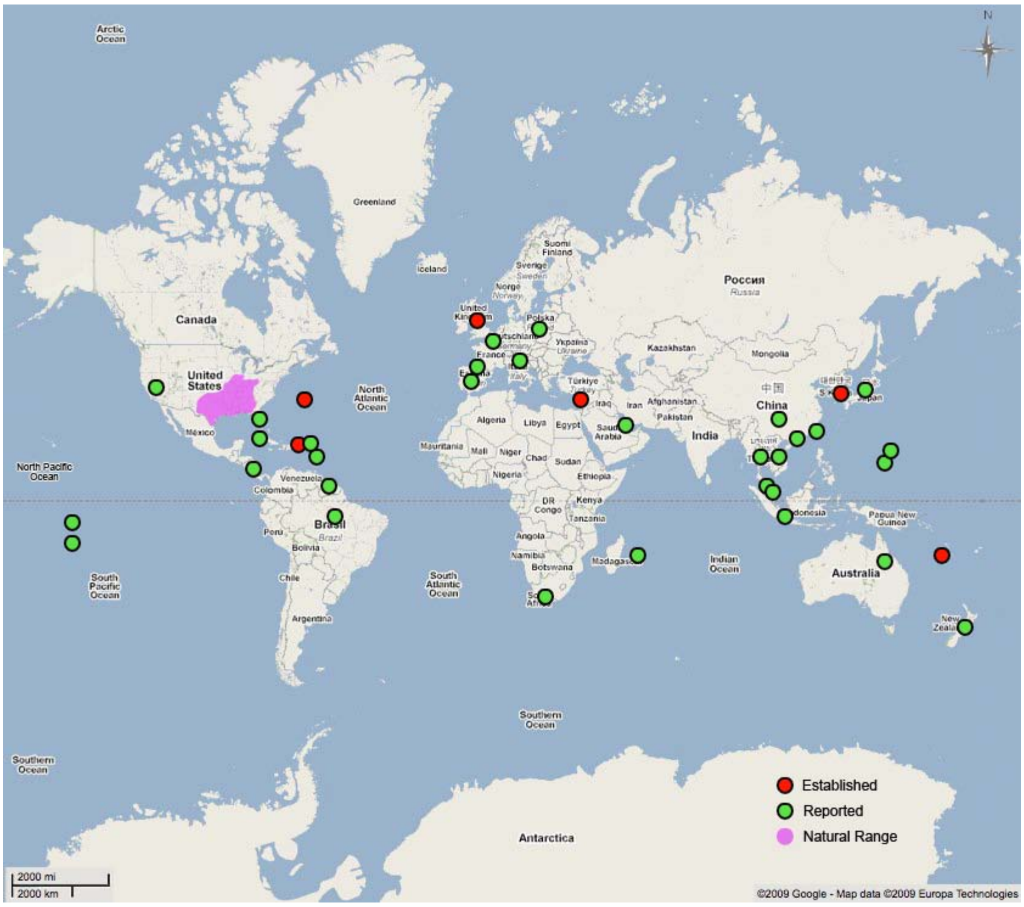


Figure 1.3 Natural and introduced distribution of the red-eared slider

(a) (b)

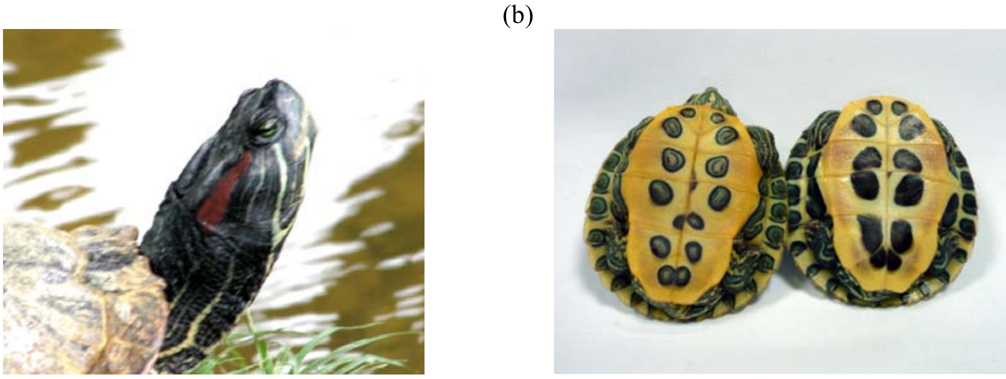


Figure 1.4 Photograph of red-eared slider (*Trachemys scripta elegans*) showing a) red post-orbital stripe and b) ocelli on plastral scute.

1.2.2 Ecology and Biology

Most research on the ecology and biology of red-eared sliders has been in its native temperate regions (Cagle, 1942; 1944a; 1944c; 1944b; 1946; 1950). This species is generally diurnal. Red-eared sliders spend most of the rest of the time basking on shores and fallen logs and sometimes while floating (Morreale and Gibbons, 1986). Red-eared sliders sleep at night while lying on the bottom or resting on the surface vegetation (Ernst, 1972). However, some males may move overland at night (Ernst, 1972). Basking, feeding, and courtship has been correlated with temperature and this species does not feed beyond the extremes of the temperature range of 10 – 37˚C (and consequently do not grow) (Cagle, 1946). Adult red-eared sliders are opportunistic omnivores and eat almost anything, including plants and small animals. Juveniles, on the other hand, are mainly carnivorous, eating insects, spiders, snails and tadpoles (Newbery, 1984; Parmenter and Avery, 1990). Red-eared sliders have been observed to feed at any time of the day but feeding usually takes place in the early morning and late afternoon (Newbery, 1984). Aggressive interactions during basking among four species of emydid turtles have been observed (Lindeman, 1999) but other than this particular study, this aspect of their behaviour is not well documented.

1.2.3 Current distribution of red-eared sliders

Although originally from North America, the presence of red-eared sliders has been reported in Guam (Mariana Islands), Taiwan, Korea, Japan, Malaysia, Singapore, Thailand, Indonesia, Sri Lanka, New Zealand, Israel, Arabia, Bahrain, South Africa, Brazil, Panama, Bermuda, Italy, Spain, Britain, France, Guadeloupe, Guyana, Martinique, Polynesia, and Reunion, as well as in North America outside its natural range (figure 1.3)(Newbery, 1984; Bouskila, 1986; Uchida, 1989; Ernst, 1990; McCoid, 1992; Platt and Fontenot, 1992; da Silva and Blasco, 1995; Moll, 1995; Ota, 1995; Luiselli et al., 1997; Servan and Arvy, 1997; Chen and Lue, 1998; Thomas and Hartnell, 2000; Outerbridge, 2008).

Within Asia, many countries have reported the appearance of red-eared sliders in water bodies. Ramsay et al. (2007) described the status of red-eared sliders in Asia. In Bangkok, Thailand, adult sliders are abundant in almost all ponds in parks and temples, reservoirs, canals and even in the wild (Cox et al., 1998; Jenkins, 1995). At the Batu Caves near Kuala Lumpur, Malaysia, adult semi-captive sliders have been observed in ponds (Jenkins, 1995). The Asian Turtle Conservation Network has listed red-eared sliders from Sumatra, Java, Kalimantan (Borneo), Sulawesi, and Irian Jaya (Hendrie and Vasquez, 2004). In Vietnam, hatchlings have been found in lakes, probably due to release for religious reasons. Juveniles and two adults were also observed (Turtle Conservation Indochina, 2003). In Japan, sliders made up 62% (3708) of all turtle records (Turtle and Tortoise Newsletter, 2004) and can be found in every prefecture (Brazil, 2005). The red-eared slider has been found to be the second most abundant turtle of all the rivers surveyed in Taiwan (Lue and Chen, 1996). The Hong Kong Reptile and Amphibian Society recorded the presence of sliders in the wild in China by (www.hkas.com). Surveys of Kau Sai Chau, Sai Kung by Dahmer et al. (2001) found a new record for a slider in 2000 compared with a 1993 survey (Lau and Dudgeon, 1999).

Although the red-eared slider is now found on every continent except Antarctica (Salzberg, 2000), the ecological effects of introductions of red-eared sliders have been poorly documented (Platt and Fontenot, 1992). With its broad ecological tolerances, omnivorous diet, and dispersal ability, there is the potential for establishing breeding populations in many areas of the world but little research has been carried out yet. In some countries, where it has been introduced, red-eared sliders have been said to compete with indigenous species for food and basking spots (Salzberg, 2000). There is some preliminary evidence that introduced red-eared sliders, now common in Bermuda, are eating mosquito fish (Gambusia sp.) as well as a variety of local snails and arthropods (Davenport et al., 2003; Outerbridge, 2008). In almost all countries where they have been introduced, there already exist species of indigenous freshwater turtles.

1.3 Past and present studies on red-eared sliders

Although there has been research carried out on the possible impacts of sliders in Europe, there is no evidence that sliders are indeed a threat to native turtles such as *Emys orbicularis*, *Mauremys leprosa*, and *Mauremys caspica* or to the freshwater ecosystems they have established themselves in. However, they have been found to out-compete *Emys orbicularis* for basking sites in an experimental set up in France (Cadi and Joly, 2003). Furthermore, sliders are widely distributed and reproducing (production of both sexes in the wild) in three regions that *Emys orbicularis* occurred in (Servan and Arvy, 1997; Cadi et al., 2004). Comparing biological parameters with *Emys orbicularis*, red-eared sliders were bigger and had larger populations, in addition to having a more precocious reproduction with larger and heavier eggs (Servan and Arvy, 1997). Male red-eared sliders also mature at a smaller size and earlier age than *Emys orbicularis*: two to five years (Cagle, 1950) versus six to 16 years for *Emys orbicularis* (Servan and Arvy, 1997). Researchers in Spain have suggested that the sliders breeding in south-western Spain could become established and might potentially compete with indigenous species of turtles such as *Mauremys leprosa* and *Emys orbicularis*, especially since the habitat and climate are similar to the slider's natural range (Morreale and Gibbons, 1986; da Silva and Blasco, 1995). In Valencia there is evidence of reproduction; nest sites and hatchlings (Sancho et al., 2005; N.F. Ramsay and R.M. O'Riordan pers. comm.)

Outside of their native range, sliders have adapted to the different seasons of their new habitats. They breed from late August to February in South Africa, which is equivalent of spring and summer months of March to September in their native range. Successful reproduction has also been observed in sliders kept in large open pits in South Africa, indicating that reproduction might also be successful for feral populations. It is also suspected that the sliders have displaced the native range of *Pelomedusa subrufa* through competition. Warnings have been made that if the slider's range expands, it can be expected that indigenous species will be displaced (da Silva and Blasco, 1995). In Israel, sliders are believed to compete with *Mauremys caspica* (Bouskila, 1986) and in 1997, the European Union banned the import of red-eared sliders. This was based on the grounds that they had an unfavourable effect on the indigenous European pond terrapin (*Emys orbicularis*).

Established populations of red-eared sliders have been found in Australia (Burgin, 2007) despite the fact that in Queensland, the red-eared slider was declared a Class 1 pest species in 2003 (Department of Primary Industries and Fisheries Queensland Government, 2002), Class 1 pests are identified as species that have the potential to cause adverse economic, environmental, or social impacts.

Asia warrants a high priority in immediate action plans as it is the world's most speciose region for turtles, more than 75% of which are considered Critically Endangered, Endangered, or Vulnerable. About 91% of the turtles on the IUCN Red list come from this region (Turtle Conservation Fund, 2002). Further, 19 out of 28 of the world's Critically Endangered turtle species occur in the Asian region (IUCN, 2008).

Research effort and funding so far has focused on indigenous species which are both often poorly known and highly endangered. Decline in species numbers can be attributed to habitat loss due to development, increasing agricultural, industrial and domestic pollution of waterbodies and over-collection for sale (Ramsay et al., 2007). Introduced non-native species also pose a threat to the survival of indigenous species by being potential competitors or perhaps carrying new diseases and parasites. Commercial farming of turtles in Asia also poses a risk of becoming a reservoir for diseases. Furthermore, in 2000, the slump in the economy led to the bankruptcy of *Pelodiscus sinensis* farms in Thailand and Malaysia (CITES, 2003). This led to the suspected release of unsold animals into the wild

Red-eared sliders are currently imported into many Asian countries, unlike in the EU where the import was banned in 1997. The demands of the Asian market for turtles are different from that in Europe and North America. In the latter, the market is driven mainly by the demands of the pet trade. In Asia however, turtles are not only sold in the growing pet trade, but are also traded as medicinal and non-medicinal food sources (especially soft-shelled turtles). For example, the critically endangered three-striped box turtle (*Cuora trifasciata*) can fetch US$2000 on the black market because it is believed that the plastron is a cure for cancer (Asian Turtle Conservation Network, 2006). In Asia, turtles are also a popular choice of animal purchased for the purpose to release them for religious reasons such as to generate good karma (mercy releases) (Chen and Lue, 1998; Lue and Chen, 1996). With the thriving economy of Asian nations and the increase in consumer-driven needs, the demand from these three markets within Asia is rising (Ramsay et al., 2007).

Unfortunately, prior to the present dissertation, little research had been carried out in Asia on non-indigenous terrapins, including impacts of red-eared sliders on indigenous species, although there is ongoing research in Singapore.

1.4 Environment of Singapore

Singapore is an island republic just 137 km north of the Equator. There are no seasons except for two main monsoon seasons, the Northeast monsoon season that occurs from December to March, and the Southwest monsoon season from June to September, and two inter-monsoon periods from April to May and October to November (National Environment Agency Meteorological Services, 2007). While there are no distinct wet and dry periods, May to July is generally drier and November to January is generally wetter, with an annual average of 2342.2 mm of rain. The temperature ranges from 23°C – 34°C during the year with April to August being warmer and December to January being cooler. The diurnal temperature range is slight, from 31°C to 33°C during the day, and 23°C – 25°C during the night. The mean annual relative humidity is 84.2% and often reaches 100% during rainy periods (National Environment Agency Meteorological Services, 2007).

Figure 1.5 Map of the region showing the location of Singapore

Since gaining independence in 1965, Singapore has undergone rapid urbanisation in less than 20 years. Despite having been established as an entrepôt colonial port since 1819, development had been concentrated in the southern-central part of the island until the nation's independence (Teo et al., 2004). During the period of development, centralised planning led to land allocation specifically for residential, industrial and commercial purposes. The business, civic and cultural districts were located within the southern-central part of the city and the rest of the island was divided into multiple industrial estates and new (residential) towns. These new estates were interspersed with recreational / open spaces and water catchment areas (Teo et al., 2004). These nature parks provided green lungs for the city and also contributed much recreational and aesthetic value to the landscape hence lending Singapore the nickname the "Garden City". Although Singapore is regarded as having successfully managed its environmental resources, much of the island's original forest and swamps decreased dramatically in land size (Teo et al., 2004; Wong, 1989). Of the original 578 km^2 original forest cover, only 28.6 km^2 remained (less than 10% of which is primary) after clearing to make way for housing and infrastructure. The current landscape is mostly urban and suburban, with tall buildings and many concrete structures and concrete/Tarmac surfaces.

The remaining natural areas include four nature reserves, such as the Central Catchment Nature Reserve which functions as a water catchment area. MacRitchie (figure 1.6a) and the Upper and Lower Peirce Reservoirs (figure 1.6b) (including their lowland dipterocarp forests) are part of the Central Catchment Nature Reserve. MacRitchie Reservoir is Singapore's oldest reservoir and was created by impounding water from an earth embankment in 1868 (National Parks Board, 2008a). Because of the development of the reservoir, the forest surrounding it was preserved to provide a water catchment area. Some parts of the forest are still primary, while other parts contain patches of rubber trees, which are remnants of plantations from the 1800s. Upper and Lower Peirce Reservoirs are the sources of water for the Kallang River (Singapore's longest river). A dam was built across what was then known as the Peirce Reservoir to create the two sections, with a total capacity larger than the original reservoir. As with MacRitchie Reservoir, development of the surrounding forest was halted when the construction of the reservoirs was commissioned (National Parks Board, 2008a). In addition to serving their water catchment purposes, all three reservoirs are currently also popular recreation areas for Singaporeans to relax and enjoy nature. Boardwalks and park facilities are among some structures that have been built alongside some parts of each reservoir. There are some reservoirs with only sparse tree growths in adjacent areas such as Bedok Reservoir (figure 1.6c). In these instances, the areas surrounding these reservoirs are still used as recreational grounds for the general public. The reservoirs are managed by the Public Utilities Board of Singapore (PUB), while the parks and green areas surrounding them are managed by the National Parks Board (NParks).

The other nature reserves include Bukit Timah Nature Reserve (a primary dryland hill dipterocarp forest), Sungei Buloh Wetland Reserve (wetlands important for migratory birds) and Labrador Nature Reserve (the only accessible rocky sea-cliff shore on Singapore's main island). Another area that has been protected from development includes the forested areas used by the Ministry of Defence (MINDEF) for live firing exercises. The general public has restricted access to these patches of greenery and consequently, they are still more or less intact and serve as some of the few pockets of untouched nature remaining in Singapore.

The island of Singapore is also dotted with nature parks, many of them containing ponds. Areas surrounding a reservoir are also sometimes developed into parks and nature areas. There are currently 34 parks under the purview of the National Parks Board of Singapore (NParks). Swan Lake (figure 1.6d) and Eco Lake (figure 1.6e) at the Singapore Botanic Gardens are two such ponds that are frequently visited by members of the public for recreation. The cleaning and maintenance of these ponds are often outsourced to commercial gardening and cleaning companies (pers. obs.). Most reservoir and pond life tend to deliberately introduced and includes plants and animals that are not native to Singapore but carry ornamental value (Tan et al., 2007).

Despite efforts to conserve natural areas, at least 28% of Singapore biodiversity has gone extinct due to the dramatic habitat loss (Brooks et al., 2003). This includes 53%, 67% and 59% of forest species of freshwater fish, and 0%, 11% and 13% o their counterparts from open-habitats (Brooks et al., 2003). Furthermore, 71% of the animal biodiversity in Singapore is considered threatened based on the criteria set by the International Union for the Conservation of Nature (Davison et al., 2008). These threatened animals include 100% of mammal, reptile, amphibians and fish species and 98% of bird species (Davison et al., 2008). The low levels of endemism in Singapore, due to late separation from Peninsular Malaysia (Corlett, 1992), means that most of these extinctions were of local populations. However, local extinctions in Singapore warn of an impending biodiversity crisis for Southeast Asia, should habitat destruction continue to take place at current rates (Sodhi et al., 2004).

(a) MacRitchie Reservoir

(b) Lower Peirce Reservoir

(c) Bedok Reservoir

(d) Swan Lake

(e) Eco-Lake

Figure 1.6 Water bodies at various localities in Singapore.

The remaining biodiversity in Singapore definitely warrants conservation efforts, especially when new species are still being discovered locally. While the peak of habitat destruction has passed, native species face new challenges in the form of introduced species. Studies on introduced freshwater species in Singapore showed that the introduced and native species of fish do not occur in the same habitat; native species preferring undisturbed forest streams and the introduced taxa populating mostly open-country waters (Ng et al., 1993). However, there are examples of certain highly adaptable species that have successfully displaced local populations. One example is the non-native changeable lizard (*Calotes versicolor*) which is now more common than the green-crested lizard (*Bronchocela cristatella*), its local equivalent (Tan et al., 2007). Many other non-native animal species are also commonly found in Singapore. Some examples include the giant snakehead (*Channa micropeltes*) the American bullfrog (*Rana catesbeiana*) and the giant apple snail (*Pomacea sp.*) (Ng, 1992; Ng et al., 1993).

1.5 Status of freshwater turtles in Singapore

There exists at least 11 species of indigenous and introduced species of turtles reported from Singapore (Lim and Chou, 1990; Lim and Lim, 1992; Chou, 1995; Teo and Rajathurai, 1997). A noteworthy native species is the Mangrove or River Terrapin *Batagur baska*, which is ranked as Critically Endangered by the IUCN and was first on the list of the World's Top 25 Most Endangered Turtles released by the Turtle Conservation Fund in May 2003. Two other native species of turtles, the Spiny or Spiny Hill Terrapin *Heosemys spinosa* and the Giant Soft-shell Turtle *Pelochelys cantorii* are categorized as Endangered by IUCN. About 5% of Singapore's reptiles have become extinct over the last 183 years (Brooks et al., 2003), possibly due to the loss of natural habitats. The red-eared slider is an introduced species of turtle that has become common in Singapore in large numbers (Goh and O'Riordan, 2007).

Red-eared sliders are being exported widely as pets from farms in the United States, China and Hong Kong due to their hardiness, easy maintenance and low cost (Goh and O'Riordan, 2007). The occurrence of the sliders in the wild in Asia is most probably due to the intentional or unintentional release by pet owners. This is common as few pet owners are aware that the female red-eared slider can grow to more than 20 cm in carapace length. This is aggravated by the fact that young sliders are sometimes marketed as “miniature” terrapins, and/or easy “starter” pets for novice pet owners. Rarely are the new pet owners prepared to take care of the sliders for more than 30 years (the average life span of the sliders), especially when the sliders lose their attractive coloration and become increasingly aggressive with age.

In Singapore, there are the same three markets as mentioned earlier for turtles. The red-eared slider has been the only permitted species of turtle imported for the pet trade in Singapore until 2008 (when the Malayan box terrapin, *Cuora amboinensis* was also approved for sale). The numbers of red-eared sliders imported both for sales locally and re-export has increased drastically from 2001 to 2007, peaking in 2006 at more than one million animals (Agri-Food and Veterinary Authority, Singapore) Table 1.1 shows a decline in the numbers imported from 2001 to 2003, but then an increase again in 2004 to more than half a million in 2005. Numbers imported increased by more than double for 2006 and 2007. Table 1.1 also shows that the majority of the imports were from U.S.A., with the rest of the imports coming from either China or Hong Kong. To date, there are no known turtle captive-breeding farms in Singapore (Lye Fong Keng, AVA, pers. comm).

Table 1.1 Numbers and origins of red-eared sliders imported into Singapore from 2001 to 2007 (Source: Agri-Food & Veterinary Authority, Singapore).

Year	From U.S.A.	Total imported
2001	284 000	301 245
2002	266 604	269 904
2003	147 363	149 863
2004	388 236	389 036
2005	522 502	587 852
2006	-	1 355 734
2007	-	1 253 091

Turtles are also consumed in Singapore. While the main species imported for the food trade is *Pelodiscus sinensis*, it is commonly supplemented with red-eared slider meat in some food stalls. Red-eared sliders are also commonly released into the wild due to religious reasons. Some practitioners of Buddhism believe that releasing captive animals would lead to good luck and good karma. Animals that are released include various species of birds, fishes and terrapins, as they can be easily purchased from pet stores. The release of introduced terrapins for either religious or other reasons has gone on for decades (Lim and Lim, 1992).

Unfortunately, there is a paucity of data for the red-eared sliders in the tropics and nothing is known of their status in Singapore. Previous documentation of their presence includes a mention in the book Singapore Green by Bonnie Tinsley (Tinsley, 1983). The red-eared slider was also included in the herpetofauna checklist of Singapore by Lim and Chou (1990) and in a study on the local nature reserves. Teo and Rajathurai (1997) noted that while this species is abundant in the Singapore

Botanic Gardens, they are not yet established in the forest streams. Red-eared sliders have also been observed laying eggs at the Singapore Botanic Gardens, Singapore Zoological Gardens and in parks and reservoirs in Singapore (pers. comm., Nparks and SZG management, Liew W.H. and Amy C.).

Concerns are raised over the status of these invasive turtles not just because they are a possible cause of zoonotic transmission of *Salmonella* to humans, but also because of the potential impact that they might have on the native flora and fauna, especially native species of turtles. The native turtles of Singapore include the black marsh terrapin (*Siebenrockiella crassicollis*) and the Malayan box terrapin (*Cuora amboinensis*), both of which share a similar habitat with the red-eared slider. The impact of the red-eared sliders on the native species of Singapore is yet unknown.

Prior to this project no research had been carried out on the basic biology and ecology of red-eared sliders nor other introduced turtles and their potential impact on native species in Singapore. However, effects of light intensity, photoperiod and temperature on the growth and survival of red-eared slider hatchlings have been studied in the laboratory (Chou and Venugopal, 1980; Chou and Venugopal, 1984; Chou and Venugopal, 1986). Sulaiman (2002) noted that a major concern for conservationists in Singapore is that red-eared sliders may out-compete local species, such as the spiny terrapin, *Heosemys spinosa* and the Malayan box terrapin *Cuora amboinensis*.

1.6 Overview of this study

The scope of this study is restricted to Singapore, where a unique situation exists that much of the natural habitat for native species for freshwater turtles has been altered and red-eared sliders are introduced continually via the pet trade. The chapters of this dissertation focus on various aspects of red-eared slider biology and ecology, which has not been studied in a tropical equatorial climate prior to this dissertation. Associated concerns such as the incidence of release and the attitudes and opinions of the public will also be discussed.

1.6.1 Objectives of this dissertation

The overarching objectives of this study are to:

a) Establish and provide baseline data on the biology and ecology of red-eared sliders in the wild in Singapore in order to make an assessment of the potential impacts on the local environment and in other parts of Southeast Asia; and
b) Based on the findings of this study, recommend management strategies to stakeholders for the management of red-eared sliders in Singapore.

1.6.2 Brief overview of chapters

Chapter 2: The distribution, abundance and demography of freshwater turtles

This chapter is the first study carried out to determine the demography of feral populations of red-eared sliders in Singapore. The population size, density and structure were examined at both man-made ponds as well as reservoirs. Any other species of freshwater turtle observed or caught were also noted. Information collected on these red-eared slider populations is useful in understanding the success of establishment of these non-native species in Singapore. This chapter also discusses some methods for studying freshwater turtles specific to Singapore which might be useful for further studies.

Chapter 3: The reproductive biology of red-eared sliders

Despite several anecdotal observations of nesting red-eared sliders in parks and reservoirs in Singapore, there has been no study on reproductive cycles (if any) and the clutch frequency of this species. This study seeks to examine if red-eared sliders exhibit seasonality in reproduction in an aseasonal climate and if clutch frequency is increased in the presence of warmer climates and abundant resources. The ability to increase reproductive output further demonstrates that red-eared sliders have the potential to be a formidable invasive species with greater implications for management of this species both in Singapore and in Southeast Asia.

Chapter 4: The diet of red-eared sliders

It is necessary to gather information on the diet of this species outside of its natural range as little is known of this aspect in feral populations. The gut composition, gut content quantity and seasonality of contents were investigated in red-eared sliders caught over a 13-month period.

Chapter 5: The behaviour of red-eared sliders

This chapter focuses on the comparative behaviour of male and female red-eared slider population at Eco-lake, Singapore Botanic Gardens. This population was observed for twelve months to document daily activity patterns. Observations on courtship behaviour and interactions among freshwater turtles were also documented.

Behavioural data substantiated the findings from other aspects of this dissertation, such as reproduction and dietary preferences of red-eared sliders. The behavioural response of red-eared sliders to being fed by humans is also of interest considering these are animals that were previously pets of humans.

Chapter 6: Survey of pet ownership and attitudes towards releasing of pets

The feral populations of red-eared sliders in Singapore are assumed to be releases from the pet trade. There had been no study assessing the factors that contribute to their release. Four hundred households in Singapore were surveyed to investigate the popularity of red-eared sliders as pets and the extent of release both by the general public and pet owners. Attitudes towards feeding and releasing and the current understanding of legal and ecological issues of red-eared sliders were also examined.

Chapter 7: Conclusions and recommendations for management

The last chapter of this dissertation summarises the key findings of the different sections of this study. Management strategies that seek to address various issues such as the introduction of red-eared sliders and population control are discussed and recommendations are made.

Chapter 2: The distribution, abundance and demography of freshwater turtles in Singapore

2.1 Introduction

2.1.1 Turtles in Singapore

Turtles in Singapore occupy both marine and freshwater environs. In their revised checklist of the reptiles and amphibians of Singapore, Lim and Lim (1992) reported at least 137 reptiles, out of which 14 were turtles. There exist historic records of the green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*) and leatherback turtles (*Dermochelys coriacea*) occurring in the coastal areas of Singapore. At present, regular sightings of the hawksbill turtle at coral reefs areas around several southern islands of Singapore still occur (Jeffrey Low, National Parks Board, pers. comm.). There have also been several reports of observed nestings and hatchings on beaches both on the mainland and offshore islands (pers. obs.).

Freshwater turtle species comprise more than two-thirds of all turtles found locally (Lim and Lim, 1992). Of the species documented in that study, two are not native to Singapore, viz., the red-eared slider (*Trachemys scripta elegans*) and the Chinese soft shell turtle (*Pelodiscus sinensis*). During a four-year survey of mammals, reptiles and amphibians of Singapore, Teo and Rajathurai (1997) recorded five species of emydid turtles (family Emydidae) and three species of soft-shelled turtles (family Trionychidae). They found that the native Malayan box terrapin (*Cuora amboinensis*) was the most common reptile with 133 records, compared with only 87 records of the red-eared slider. Other species found in smaller numbers included the spiny hill terrapin (*Heosemys spinosa*), the Malayan flat-shelled terrapin (*Notochelys platynota*), black marsh terrapin (*Siebenrockiella crassicollis*), Asiatic soft-shelled turtle (*Amyda cartilaginea*), the Malayan (or forest) soft-shelled turtle (*Dogania subplana*) and the Chinese soft-shelled turtle (*Pelodiscus sinensis*). In addition to the species mentioned above, Rajathurai and Teo (1997) reported the presence of three other species in the Central Catchment Nature Reserve of Singapore: the river terrapin (*Batagur baska*), the Indian flap-shelled terrapin (*Lissemys punctata*), the giant pond terrapin (*Heosemys grandis*), as well as the red-eared slider (*Trachemys scripta elegans*). In total, eleven species of both indigenous and non-indigenous terrapins have been recorded in the wild in Singapore (Lim and Chou, 1990; Lim and Lim, 1992; Chou, 1995; Rajathurai and Teo, 1997; Teo and Rajathurai, 1997).

While the red-eared slider has been the only species of chelonian allowed for sale in the pet trade in Singapore (the Malayan box terrapin was recently included), a number of other turtle species have been found for sale in pet shops illegally (table 2.1) (Goh and O'Riordan, 2007). Many of these species have not been documented in the checklists of Lim and Lim (1992) and Teo and Rajathurai (1997). Red-eared sliders were found for sale in all of the 27 pet shops surveyed.

Table 2.1 Species of tortoise and freshwater turtles for sale in 27 pet shops in Singapore, with their source country, number of shops which had them on sale and CITES Appendix listing. Taken from Goh and O'Riordan (2007).

Species	Source	Number of shops where on sale	CITES Appendix
Pig-nose turtles *Carettochelys insculpta*	Indonesia	7	II
Malayan box terrapin *Cuora amboinensis*	South-east Asia	1	II
Indian start tortoise *Geochelone elegans*	India	1	II
Leopard tortoise *Geochelone pardalis*	Africa	1	II
Argentine snake-necked turtle *Hydromedusa tectifera*	South America	3	
Bell's hinged tortoise *Kinixys belliana*	Africa	1	II
Home's hinged tortoise *Kinixys homeana*	Africa	2	II
Alligator snapping turtle *Macroclemys temminckii*	USA	1	III
Pancake tortoise *Malacochersus tornieri*	Africa	1	II
Chinese soft-shell turtle *Pelodiscus sinensis*	Malaysia	3	III (for a short period in early 2005)
Razor-back musk turtle *Sternotherus carinatus*	USA	1	
Red-eared slider *Trachemys scripta elegans*	USA	27	

2.1.2 The red-eared slider in Singapore

Red-eared sliders have been living in various water bodies of Singapore for over 25 years (Tinsley, 1983). Many different accounts have been offered to explain the large populations of red-eared sliders in some of these water bodies. According to Sulaiman (Sulaiman, 2002), many of these red-eared sliders were abandoned by their owners and released into ponds and reservoirs throughout the island (Chapter 6). The average lifespan of a red-eared slider is about 50 years (Cagle, 1950) and many pet owners are unable to provide a habitat for their pet throughout this duration. As red-eared sliders mature, they lose their bright colouration and grow to large sizes (average carapace length 18.6 cm). It is also a common religious practice for Buddhists to release captive animals to accumulate good karma. Red-eared sliders, together with birds and fishes, are a popular choice for this purpose (Goh and O'Riordan, 2007).

As mentioned above, a survey of the nature reserves in Singapore by Teo and Rajathurai (1997) included 87 records of red-eared sliders in the nature reserves, as well as in the adjacent reservoirs and lakes. They further reported that the species had not established itself in forest streams, despite their ability to move over land. The sliders have been recorded to move up to 1.6 km from the nearest water body to the nest site (Cagle, 1950). The likelihood of this species moving into natural forest streams is high as they have been known to migrate when a habitat becomes unsuitable or over-crowded, to forage and in search of mates (Parker, 1984).

Goh (2004) carried out a preliminary, semi-quantitative survey at 29 localities around Singapore. The results suggested that slider densities were highest in areas with relatively high human activity (Goh, 2004). Table 2.2 is adapted from this study, showing estimates of slider population densities at 16 locations in Singapore (Figure 2.1) with a total of about 670 observed individuals (Goh, 2004). In general low to very low numbers were found in inaccessible areas, despite some areas having relatively large water bodies.

It is still unclear if the large numbers present in the water bodies in Singapore are the result of continual release of the terrapins by humans, or due to their ability to breed in these water bodies, or both. The continued high import densities and abundances strongly suggest that the release of this species is a dominant factor. The imported number of red-eared sliders has increased to 1,253,091 individuals in 2007 from

301,245 individuals in 2001 (Lye Fong Keng and Poh Yew Kwang, Agri-Food and Veterinary Authority, Singapore, pers. comm., see Table 1.1 in Chapter 1 for details). If the current rate of importation is sustained, it is possible that more sliders will be released in the coming years.

Table 2.2 Estimated population densities of red-eared sliders at accessible (A) and inaccessible (I) localities. Where Very Low (VL): very low population density (< 10); Low (L): low population density (10 – 19); Moderate (M): moderate population density (20 – 29); Fairly High (FH): fairly high population density (30 – 39); High (H): high population density (40 – 59); Very High (VH): very high population density (> 59)

Locality	Approx. water surface area surveyed (m^2)	Mean total no. of terrapins	Estimated population density	Accessibility
Bedok Reservoir	30,000	77.0	VH	A
Bishan Park	15,000	20.5	M	A
Botanic Gardens	30,000	133.0	VH	A
Bukit Batok Nature Park	15,000	39.5	FH	A
Bukit Batok Town Park	35,000	97.0	VH	A
Bukit Panjang Park	30,000	11.5	L	A
East Coast Park	1,000	67.0	VH	A
Jurong Lake	30,000	24.5	M	A
Lower Peirce Reservoir	25,000	20.5	M	A
MacRitchie Reservoir	30,000	27.5	M	A
Marina City Park	25,000	35.5	FH	A
Pandan Reservoir	30,000	21.0	M	A
Punggol Park	30,000	11.5	L	A
Sungei Serangoon (upstream)	25,000	0.0	VL	A
West Coast Park (pond & Marsh Garden)	10,000	19.5	L	A
Woodlands Town Garden	30,000	4.0	VL	A
Kranji Reservoir (downstream)	30,000	0.5	VL	I
Kranji Reservoir (Sungei Kangkar)	2,500	0.0	VL	I
Kranji Reservoir (Sungei Tengah)	2,500	0.0	VL	I
Lower Seletar Reservoir (downstream)	18,000	14.0	L	I
Lower Seletar Reservoir (upstream)	10,500	7.0	VL	I
Sungei Buloh Wetland Reserve freshwater ponds	15,000	5.0	VL	I
Sungei Punggol	15,000	0.0	VL	I
Sungei Serangoon (downstream)	9,000	0.0	VL	I
Tampines Quarry	15,000	0.0	VL	I
Upper Peirce Reservoir (reservoir park)	19,500	6.0	VL	I
Upper Peirce Reservoir (restricted area)	13,500	5.5	VL	I
Upper Seletar Reservoir (northern banks)	15,000	11.5	L	I
Upper Seletar Reservoir (reservoir park)	16,500	10.5	L	I
Kranji Reservoir (downstream)	30,000	0.5	VL	I
Kranji Reservoir (Sungei Kangkar)	2,500	0.0	VL	I
Kranji Reservoir (Sungei Tengah)	2,500	0.0	VL	I

Figure 2.1 Red-eared slider density in Singapore according to Goh (2004).

2.1.3 Red-eared slider populations and demography

Sliders have been found to occupy a wide variety of habitats including streams, lakes, ponds, swamps and even roadside ditches (Carr, 1952). Gibbons (1990b) mentioned that sliders were the only surviving animals (vertebrate or invertebrate) found in an aquatic habitat filled with run off from a hog farm.

The life span of sliders is still contested. Moll and Legler (1971) estimated it to be about 30 years based on their observations in Panama but other estimates places the age between 50 and 75 years (Cagle, 1950). In native populations in Illinois, the ratio of adult males to females is approximately 1:1 but in Panama, males roughly doubled the number of females (Moll and Legler, 1971).

Sliders exhibit sexual dimorphism with the males being distinctly smaller when mature, and with longer foreclaws and tails (Gibbons, 1990a). The adult size of sliders can be variable but studies at a protected site in western Mississippi (the natural range of sliders) found the mean carapace length of females and males to be 22.9 cm and 19.0 cm respectively (Close and Seigel, 1997). However, it has been observed that sliders in thermally altered water bodies within their natural range are larger than natural populations nearby (Gibbons, 1970). Sliders from neotropical Panama were also reported to be larger than those found in North America. Presently, there is no equivalent data regarding established slider populations in tropical Asia.

Moll and Legler (1971) suggested that sliders in the tropics face fewer environmental hazards that those in temperate regions. The absence of an overwintering period offers a lower chance of mortality during hibernation. Furthermore, there are fewer reasons to move overland other than to nest.

2.1.4 Objectives of this study

Other than the preliminary survey by Goh (2004), there has been no study of the status of freshwater chelonians in Singapore water bodies since that of Teo and Rajathurai (1997) and Rajathurai and Teo (1997). The aim of this study was to examine the red-eared slider populations in Singapore with foci on:

1. Population size;
2. Population structure (sex ratio and size classes);
3. Differences in populations between small man-made ponds and large reservoirs that have more natural surroundings; and
4. Any information that can be accumulated on other species of freshwater turtles.

In addition to the above objectives, this study assessed a range of methods (e.g. visual census, trapping, mark and recapture) of estimating populations of freshwater turtles with potential application to future census work.

2.2 Materials and methods

2.2.1 Testing trap efficiency

From February to March 2004, four different types of traps were tested for their effectiveness in trapping turtles. The first trap was a basking trap designed to exploit the turtles' natural basking behaviour in order to capture them (Figure 2.2 a and b). The trap was constructed using a 1.5 m by 1.5 m PVC pipe frame fitted with a wire or plastic mesh cage of 1 m depth. This square open-top trap is partially submerged and plywood planks are placed across the frame. The principle is that turtles climb up the plywood planks to bask. When these turtles slide off the plank to return to water, they get trapped in the mesh cage.

A turtle trap (Pied Piper Turtle Trap, Forestry Suppliers) was purchased and tested in the field. The cage was constructed of aluminum wire mesh and was composed of two chambers (figure 2.2 c and d). Turtles would swim into the first chamber, attracted to the bait located within the second chamber. After entering the first chamber, turtles would inadvertently enter the second through a one-way flap.

A modified dual-entry version of the Pied Piper turtle trap was constructed from aluminum wire mesh (figure 2.2 e and f). Similarly, this trap makes use of bait to attract the turtles that can enter through either of two one-way flaps located on either side of the trap. This trap only has one chamber and once entered, turtles are trapped.

The last trap was a commercially available baited crab trap used by local fishermen (figure 2.2 g and h). The crab traps were constructed of a wire frame and nylon fish netting, with a small draw-string mesh bag for bait. Because of the ease with which

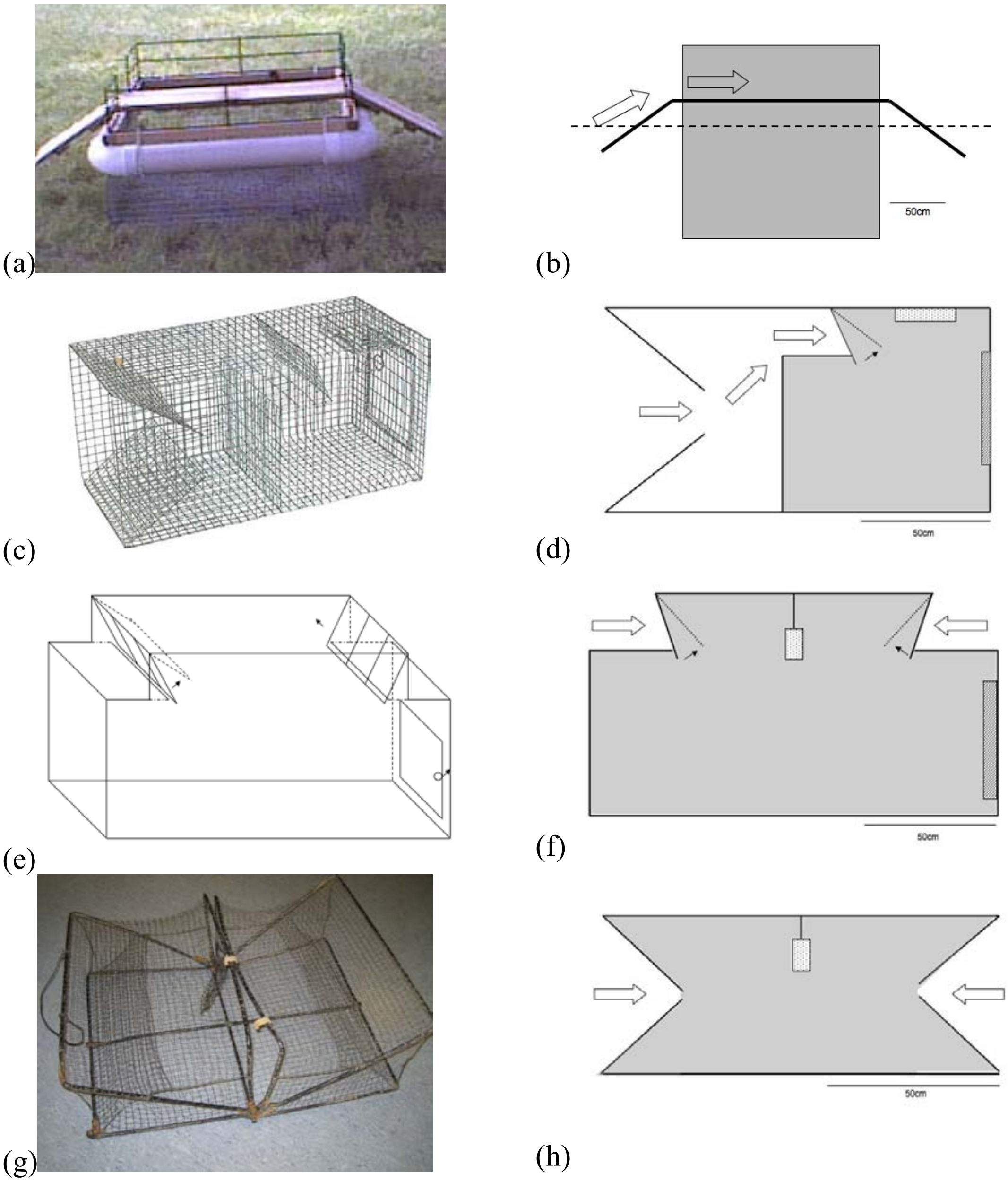


Figure 2.2 The different types of traps that were tested for trap efficiency. 4 types of traps were used – (a and b) basking trap; (c and d) Pied Piper turtle trap; (e and f) dual-entry turtle trap and (g and h) commercial crab trap. Large arrows indicate direction of entry of turtles and grey shaded regions indicate the area turtles get trapped within. Water level, bait containers, doors for removing turtles and movable flaps are indicated with dashed lines, dotted boxes, striped boxes and small arrows respectively.

turtles could get access to the bait through the bag, a modification was made and bait was placed in perforated containers and hung from the centre of trap instead. Turtles can enter from either side of the trap via slits in the netting and are usually unable to find their way out because their claws would become entangled in the netting. These crab traps were eventually selected for use in the main study as they were collapsible, inexpensive and consistently effective in trapping turtles.

2.2.2 Visual census

A visual census was carried out at two sites, Eco-lake and Swan Lake at the Singapore Botanic Gardens in March 2004. At least three equally skilled observers were required for this method and prior to the counts the ponds were visually subdivided into sections. Using a pair of binoculars, each observer then scanned the designated section five consecutive times and made counts of all the turtles observable within each section. Turtles could be identified while basking, swimming with head above the water or if close enough, underwater. The highest count (among the three observers) for any given section was taken. The highest counts for all sections were totaled to give the estimated total number of turtles for the area. Each site was surveyed two to four times and the total number from each session was averaged to obtain the final estimate. It should be noted that for this method, practice prior to the surveys was essential to ensure that the data collected by different observers was standardised.

2.2.3 Mark and recapture using traps

From April to July 2004, mark and recapture was used to obtain estimates of the population size and structure at four sites that were, from preliminary observations by (Goh, 2004), relatively accessible to the public and appeared to have relatively large populations of sliders. See table 2.3 for descriptions of the sites.

Table 2.3 Area and perimeter of the four survey sites where LPR: Lower Peirce Reservoir, MRR: MacRitchie Reservoir, SEL: Eco-Lake and SSL: Swan Lake.

	Central Nature Reserve		Singapore Botanic Gardens	
	LPR	MRR	SEL	SSL
Area (ha)	50	70	1.059	1.031
Perimeter (km)	6.6	10	0.7	0.6

a) Traps

Traps were deployed from the banks at Eco and Swan lakes, and from a boat at MacRitchie and Lower Peirce reservoirs (figure 2.3 and 2.4). When using a boat, traps were deployed within 20 m of the bank and suspended 1m from the surface with the aid of a buoy and rope. The number of traps was fixed at each site and ranged from seven to ten, depending site area (table 2.4) - the larger the site, the more traps were required to cover the area. The traps were baited with squid, fish and prawn heads contained within a perforated plastic bottle to ensure that bait is not consumed and able to last until the end of the trapping session.

(a)

(b)

Figure 2.3 Maps of a) Lower Peirce reservoir and b) MacRitchie reservoir. Orange dots represent the locations where traps were laid, green squares represent the location of the processing station.

Figure 2.4 Retrieval of red-eared slider from a baited crab trap.

b) Trapping sessions

A trapping session consisted of deploying the total number of traps for a fixed period of time. The length of each session ranged from 25 minutes to 40 minutes and was dependent on the size of the site and the number of traps. The larger the site and the more traps deployed, the longer it took to complete one round of trap retrieval - up to a maximum of 40 minutes to ensure that turtles did not drown in the traps. When the traps were retrieved, trapped turtles were removed and set aside in labeled buckets to be processed and traps were then immediately re-deployed. Turtles collected from each session were brought to a processing centre for data collection. Turtles were held within plastic tubs post processing and were released at the end of the day.

The number of sessions was fixed at each site and ranged from three to five. This was dependent on the capture rates of turtles at the sites (table 2.4). At sites where turtles were numerous, the number of turtles that could be processed limited the number of sessions. There was also a limitation on the number of sessions that could take place when the sites were larger because of the length of time it took to travel from one trap to the next by boat.

c) Trapping occasions

Each trapping occasion (i.e. different dates) consisted of all the sessions that took place in one day and usually lasted from 0900 hrs to 1700 hrs. Four or five occasions were carried out per site and all occasions for each site were completed within a period of six weeks (table 2.4). More than two trapping occasions were essential in order to obtain multiple sets of recapture data for a higher degree of accuracy in estimation.

Table 2.4 Summary of the number of traps, sessions, occasions and sampling period for each site.

Location	Sampling period (2004)	Number of occasions	Number of sessions per occasion	Number of traps per session
Swan Lake (SSL)	28/4 – 25/5	4	3	7
Eco-lake (SEL)	12/5 – 24/5	5	3	7
Lower Peirce Reservoir (LPR)	16/6 – 22/7	5	5	9
MacRitchie Reservoir (MRR)	17/6 – 26/7	5	4	10

d) Marking and measuring

All turtles were marked starting from the first occasion and the number of recaptures was recorded for each subsequent trapping occasion. Processing involved marking individuals by notching the marginal scutes, using the system described by Cagle (1939).

Marginal scutes are numbered 1 to 12 on the left and right sides. Notching was carried out serially using a square file. If the first scute on both sides was notched, the animal's identity number would be "1-1". See figure 2.5 for another example. Using this method, a total of 2516 individuals can be uniquely identified and if notching is deep enough, individuals can be identified for more than one year (Cagle, 1939).

Individuals caught during all occasions had their carapace and plastron length, height, and cloaca to tip of tail length (pre-anal tail length) measured (in cm). They were weighed (in g) and sexed to collect information on the population structure. Males were identified by long fore claws, larger plastron to cloaca to tail length ratio, and a slightly concave plastron (Chapter 3). Any other species of turtles caught were also identified, photographed and measured.

In addition to the four sites mentioned, trapping was also carried out at a number of other man-made ponds such as the Symphony Lake at the Singapore Botanic Gardens, the two ponds at East Coast Park, the pond at Kent Ridge Park and the lake at Bukit Batok Town Park. However, data obtained from these trapping exercises could not be used for population estimates either because of low trapping success, or as a result of restrictions imposed by the park managers, we were unable to conduct sufficient trapping sessions and/or occasions.

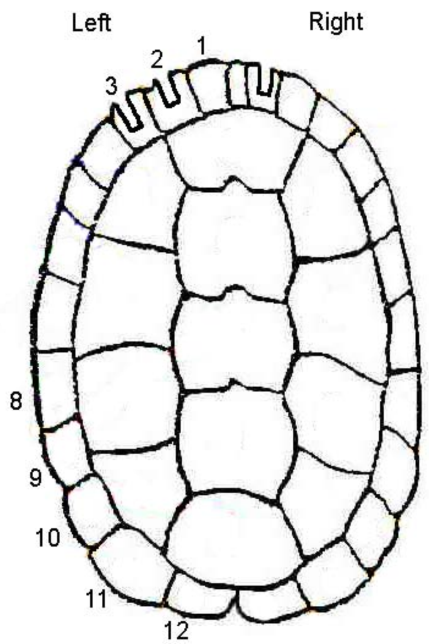


Figure 2.5 Diagram of a turtle carapace showing notches on the second and third scute on the left, and first on the right. The identification number of this individual would be "2,3-1".

e) Mark and recapture

The mark and recapture method is based on the Lincoln-Peterson model (Young and Young, 1998):

$$\frac{n_1}{N} \approx \frac{m_2}{n_2}$$

Where N is the total population, n_1 is the number of animals caught and marked on the first occasion, n_2 the total number of animals caught in the second occasion and m_2 the number of animals caught the second occasion that had previously been marked in the first occasion (Young and Young, 1998). Data were analysed using the program CAPTURE (Rexstad and Burnham, 1991) and based on the M_{bh} model (which permits heterogeneity of capture probabilities and trap response) and estimates of the slider population size were made using the Jackknife estimator. The unit density of sliders was calculated as number of turtles per hectare (10, 000 m^2).

2.3 Results

2.3.1 Trapping efficiency

The basking trap was found to be unsuitable for the purposes of this study due to the limited deployment duration. The primary benefit of this method is that traps can be left for days at inaccessible areas without the turtles drowning.

Both the Pied Piper turtle trap and the dual-entry trap were heavy and are submerged traps. Hence they could only be deployed for a maximum period of one hour to minimize the risk of drowning trapped turtles. They were found to be unsuitable due to inconsistent capture rates. It is possible that they sank too deep into the substrate when deployed in muddy water. Their large sizes also made them extremely unwieldy and almost impossible to haul out of the water during the instances when they were full of terrapins.

The crab trap proved to be the most successful of the four traps. It was portable, lightweight and easy to deploy. It was also relatively inexpensive and easily available. However, the maximum capacity of this trap is low due the small size (19 adults and/or subadults). Another limitation of this trap lies in the need for high maintenance of the nylon mesh to ensure that it is in optimal condition. See table 2.5 for a summary of the traps and the results of the trial.

Table 2.5 Summary of the factors involved in deciding on the most effective trapping method.

	Basking trap	Pied Piper trap	Dual-entry trap	Crab trap
Cost (Singapore dollars)	About $150	About $250	About $200	$10
Availability	Has to be constructed	Has to be ordered from USA	Has to be constructed	Easily available locally
Method of capture	Floating – makes use of turtles' basking behaviour	Submerged – requires bait	Submerged – requires bait	Submerged – requires bait
Maximum capture	0	12	0	19
Ease of escape of turtles	Almost impossible to escape	Unlikely to escape	Unlikely to escape	Escape possible when netting is loosened or frame is out of shape
Portability	Extremely bulky and heavy	Bulky and heavy	Bulky and heavy	Collapsible and light
Ease of use	Difficult to deploy and collect	Moderately simple to deploy, danger of getting cuts	Moderately simple to deploy, danger of getting cuts	Extremely easy to deploy and collect
Durability	Requires maintenance	Long-lasting	Long-lasting	Requires maintenance to tighten and mend netting, easily bent out of shape

2.3.2 Visual census

Visual estimates were consistent among the three observers and the highest count for Eco-lake was 213 and 177 for Swan Lake. Meaningful estimates for the reservoirs could not be obtained because the reservoirs were too large and had many inlets which were not possible to observe.

2.3.3 Population size

Mark and recapture estimates

The total number of red-eared sliders caught and marked during the course of this study was 662. The maximum capture of terrapins using one crab trap was 19 individuals of various sizes (usually not including juveniles with a carapace length less than 10 cm). Please refer to table 2.6 for these results

Table 2.6 Total number of recaptures at the four sampling sites.

	Occasion number	Total captures	Number of recaptures
Swan Lake (SSL)	1	62	-
	2	77	10
	3	14	4
	4	27	6
Eco-lake (SEL)	1	26	-
	2	34	0
	3	21	1
	4	15	0
	5	46	5
Lower Peirce Reservoir (LPR)	1	28	-
	2	39	1
	3	40	2
	4	38	6
	5	34	5
MacRitchie Reservoir (MRR)	1	22	-
	2	16	0
	3	35	2
	4	26	4
	5	7	1

Results from mark and recapture studies indicate that Swan Lake and Eco-Lake have large populations of red-eared sliders, estimated at 363 and 395 individuals respectively. Lower Peirce and MacRitchie Reservoirs had an estimated 562 and 274 individuals respectively (Table 2.6). Reservoirs are more than 40 times larger in area than the ponds and consequently, Swan Lake and Eco-lake had a higher density (total number per hectare) of red-eared sliders than Lower Peirce and MacRitchie Reservoirs, by about 30 – 100 times (Table 2.7). The total number of individuals estimated by mark and recapture method was found to be approximately double the number estimated by the visual survey method.

Table 2.7 Estimates of population sizes at four sites using visual surveys and trapping.

	Lower Peirce Reservoir	MacRitchie Reservoir	Swan Lake	Eco-Lake
Area	50ha	70ha	1.0590ha	1.0312ha
Total number of individuals captured	170	99	150	130
Total number estimated by visual survey	-	-	177	213
Total number estimated by mark and recapture estimate	562 ± 38	274 ± 23	363 ± 23	392 ± 28
No. of animals per hectare	11	4	344	380

2.3.4 Sex Ratio at five sites

Sex ratio and the population structure from five sites were examined; the above four sites and Symphony Lake, a man-made pond. Female red-eared sliders outnumbered the males at all five sites. The ratio of females to males ranged from 3.71 at Swan Lake to 8.90 at MacRitchie Reservoir (Fig 2.6).

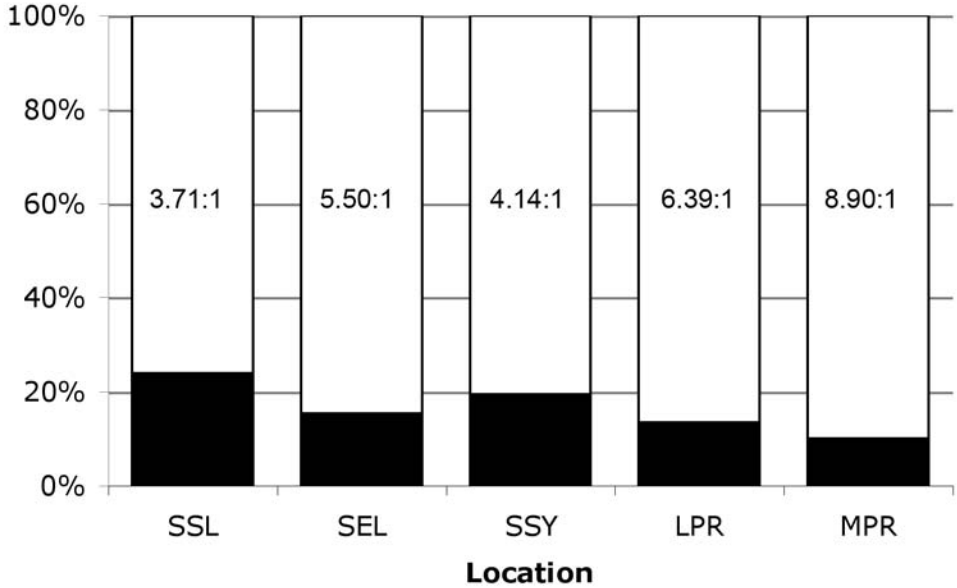


Figure 2.6 Percentage of male (shaded) and female (unshaded) sliders caught at five sites in 2004 (SSL: Swan Lake; SEL: Eco-Lake; SSY: Symphony Lake; LPR: Lower Peirce Reservoir; MPR: MacRitche Reservoir). The ratios within the bars indicate the ratio of females to males.

2.3.5 Terrapin sizes at five sites

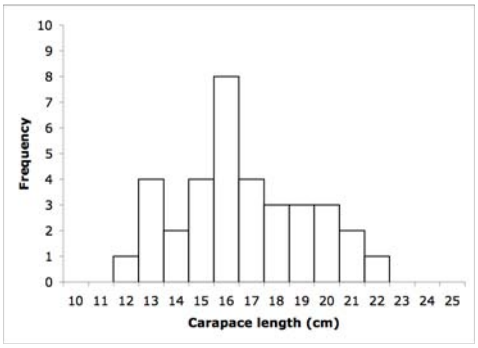
All terrapins caught at the above five sites are used in this analysis. The largest male and female caught using a crab trap were found at the reservoirs, and both had a carapace length of 25.9 cm (Table 2.8). The smallest male and female caught were found at Eco-Lake and they had carapace lengths of 10.2 cm and 10.0 cm respectively. The smallest red-eared slider caught throughout the entire course of this study had a carapace length of 9.2 cm (Swan Lake) but its gender could not be ascertained due to the absence of secondary sexual characteristics.

Table 2.8 General descriptions of the red-eared slider populations at five sites. SSL: Swan Lake; SEL: Eco-Lake; SSY: Symphony Lake; LPR: Lower Peirce Reservoir; MPR: MacRitchie Reservoir).

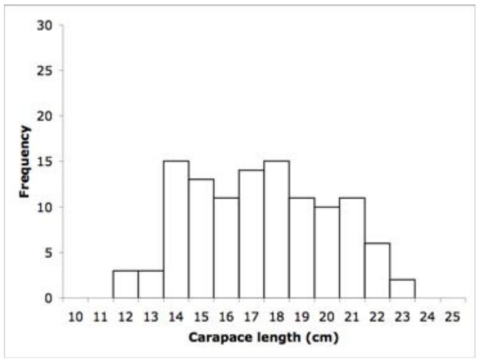
		N	Carapace Length (cm)				
			Mean	Median	Std. Dev.	Max.	Min.
SSL	Male	36	17.26	16.75	2.65	22.0	12.8
	Female	114	17.83	19.85	2.73	23.4	12.0
SEL	Male	20	16.89	16.25	3.65	23.6	10.2
	Female	110	18.56	19.00	3.71	24.6	10.0
SSY	Male	15	15.65	14.50	2.55	20.3	12.8
	Female	58	16.53	17.15	3.12	22.3	10.3
LPR	Male	23	20.87	21.20	2.30	25.9	16.7
	Female	147	20.27	21.00	3.00	25.7	11.6
MRR	Male	10	19.19	19.45	2.82	23.5	14.7
	Female	89	19.00	19.20	2.92	25.9	11.4

Length-frequency histograms for males and females at the five sites show the distribution of carapace lengths. The distribution of sizes of males and females varied among the five sites (figure 2.7). It can be noted from figure 2.7 that only two sites, Lower Peirce Reservoir and MacRitchie Reservoir had individuals exceeding 25 cm in carapace length.

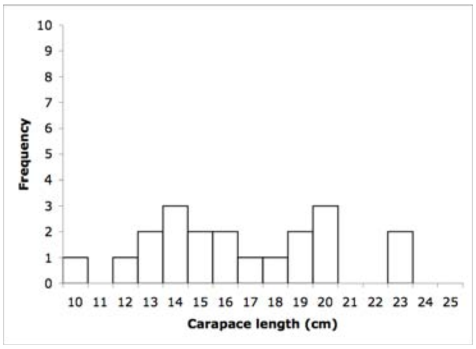
SSL male



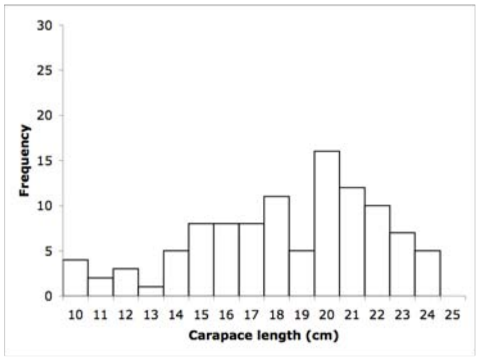
SSL female



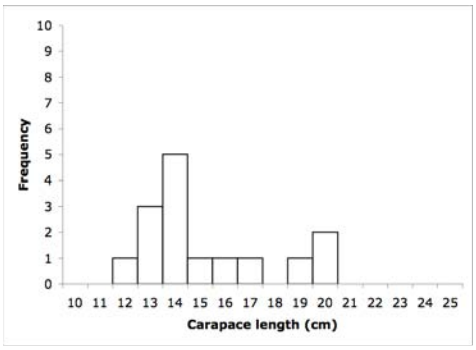
SEL male



SEL female



SSY male



SSY female

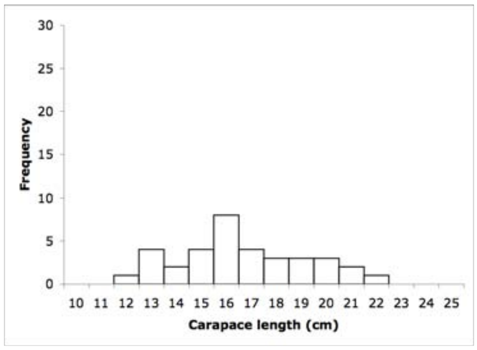
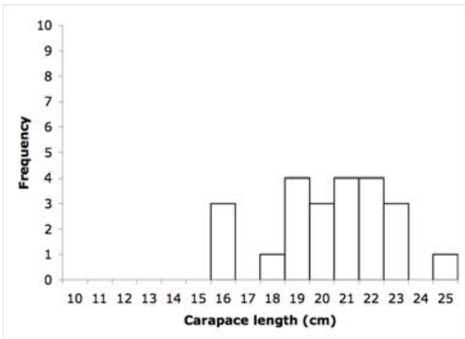
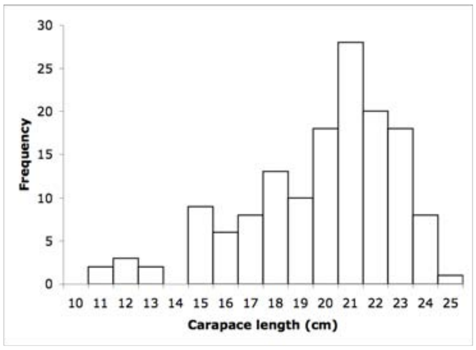


Figure 2.7 Length-frequency histograms (actual numbers) at 5 sites (SSL: Swan Lake; SEL: Eco-Lake; SSY: Symphony Lake; LPR: Lower Peirce Reservoir; MPR: MacRitche Reservoir). Note that males and females are on different scales.

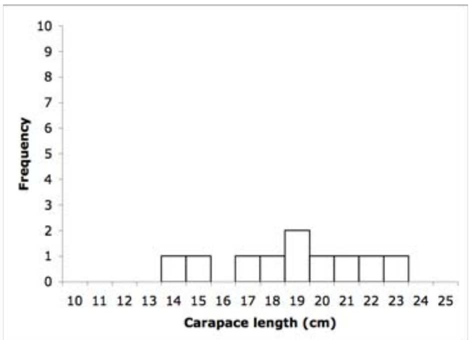
LPR male



LPR female



MRR male



MRR female

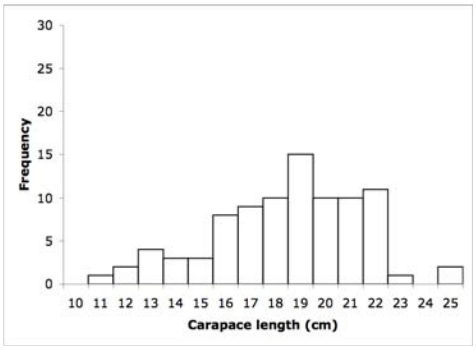


Figure 2.7 (continued) Length-frequency histograms (actual numbers) at 5 sites (SSL: Swan Lake; SEL: Eco-Lake; SSY: Symphony Lake; LPR: Lower Peirce Reservoir; MPR: MacRitche Reservoir). Note that males and females are on different scales.

The male and female populations at each site were tested for normality using the Anderson Darling Normality Test (Minitab 12) and because not all populations were normal, the non-parametric Mood Median test was chosen to test for differences between carapace lengths. There were no significant differences between carapace lengths of males and females within each population at all five sites (SSL $P = 0.444$; SEL $P = 0.145$; SSY $P = 0.064$; LPR $P = 0.597$; MRR $P = 0.973$). Among sites, there were highly significant differences in carapace lengths among both male populations ($P < 0.005$) and female populations ($P < 0.005$) with a 95% confidence interval. Pooling the data for the three ponds (SSL, SEL and SSY) and the two reservoirs (LPR and MRR), both males ($P < 0.005$; $N = 33$ at reservoirs, $N = 71$ at ponds) and females

($P < 0.005$; N = 236 at reservoirs, N = 282 at ponds) were significantly larger at the reservoirs than at the ponds.

2.3.6 Home range and homing behaviour of sliders

At Lower Peirce and MacRitchie Reservoirs, a high proportion of re-captures were found to be at the same location as when initially captured (table 2.9). Approximately 50% at MacRitchie and 83% at Lower Peirce of the re-captured sliders had made their way back to the original location between trapping occasions. The distance between traps ranged from 660 m to 1000 m and of the five recaptures that were found at a different location from the original capture, only two were more than one trap away, meaning 89% of re-captures were made at the same trap or an adjacent trap.

Table 2.9 Re-captures at the same location for two sites. The locations of the captures are in the format "xx-Tyy" where "xx" refers to the trap occasion and "yy" refers to the trap number. Refer to figure 2.2 for a map of trap locations.

	Turtle ID	1st capture	2nd capture	3rd capture
Lower Peirce Reservoir (50ha)	1-3	01-T05	02-T05*	
	2-8	01-T09	03-T09*	
	3-3	02-T10	03-T10*	
	12-9	03-T04	04-T04*	
	1-0	01-T04	04-T04*	05-T04*
	9-0	01-T07	04-T03&	06-T05&
	0-9,10	04-T02	05-T01^	
	1,9-0	03-T09	05-T09*	
	1-10	01-T09	05-T09*	
	0-11,12	04-T08	05-T08*	
	1,9-10	05-T06	06-T06*	
	1,3-8	04-T08	06-T08*	
MacRitchie Reservoir (70ha)	1-12	01-T10	03-T10*	
	8-2	02-T05	03-T09&	
	0-8	01-T06	04-T05^	
	8-12	03-T09	04-T09*	
	10-2	03-T01	04-T10^	
	12-3	03-T01	05-T01*	

* re-captured at the same trap location
^ re-captured one trap away from original location
& re-captured more than one trap away from original location

2.3.7 Injured and deformed sliders

Some of the turtles had shell deformities such as flattening and curving of the carapace (figure 2.8). Thirty-three turtles caught were injured (Table 2.10) and 9 had abscesses on their limbs or tails. Two had red paint on their carapace but their markings were not discernible and could not be identified as words as described by Goh and O'Riordan (2007) (figure 2.8).

Table 2.10 Number of turtles (out of 640) found with injuries, deformities and markings.

Injuries	Deformities	Markings
Missing limbs or tail (10)	Curved and/or flattened carapace (15)	Paint on carapace (2)
Missing eye (1)	Growths/abscess (9)	
Missing claws (16)	Stunted growth at waist (1)	
Broken jaw (2)		
Fish hook in mouth (1)		
Broken carapace or plastron (3)		

(a) (b) (c) (d) (e)

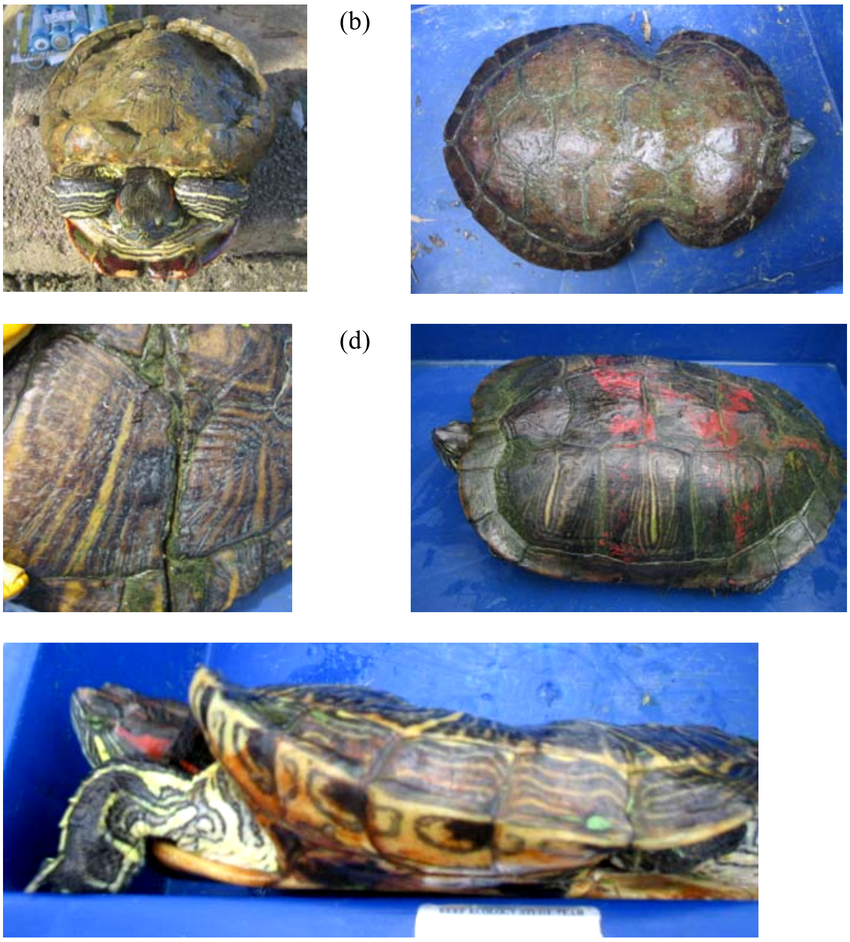


Figure 2.8 Photographs showing carapace curling and flattening, red paint markings, abnormal shell growth and cracked carapace in live specimens of red-eared sliders.

2.3.8 Other species of turtles

Species of turtles other than red-eared sliders were also observed (either captured or by visual observations) during the sampling period. The numbers are shown in table 2.11 below. Only red-eared sliders were caught/observed at Kent Ridge Park, Bukit Batok Town Park and Symphony Lake and these sites are omitted from the table below.

Table 2.11 The number of individuals of species other than *T. scripta* caught at 5 sites. (SSL: Swan Lake; SEL: Eco-Lake; LPR: Lower Peirce Reservoir; MPR: MacRitche Reservoir; ECP: East Coast Park).

	LPR	MRR	SSL	SEL	ECP
Malayan box terrapin *Cuora amboinensis*	5	-	1	2	-
Black marsh terrapin Siebenrockiella crassicollis	20	-	-	-	-
Chinese striped necked turtle *Ocadia sinensis*	-	1	-	6	1
American cooter *Pseudemys* sp.	-	-	-	1	-
River terrapin *Batagur baska*	-	-	-	1	-
Pig-nosed river terrapin *Carettochelys insculpta*	-	-	-	4	-
Chinese softshell turtle *Pelodiscus sinensis*	-	-	3	-	-
Asiatic softshell turtle *Amyda cartilaginea*	-	-	3	-	-
Malayan softshell turtle *Dogania subplana*	1	-	1	-	-

Eco-lake at the Singapore Botanic Gardens had the highest diversity of turtle species including some species not previously recorded in the wild in Singapore, such as the Chinese striped necked turtle (*Ocadia sinensis*), American cooter (*Pseudemys* sp.) and Pig-nosed river terrapin (*Carettochelys insculpta*), all of which are non-indigenous to Singapore.

The most common species was *Siebenrockiella crassicollis* (black marsh terrapin), but it was only found at Lower Peirce Reservoir, restricted only to marsh-like habitats (figure 2.9). Twenty individuals were captured and their carapace length ranged from 13.2 cm to 18.4 cm. Sexual dimorphism is subtle in this species, with the most obvious distinguishing characteristic being the pre-anal tail length. Figure 2.10 shows two distinct clusters of individuals with similar carapace lengths but males having distinctively longer pre-anal tail lengths. Only one individual smaller than 16 cm in carapace length was captured.

Leeches (possibly *Placobdella* sp.) were found on the majority of the *S. crassicollis* caught, and also on the one specimen of *Cuora amboinensis*, at Lower Peirce Reservoir. It was observed that none of the red-eared sliders was infested but unfortunately, this was not quantified.

2.4 Discussion

2.4.1 Visual survey technique

The visual survey method of estimating population size underestimated the actual numbers by about half. Visual counts can only account for the turtles that are basking (either on un-submerged structures or in the water with their heads extended above the water). There are also some other limitations to the visual survey method. All observers have to be equally skilled in detecting turtles using a pair of binoculars. One way to overcome this bias is to conduct pre-survey practice sessions for the observers to learn to distinguish a turtle from floating debris or other animals. The amount of data that can be collected using this method is limited. Data such as species and sex are difficult to ascertain while others such as carapace length and weight are not

Figure 2.9 Lower Peirce Reservoir — habitat of black marsh terrapins and Malayan box terrapins.

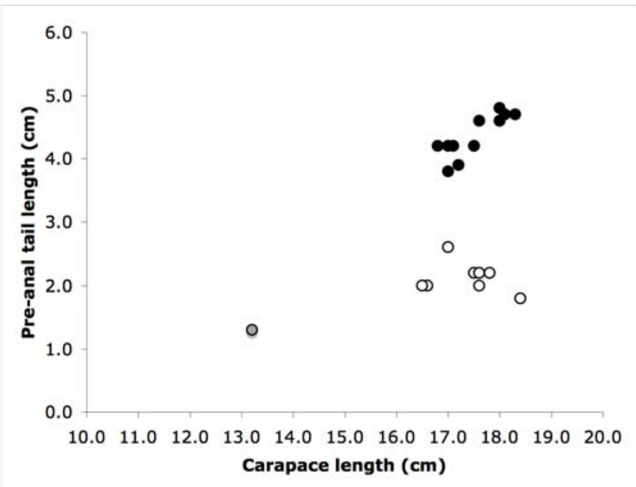


Figure 2.10 Scatter plot of carapace length vs. pre-anal tail length of 20 *Siebenrockiella crassicollis* caught at Lower Peirce Reservoir. Black dots represent males, empty circles represent females and grey grey-filled circle represented the individual not exhibiting any sexual characteristics.

obtainable. Lastly, this method can only be carried out at small water bodies since good visibility is required. Goh (2004) overcame this by visually surveying an approximate fixed area of water surface at each site. Despite the limitations of visual surveys, they have proven to be a quick method for collecting semi-quantitative data for preliminary population assessments that can be useful for management decisions.

2.4.2 Trapping methods

Gibbons (1990b) commented that there is no one perfect way to trap aquatic terrapins. The methods he employed included aquatic traps, basking traps, trammel nets, seining, trotline/longline, cast nets, shooting, fly rods, dip-netting, drift fences with pitfall traps, snorkeling, scuba diving and a method which is termed “noodling” or “muddling” (whereby terrapins are found by feeling for them with hands and feet). For the purpose of mark and recapture studies, it is necessary to use methods which can be repeated. Previous observations proved that the sliders have minimal overland activities and therefore pitfall traps would not be useful. The only options were aquatic traps and basking traps. Basking traps need to be deployed for an extended period but permits for overnight trapping could not be obtained. In any case, numerous basking sites already present at all of the study sites reduced the need for the sliders to climb up the basking platform of the trap and hence reduce the effectiveness of this method. Gibbons (1990b) noted that basking traps are usually the first trapping method to be discontinued in many research studies (Moll and Legler, 1971; Gibbons, 1990b) and it was the same in the present study.

Another method which Gibbons (1990b) described was the use of generator-powered electrical shockers mounted on boats (Gunning and Lewis, 1957). This causes terrapins to stop moving but seemingly without being harmed. Chaney and Smith (1950) also described a method which they called "boat revving", and Sanderson (1974) supported that method by reporting that *Graptemys* were attracted to the boat while the motor was running. Neither of these was suitable for the present survey.

Baited aquatic traps were eventually chosen due to their efficient capture rate, portability and the ease in replicating trapping effort (number of traps and deployment time). Of the variety of aquatic traps, Gibbons (1990b) used steel hoop nets and fyke nets, both of which are costly. In the present study crab traps worked just as well as those reported by Gibbons (1990b). One disadvantage of using crab traps is that the trap is able to hold a maximum of approximately 19 average sized sliders. However this limitation is of low consequence, as traps had to be checked every hour to avoid drowning the trapped turtles and many traps could be deployed simultaneously.

2.4.3 Slider populations size

The population density estimates of red-eared sliders at Eco-lake (380 individuals ha^{-1}) and at Swan Lake (344 individuals ha^{-1}) are similar to that of a studied population in Florida (361.4 individuals ha^{-1}) where they are native (Iverson, 1982). However, some natural populations of sliders have been found to be much smaller like those studied at Ellenton Bay (61.5 individuals ha^{-1}) and Risher Pond (41.8 individuals ha^{-1}) in South Carolina (Congdon et al., 1986). Other population studies of red-eared sliders showed varied population densities such as in Belize (315.9 individuals ha^{-1}) (Moll, 1990) and Panama (190.3 individuals ha^{-1})(Moll and Legler, 1971). The population densities at Lower Peirce and MacRitchie reservoirs were much lower, approximately about one hundredth of the density found at the two ponds.

The maximum viable density of a slider population is yet uncertain. Based on published literature and sites surveyed for the present study, population densities do not exceed 400 individuals ha^{-1}. The only exception is a population density of 1000 individuals ha^{-1} living in a hog farm run off (Gibbons, 1990b). Barring this site, population densities at the two ponds in this current study were near the upper limit of documented population densities.

Goh (2004) carried out a visual survey at 29 sites in Singapore. He categorized these sites as "accessible" or "inaccessible" based on their proximity to urban and residential areas and the number of roads leading to the sites. These factors positively correlate to the amount of human activity within the site. Findings of the present study concur with those of Goh (2004) for the same sites. Both studies found "very high" density of red-eared sliders at the Singapore Botanic Gardens (including Eco-lake, Swan Lake and Symphony Lake) and "moderate" density of red-eared sliders at both Lower Peirce Reservoir and MacRitchie Reservoir. The density classes used were adapted from Teo and Rajathurai (1997) with "very high" and "moderate" densities corresponding to an average of > 59 and 20 – 29 individuals respectively per about 2 to 4 hectares of water surface surveyed.

Congdon et al. (1986) suggested that habitat suitability is a major contributing factor to the characteristics of turtle populations. Moll and Moll (1990) and Morreale and Gibbons (1986) listed favourable characteristics to include abundant aquatic vegetation, basking sites, slow-moving water, open-land for nesting adjacent to the stream. It is unclear if factors such as natural food abundance are as crucial to the red-eared sliders in Singapore. Red-eared sliders here are regularly fed items such as bread by members of the public (see chapter 6). The red-eared sliders not only consume the bread, but they are attracted to and crowd around such feeding sessions (see chapter 5). Sites that are more accessible to and popular with the public are likely to contain more sliders within their ponds or lakes because of two main reasons; a) members of the public are more likely to release their unwanted pet terrapins at these sites and b) higher visitorship numbers suggest that more people feed the terrapins and they consequently have higher chances of survival due to abundant food availability.

On a few occasions, red-eared sliders were observed near the mangroves at Sungei Tampines during high tide. These accounts, together with observations by Goh (2004) of red-eared sliders at Marina City Park and ponds at Sungei Buloh Wetland Reserve suggests that the red-eared slider can survive in brackish waters (Lim and Lim, 1992). Other instances (reported by zoologists who are aware of the distinguishing characters of sliders from other turtles) included the red-eared slider; a) walking across the intertidal area and swimming into the sea at Labrador Nature Reserve (Lim, C.P., pers. comm.); b) red-eared slider swimming inshore at Changi Beach (Jaafar, Z., pers. comm.) and c) red-eared slider swimming at the jetty of St. John's Island (an island 6.5 km away from Singapore island) (Teo, L.M.S., pers. comm.) that had probably escaped from the nearby Kusu Island where a freshwater turtle pond exists.

2.4.4 Population structure

Results of population compositions of red-eared sliders in Singapore were constant among all five surveyed sites. On average, females outnumbered males by about 5:1, and very few (less than five) juveniles with carapace length less than 10 cm were found. Cagle (1950) reported the sex ratio in natural populations to be 1:1. However, natural populations studied by Moll and Legler (1971) and Bury (1979) found the opposite to be true. Red-eared slider females are thought to outnumber the males only during the nesting months when the females were less sedentary in search of nesting sites (Moll and Legler, 1971). As the present study was carried out during the day and aquatic traps were used, nesting activity is unlikely to be the cause for the population bias towards female sliders.

Several possibilities are here offered to explain the skew in sex ratio. Since females are larger in size, there is greater need to forage and consequently leading to higher capture chance. This may explain their incidence in baited traps.

Secondly, the sex of hatchlings may be skewed due to warm temperatures in Singapore. Temperature dependent sex determination in turtles and other reptiles has been discussed at great length (Bull et al., 1982; Pieau, 1974; Bull and Vogt, 1979; Bull, 1980; Morreale et al., 1982; Vogt and Bull, 1984; Choo and Chou, 1992). Egg incubation at temperatures 31°C or higher leads to females. Further, zygote genotype rarely exerts influence on sex determination at temperatures below 28°C and above 30°C (Bull et al., 1982). However, as temperatures from nest sites in Singapore are not available, this hypothesis cannot be confirmed.

A differential mortality rate due to predation may be a cause for the difference in sex ratios. Larger predatory animals such as the Malayan water monitor lizard (*Varanus salvator*) and the giant snakehead (*Channa micropeltes*), present at almost all of the study sites, have been observed anecdotally during this study to prey on red-eared sliders. Smaller red-eared sliders, such as males and juveniles of both sexes may be at a greater risk of predation compared to larger females.

The type of predators present at the study site may explain the low catch rates of red-eared sliders with carapace length less than 10 cm. In the wild, mortality rate of juveniles by predation is markedly higher than that of adults (Frazer et al., 1990). Hence, predators such as the water monitor lizard and giant snakehead may have a preference for smaller red-eared sliders as compared to larger ones. Juveniles prefer to utilise the edges of ponds (Moll and Legler, 1971) and as a result, are rarely caught using baited traps. Due to their size, hatchlings and smaller juveniles may also be able to escape through the opening of the traps. However, there is no evidence supporting this, although only a few sliders below 10 cm were caught in the crab traps, smaller turtles were seen by Goh (2004) in the present survey, but appeared to represent only a small percentage of those observed.

Capture using basking traps might provide a less biased estimate on sex ratios since males and females do not exhibit differential basking rates (Chapter 5, page 145) and there exists no restrictions on the duration of deployment of the trap. This might be worth examining in the future.

Perhaps another explanation that might to be unique to Singapore and other countries where there is a possibility that sliders are a result of the release from irresponsible pet owners is that large females might be more likely to be released than smaller females and males. In Chapter 6 of this dissertation (page 180), it is shown that among the reasons cited for releasing their pet red-eared sliders, “it had grown too big for my house” was cited most frequently (42.9% of 28 households). Furthermore, Goh and O’Riordan (2007) observed that medium to large red-eared sliders have been seen on sale at market stalls for release.

The size ranges of red-eared sliders were significantly different between sites, notably between different habitat types such as the reservoirs and the ponds. The reservoirs had larger males and females sliders and can be interpreted as having older populations (Legler, 1990). This find is indicative that temperature and the lack of seasonality may not be an important factor in red-eared sliders attaining maximum potential size. However, elevated temperatures, up to a limit of 35˚C, have been shown to have a positive effect on growth rate of red-eared sliders (Chou and Venugopal, 1984). Temperature and enhanced diet quality (which may be a result of elevated temperatures) may be important factors in the rate of growth of sliders (Cagle, 1946; Gibbons, 1970; Gibbons et al., 1981).

2.4.5 Home range and homing behaviour

The home range of freshwater turtles is most likely affected by feeding and basking activities (Cagle, 1944b). Various methods of estimating the home range of red-eared sliders were discussed by Moll and Legler (1971). They recommended calculating the maximum length of the home range to be the curved length of the two furthest relocation points of a captured turtle, and drawing straight lines at right angles through these two points. The area enclosed would then be the home range of the adult turtle. However, this would be effective only in streams and rivers, areas which are not applicable in this study.

Eighty-nine percent of 18 recaptures were at their original location despite being released more than 1 km away) suggests that not only do the red-eared sliders have a specific home range, they are also able to find and return to the same site within a few days. This behaviour, termed 'philopatry', has been documented for the common musk turtles (Andres and Chambers, 2006). However, this observation of the red-eared slider is the first for its species

2.4.6 Other turtle species

During the course of the present study, nine other turtle species were caught in the traps. Of these, four species are not native to the region. It is likely that almost all (even native species) of the terrapins found in ponds such as Eco-Lake are released pets, or have been released for religious reasons. The river terrapin (*Batagur baska*), for example, is native to the region but prefers tidal areas of large estuaries (Ernst and Barbour, 1989). That they arrived via migration is an unlikely scenario, as they are not known to travel long distances overland. Also, Singapore is an isolated island, connected only to Peninsular Malaysia via two causeways. Chances of the river terrapin, or other freshwater terrapin species arriving naturally are slim. The release of terrapins from the pet trade remains the most likely cause for their presence in areas such as Eco-Lake, especially with their growing popularity as pets in South East Asia (Jenkins, 1995).

In their survey of 27 pet shops, Goh and O'Riordan (2007) found 13 shops illegally selling protected species of chelonians. These include 12 species of tortoise and freshwater turtles; the pig-nose turtle (*Carettochelys insculpta*), Malayan box terrapin (*Cuora amboinensis*), Indian star tortoise (*Geochelone elegans*), leopard tortoise (*Geochelone pardalis*), Argentine snake-necked turtle (*Hydromedusa tectifera*), Bell's hinged tortoise (*Kinixys homeana*), alligator snapping turtle (*Macroclemys temminckii*), pancake tortoise (*Malacochersus tornieri*), Chinese soft-shell turtle (*Pelodiscus sinensis*), razor-back musk turtle (*Sternotherus carinatus*) and all of the pet shops had the red-eared slider. There are possibly many more species of turtles that are being sold in the pet trade that are unrecorded, such as the Chinese striped-necked terrapins (*Ocadia sinensis*) and the river terrapin (*Batagur baska*).

The black marsh terrapins trapped in this study most likely belong to an indigenous population. This species is not popular in the pet trade, having no distinctive colouration and emitting an unpleasant odour (pers. obs). However, it cannot be ruled out that they may also be released from pet shops perhaps due to their disagreeable scent.

Captures of the Malayan box terrapin (*Cuora amboinensis*) were relatively low when compared with Teo and Rajathurai's report in 1997 that this was the most common reptile found in the central catchment reserve (which includes Lower Peirce and MacRitchie Reservoirs) is taken into account. Only one individual was caught during the population mark-and-recapture trapping sessions at Lower Peirce reservoir in 2004 and three were observed in Eco-lake in 2007. However, the release of four box terrapins at Swan Lake on Vesak Day in 2004 (chapter 6, page 194) and the presence of this species in local pet shops (Goh and O'Riordan, 2007) are indicative that current records of this species are releases from the pet trade or for religious reasons.

There was one sighting of an extremely large terrapin with a carapace of approximately more than a metre in length in Lower Peirce reservoir. However, it could not be identified because of murky water. No individual larger than 30 cm in length was caught in the crab traps. There were no captures of the Malayan flat-shelled terrapin (*Notochelys platynota*) that Teo and Rajathurai (1997) mentioned (six records) and the current status of this rare species in Singapore is unknown.

2.5 Conclusion

This study unequivocally demonstrates that red-eared sliders are the most predominant freshwater turtle found in Singapore. Populations of red-eared sliders are denser, but maximum individual size is smaller, at the ponds in the Singapore Botanic Gardens than in Lower Peirce and MacRitchie reservoirs. Populations at all four sites and an additional site at the Singapore Botanic Gardens had about five times more females than males. There is potential for future research investigating the source of this skewed sex ratio, with investigations perhaps focusing on the ratio sexes of imported batches and the sex and survivorship of hatchlings in Singapore.

Chapter 3: The reproductive biology of red-eared sliders in Singapore

3.1 Introduction

Large numbers of red-eared sliders can be found in many of the water bodies in Singapore (see Chapter 2 for details). However, it is still unclear if the large population sizes are a result of continual introductions to the population via the release of pet turtles, or if they are capable of reproducing in Singapore. This situation is common in countries where this species is not native and has been reported in Italy (Luiselli et al., 1997). The reproduction of red-eared sliders has been studied in detail within their natural range (Cadi et al., 2004; Cadi and Joly, 2004; Tucker, 1999; Tucker and Moll, 1997; Hutchison, 1992; Cagle, 1944c; Tucker et al., 1998a; Tucker et al., 1998b; Tinkle, 1961; Aresco, 2005; Aresco, 2004; Tucker, 2001; Gibbons and Greene, 1990). However, few studies have focused on reproduction outside of their native range. One such study was in France, where sliders are reproducing in three regions where the European pond terrapin (*Emys orbicularis*) also occurs (Servan and Arvy, 1997). Ernst (1990) suggested that introduced populations of sliders might reproduce readily in an area with a sufficiently long summer or in areas with a similar climate as their native range. These environmental conditions would allow the production of viable eggs and a suitable incubation period (Luiselli et al., 1997). While it is most likely that red-eared sliders are breeding in Singapore, this aspect of its ecology has not been formally investigated.

3.1.1 Reproduction of turtles

In sexually mature male turtles, spermatogenesis occurs in the testes which are oval (sometimes slightly flattened) and have a smooth surface (Moll, 1979). Before puberty, the testes present are smaller, increasing in size with age of the male (Miller and Dinkelacker, 2008). In red-eared sliders, spermatogenesis commences upon the onset of puberty and stimulates the development of secondary sexual characteristics such as elongated foreclaws (Gibbons and Greene, 1990). Sperm is stored in the epididymides, which becomes enlarged and turgid-white during the reproductive cycle, before transfer to the female during mating (Moll, 1979).

Before puberty, ovaries are present but reduced in female turtles, with oocytes developing upon puberty (Miller and Dinkelacker, 2008). In sexually mature female turtles, the ovary contains previtellogenic follicles, which may be of several different size classes. Previtellogenic follicles are typically yellow-cream in colour (Miller and Dinkelacker, 2008). Before ovulation, the follicles undergo vitellogenesis and enlargement. For species that are able to produce multiple clutches per breeding season such as red-eared sliders, the enlarged follicles occur in groups of differing sizes (Gibbons and Tinkle, 1969). The earliest and largest clutch will ovulate first and migrate to the oviduct before the next clutch undergo enlargement (Miller and Dinkelacker, 2008). After ovulation, the stroma and theca surrounding the follicle collapse, forming corpus lutea which regress after oviposition. Regression of the remaining unovulated follicles occurs after the reproductive season and the ovaries enter a period of quiescence. This presumably allows the female to regain energy expended during reproduction (Miller and Dinkelacker, 2008).

The cloaca is present in both males and females, although it is longer in males to accommodate the penis (Kuchling, 1999). During mating, the male inserts his penis into the female's cloaca. Sperm is transferred into the female's cloaca and subsequently to the oviducts for fertilisation. Female red-eared sliders can store sperm in undifferentiated tubules and ducts near the oviduct. However, it is unclear how long the sperm can be stored for. In other species of turtles, such as *Chrysemys picta*, sperm can be stored for periods of up to three years (Pearse and Avise, 2001). Sperm storage is beneficial for female turtles because it reduces the need for females to find mates in between clutches (Pearse and Avise, 2001). This is advantageous in populations where there are more females than males (see chapter 2).

In Panama, nesting usually coincides with the dry season (Moll and Legler, 1971). The peak of nesting activity took place between 1800 hrs and 0030 hrs and did not occur when temperatures were below 22˚C or in direct sunlight (Moll and Legler, 1971). The latter is presumably due to the extended duration of one to two hours required for nesting and may result in the female's body temperature to be elevated to critical thermal maximum temperature (Moll and Legler, 1971). Sliders in Panama exhibited a preference for open areas that are exposed to direct sunlight during the day (Moll and Legler, 1971). Nest site selection is not arbitrary in most turtle species (Miller and Dinkelacker, 2008). However, factors governing nest site selection are not well studied, as sliders have been observed to nest between a few to several hundred meters from the water (Moll and Legler, 1971). Nesting females are observed to frequently press their snout to the ground, possibly a way to identify nests of other females to be avoided, although this has not been adequately proven (Moll and Legler, 1971).

The female excavates the nest using her hind legs and expels fluid from her cloaca at regular intervals in the initial stages. The entire process takes about one hour and the detailed stereotypical process was described by Moll and Legler (1971). After excavating the nest as deep as her hind legs are able to reach, eggs are laid in the cavity. In between laying, the female uses her hind foot to arrange the last laid egg. When all the eggs are in the nest, the female uses her hind legs to cover the cavity with the soil earlier dug up, finishing when covering the nest plug with vegetation or debris from the surrounding area (Moll and Legler, 1971).

Red-eared sliders produce thin leathery-shelled eggs (Jackson, 1988) which are ellipsoidal in shape (ratio of length/width between 1.99 and 1.10) (Ewert, 1979). Moll and Legler (1971) observed that smaller clutches contained smaller eggs and the eggs from Panama measured 37.1 mm – 47.6 mm in length and 25.5 mm – 31.3 mm in width.

3.1.2 Reproduction of the red-eared slider in Singapore

Red-eared sliders have been recorded laying eggs in the Botanic Gardens in Singapore (Teo and Rajathurai, 1997) and nesting behaviour has been observed at many sites where the sliders can be found, such as at the Singapore Botanic Gardens (Tan T. W. H. pers., comm.), Night Safari (Leong Tzi Ming, pers. comm.), Bedok reservoir (Grace Leng, pers. comm.), Upper Peirce reservoir (Benjamin Lee and Derek Liew pers. comm.), MacRitchie Reservoir (Amy Chong, pers. comm.) and at an urban park near the Kandang Kerbau Hospital (Wen Hwee Liew, pers. comm.) (Chapter 5, page 163). While it is evident that this species is breeding in Singapore, there has been no quantitative research to show to what adaptations feral populations of red-eared sliders have made to ensure successful reproduction in Singapore. Such information would be particularly useful for park management. It would also be the first study of the reproductive cycles of red-eared sliders in a tropical equatorial climate. It is unknown if in a relatively aseasonal climate, such as that in Singapore, whether the red-eared sliders can breed throughout the year or weather there is seasonality in their reproduction.

3.1.3 Objectives

The objectives of this chapter is to investigate and describe the reproductive status of red-eared sliders in Singapore with focus on important aspects of reproduction such as

a) Timing of reproduction,

b) Stage of gonad development over the year,

c) Variation in female maturity with size,

d) Clutch size and clutch frequency, and

e) Variation in reproduction between sites.

3.2 Materials and Methods

3.2.1 Fieldwork

Male and female red-eared sliders were collected from two sites: Eco-lake at the Singapore Botanic Gardens and at Bedok Reservoir. From June 2004 to June 2006 at Eco-lake and August 2004 to August 2006 at Bedok reservoir, adult male and female terrapins were collected at monthly intervals. At each location and sampling occasion five adults females were collected from two carapace length classes; a) 15.0 cm –

19.9 cm b) 20.0 cm – 24.9 cm. Five adult males of any size were collected and their maturity was determined by the presence of long foreclaws. All specimens from Eco-lake were collected between 1300 hrs and 1500 hrs using a long-handled dip-net from a bridge overlooking the pond, using bread as bait. Specimens from Bedok reservoir were collected using five crab traps (as described in chapter 2) baited with fish. Collection at Bedok reservoir was between 1000 hrs and 1700 hrs. The longer collection time was necessary as crab traps are less efficient than dip nets.

3.2.2 Laboratory sessions

On return to the laboratory, the specimens were frozen at -20˚C until dissection. Before dissection, the carapace length, width and height (as described in chapter 2) were measured to the nearest millimeter using a pair of calipers and a ruler. Measurements of the tail length, pre-anal tail length and maximum claw length was taken using Vernier calipers, but only for specimens collected in the second year of this study. The turtles were sawn at the bridge with an angle grinder and broken using bone-cutters. The plastron was removed using a scalpel and blade. If the terrapins were male, both testes and epididymides were removed (figure 3.1). The diameter of the testes was measured using Vernier calipers and the testes and epididymides were weighed to the nearest milligram using an electronic weighing scale.

For females, follicles and oviducal eggs were removed whenever present. The diameter of the follicles were assessed using a plastic strip perforated with holes of different diameters (table 3.1, figure 3.2). The follicles were then staged according to their diameter following Moll and Legler (1971) (figure 3.3). Follicles and eggs were preserved in 10% formalin and counted at a later time.

Table 3.1 Stage of follicle development (after Moll and Legler, 1971)

Stage	Size range of follicles
0	No follicles
I	≤ 6 mm
II	7 – 13 mm
III	14 – 20 mm
IV	21 – 27 mm

Temperature data were obtained from the meteorological services of the National Environment Agency of Singapore.

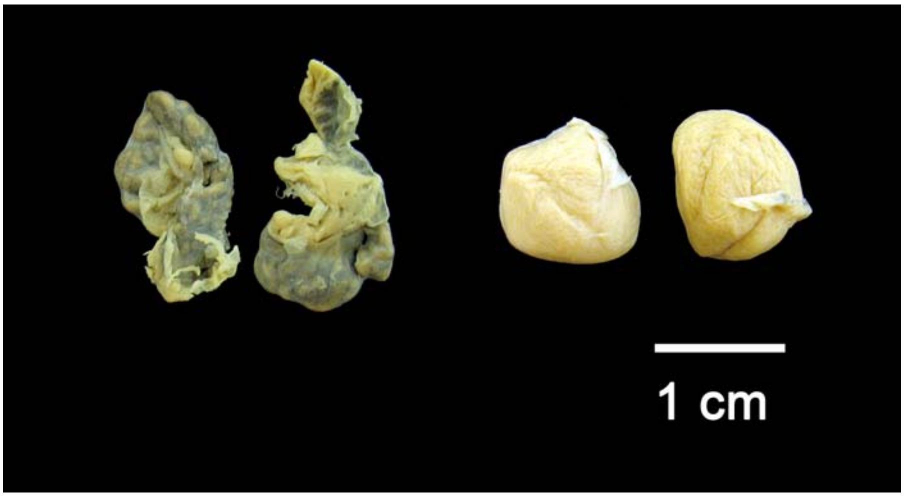


Figure 3.1 Epididymides (left) and testes (right) from a dissected male red-eared slider.

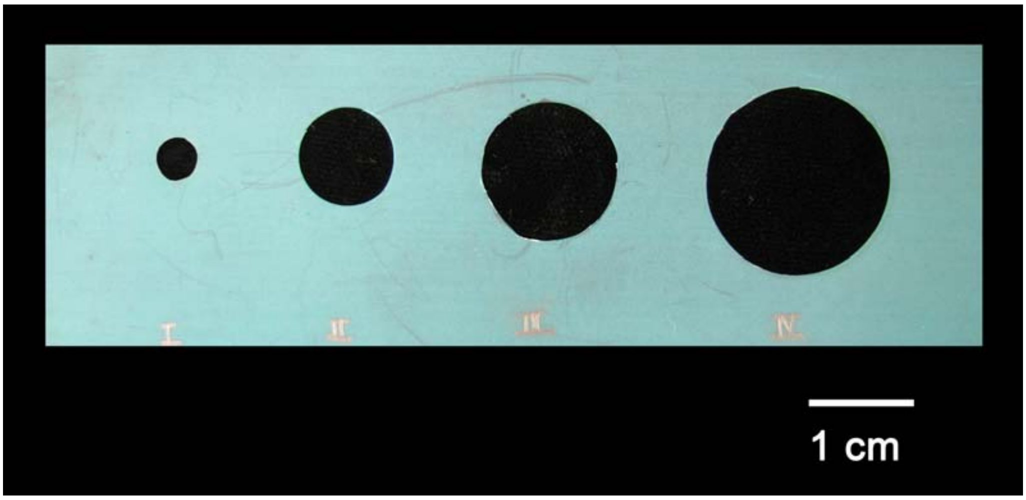


Figure 3.2 The perforated plastric strip used to categorise the egg follicles into the various stages of development.

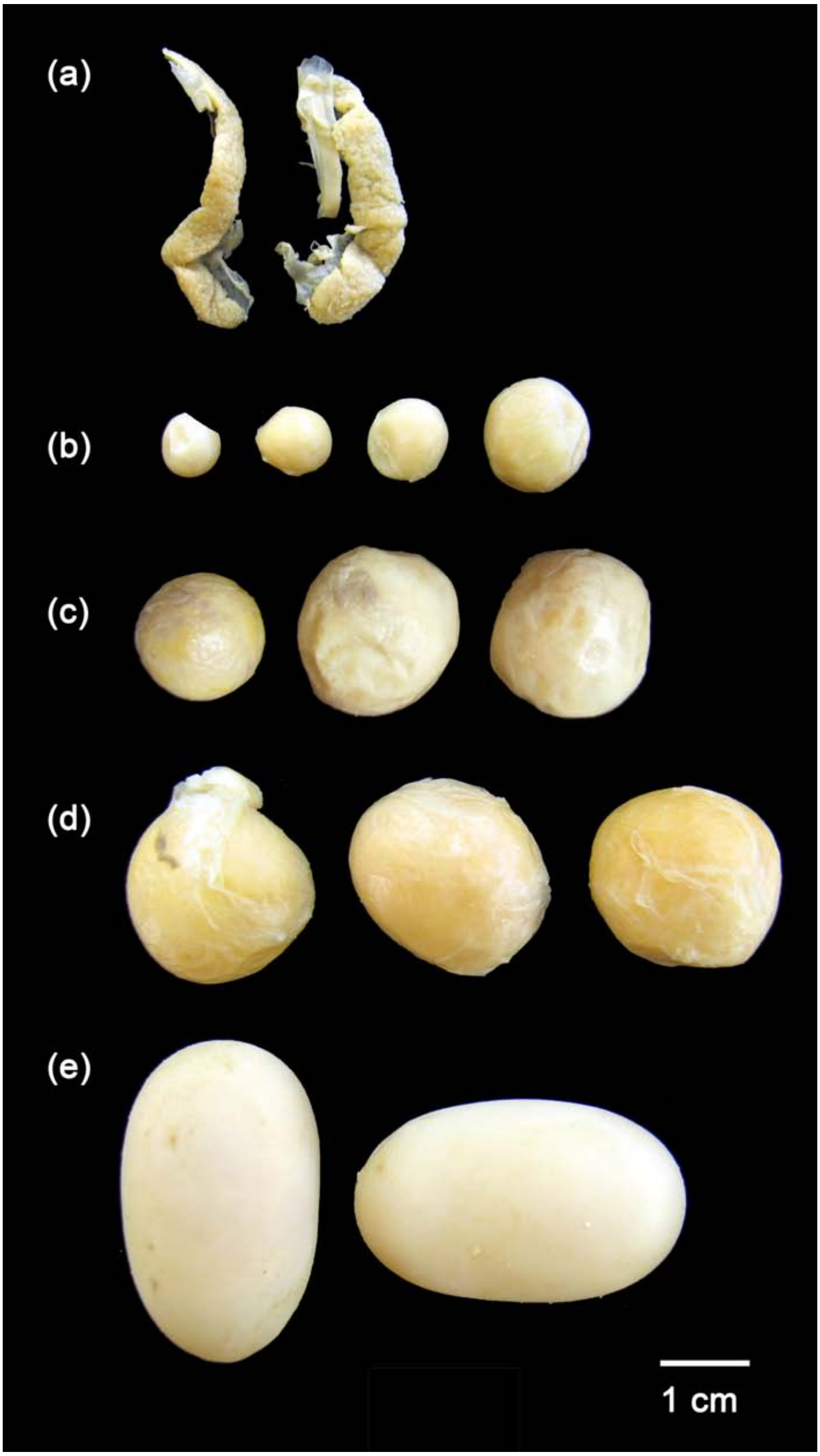


Figure 3.3 Follicles and oviducal eggs from dissected female red-eared sliders: a) stage I follicles (≤ 6 mm); b) stage II follicles (7 – 13 mm); c) stage III follicles (14 – 20 mm); d) stage IV follicles (21 – 27 mm) and e) shelled oviducal eggs.

3.3 Results

3.3.1 Sexual dimorphism

Scatter plots of carapace lengths (CL) against longest foreclaw length of males (n=18, min CL = 10.8 cm, max CL = 16.1 cm) and females (n = 36, min CL = 11.2 cm, max CL = 25.3 cm) showed that red-eared sliders in Singapore are sexually dimorphic, with males having significantly longer foreclaws than females (median test, $P < 0.0005$). The foreclaw length of the smallest male was longer than that of the largest female (figure 3.4).

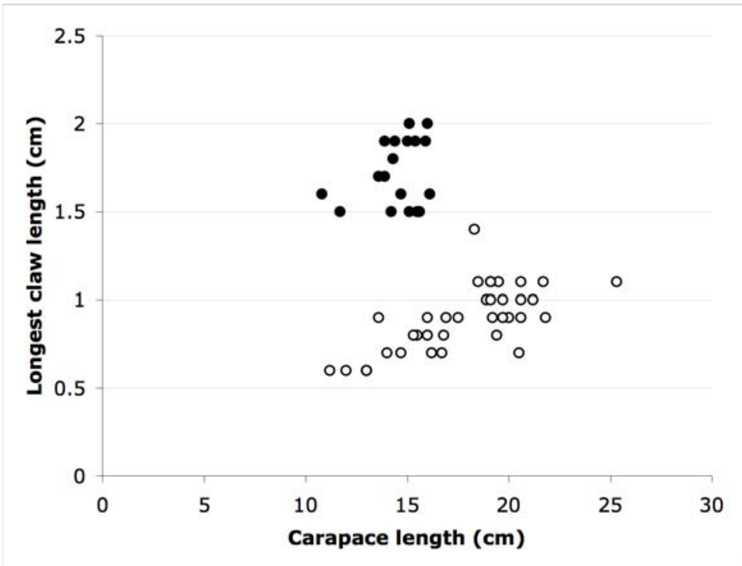


Figure 3.4 Sexual dimorphism in claw length. Dots represent male specimens and circles represent female specimens.

Males also had significantly longer tail lengths ($P < 0.05$) and pre-anal tail lengths ($P < 0.0005$) than females but the distinction is clearer for pre-anal tail lengths (figure 3.5).

(a) (b)

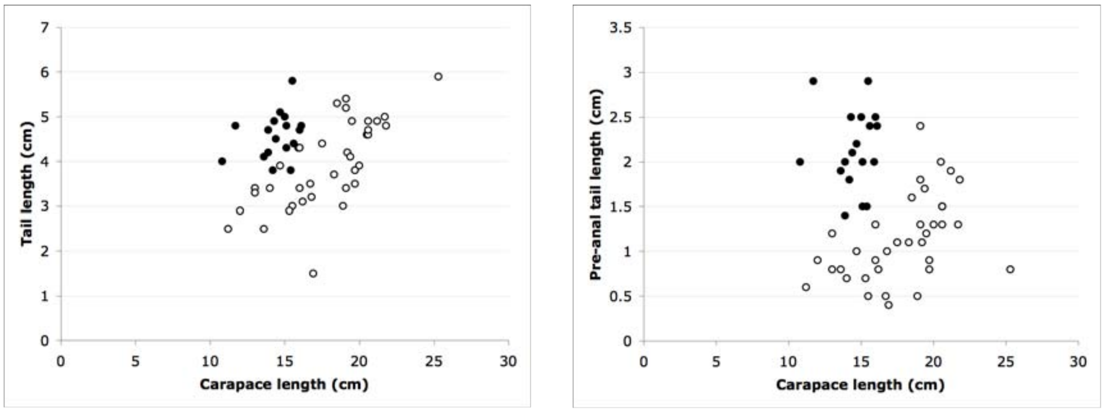


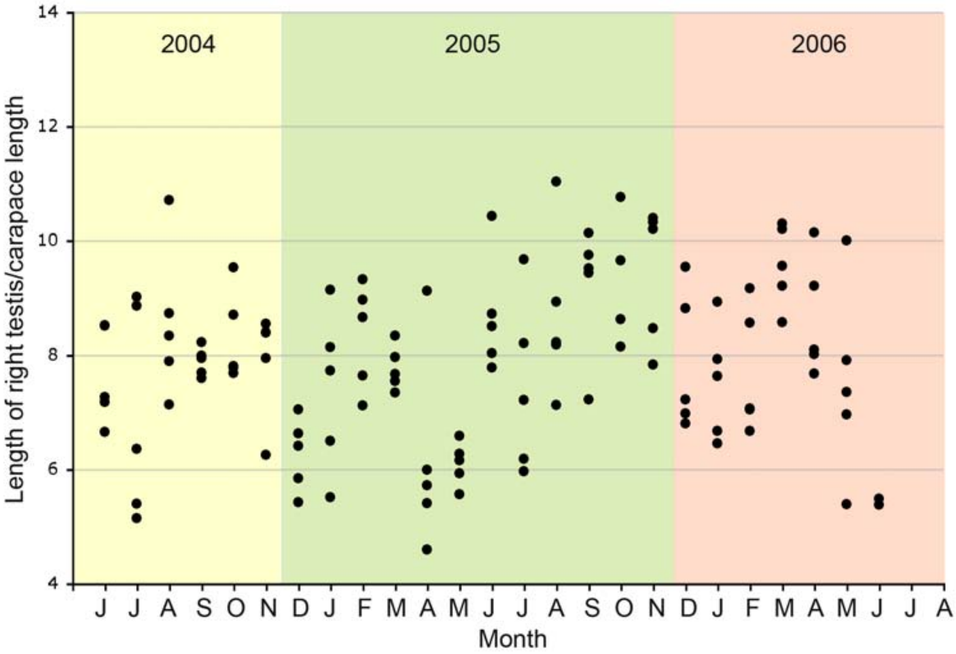
Figure 3.5 Sexual dimorphism in a) tail length and b) pre-anal tail length. Dots represent male specimens and circles represent female specimens.

3.3.2 Testes and epididymides

One hundred and twenty-five males were collected from Eco-lake and 68 males were collected from Bedok reservoir over the period of June 2004 to June 2006 and August 2004 to August 2006 respectively. As testes and epididymides sizes are known to increase with body size (Miller and Dinkelacker, 2008), all measurements are expressed as a percentage of carapace length. Non-parametric median tests found a significant difference in average testes diameter with the males from Bedok reservoir having larger testes ($P < 0.005$). No significant differences were found in the carapace lengths, average (of left and right) testis weights and average (of left and right) epididymis weights of males collected from both sites.

Right testis diameter appeared to decrease from August to December 2004 at both sites. Following this, there was a slight dip in April 2005 and then an increase to peak in June 2005 at Eco-lake. At Bedok Reservoir, an increase was also observed, peaking in August 2005 (figure 3.6). After these peaks, testis diameter decreased again reaching minimum diameter in January 2006 at both sites. Testis diameter peaked

(a)



(b)

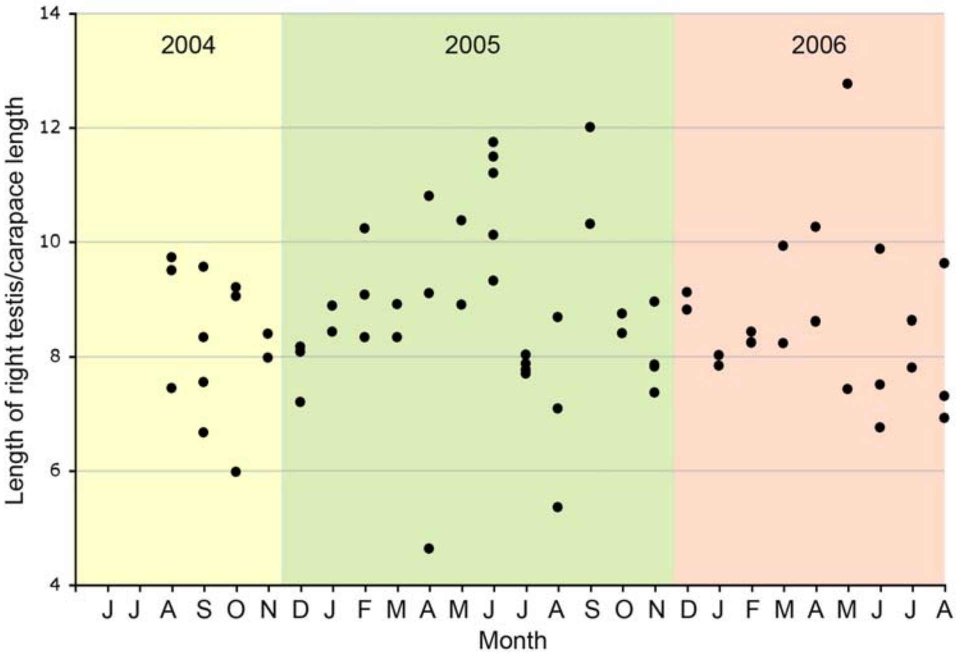


Figure 3.6 Diameter of the right testis as a percentage of carapace length from a) Eco-lake and b) Bedok reservoir.

earlier in 2006 than in 2005, in March at Eco-lake and May at Bedok reservoir. The dips in testis diameter coincided with dips in temperature. Testes weight showed similar patterns in fluctuations at both sites (figure 3.7). Please refer to figure 3.8 for mean monthly temperature fluctuation patterns from 2004 – 2006.

At Eco-lake, epididymis weight followed an approximate pattern to testis diameter (figure 3.9). Epididymis weight decreased after July and increased in December 2004. There was a dip in epididymis weight in April 2005 (as observed in testis diameter and testes weight), followed by an increase in June 2005 and the weight remained relatively high until March 2006 after which there was a decline until June 2006. There was not much fluctuation in epididymis weight at Bedok reservoir and it followed loosely the same pattern as observed at Eco-lake.

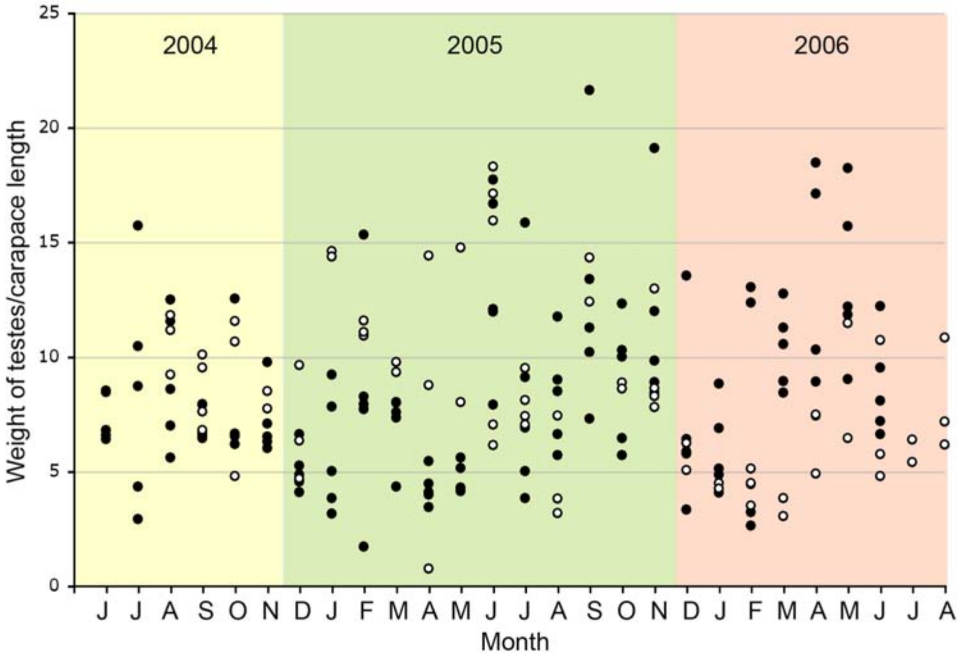


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Figure 3.7 Weight of both testes as a percentage of carapace length. Samples from Eco-lake are represented by dots and samples from Bedok reservoir are represented by circles.

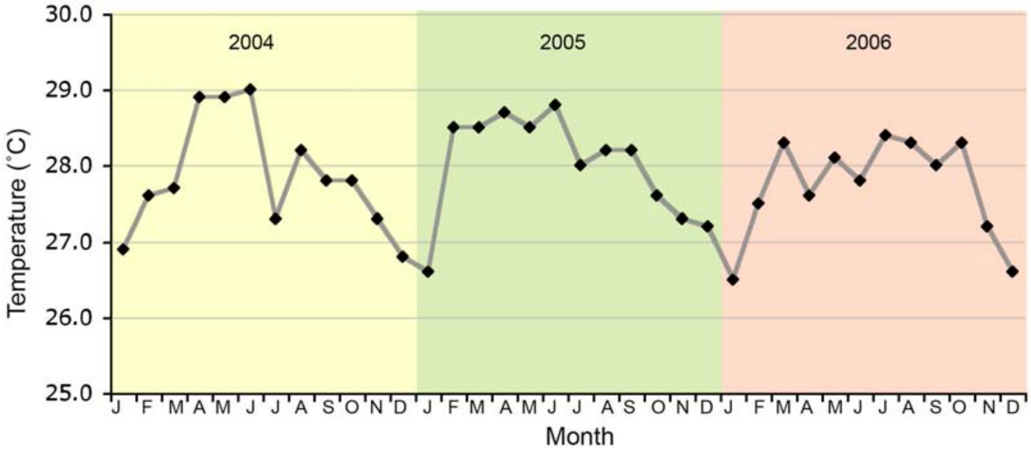


Figure 3.8 Mean monthly temperatures for 2004 to 2006.

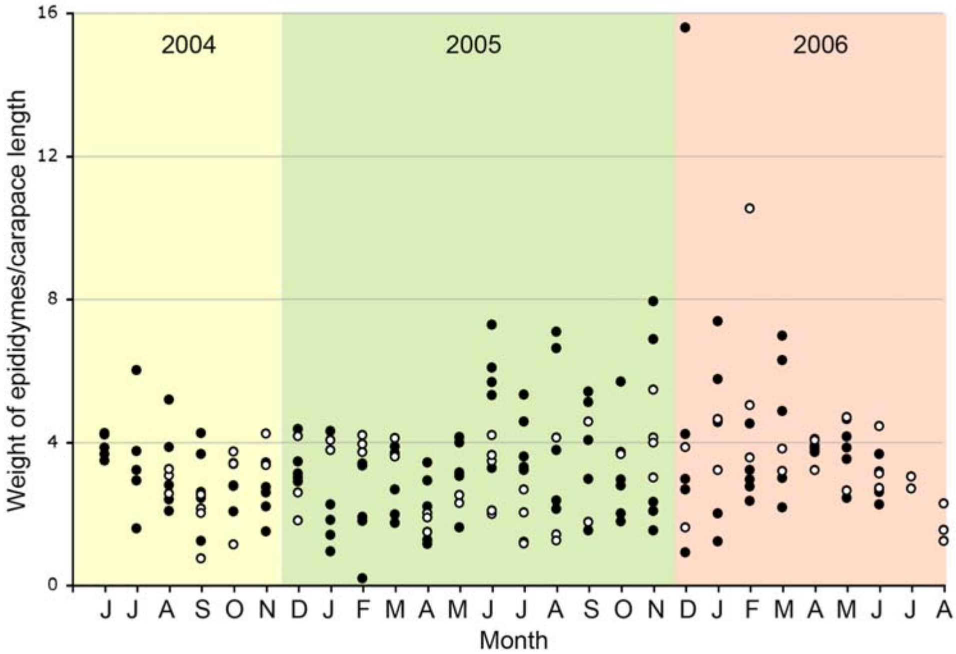


Figure 3.9 Weight of both epididymes as a percentage of carapace length. Samples from Eco-lake are represented by dots and samples from Bedok reservoir are represented by circles.

3.3.3 Ovaries

Five hundred female red-eared sliders examined from both sites and all of the specimens contained stage I follicles. Specimens containing a higher stage of follicles (presence of oviducal eggs being the highest stage) also contained all the stages preceding it. Therefore if an animal is referred to as bearing stage IV follicles, it is to be understood that it also contained stage III, II and I follicles. Oviducal eggs were only found in 12 female specimens from Eco-lake (4.8%) and none from Bedok reservoir and the presence was restricted to specimens ranging from 19.3 cm to 24.9 cm in carapace length (table 3.2, figure 3.10). Kruskal-Wallis tests comparing the size of specimens showed that turtles bearing stage IV follicles were significantly larger than those bearing only up to stage II follicles ($P < 0.05$). There were no significant differences among the carapace lengths of the specimens bearing the other stages of follicles and oviducal eggs. There were significantly more specimens with developing follicles at Eco-lake than at Bedok reservoir ($\chi^2 = 7.97$, df = 3, $P < 0.05$). There was no significant difference between the carapace lengths of females caught at both sites.

Table 3.2 Range of carapace lengths and number of specimens found with stage II, III, IV follicles and oviducal eggs at two sites. Specimens with only Stage I follicles (103 from Eco-lake and 201 from Bedok reservoir were not included).

	Eco-lake			Bedok reservoir		
	N (%)	min	max	N (%)	min	max
Stage II	147 (58.8)	15.4 cm	25.0 cm	69 (27.6)	16.0 cm	25.3 cm
Stage III	78 (31.2)	15.4 cm	25.0 cm	35 (14.0)	16.7 cm	24.9 cm
Stage IV	37 (14.8)	16.3 cm	25.0 cm	9 (3.6)	18.1 cm	24.9 cm
Oviducal eggs	12 (4.8)	19.3 cm	24.9 cm	0 (0.0)	-	-

(a) (b)

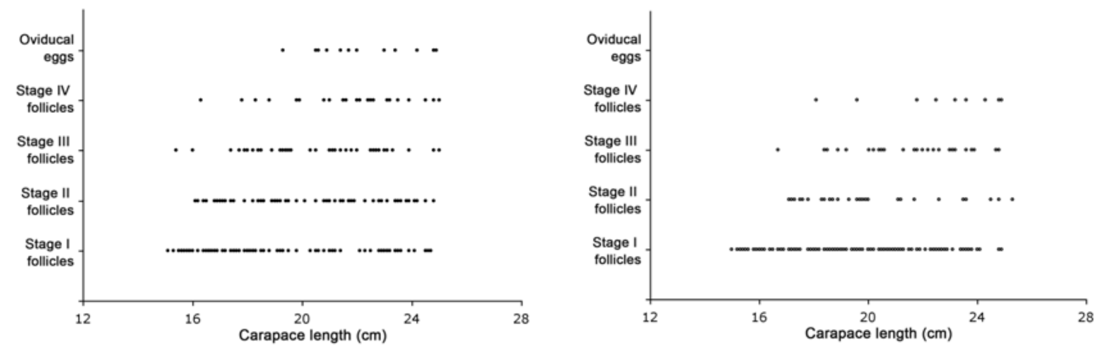
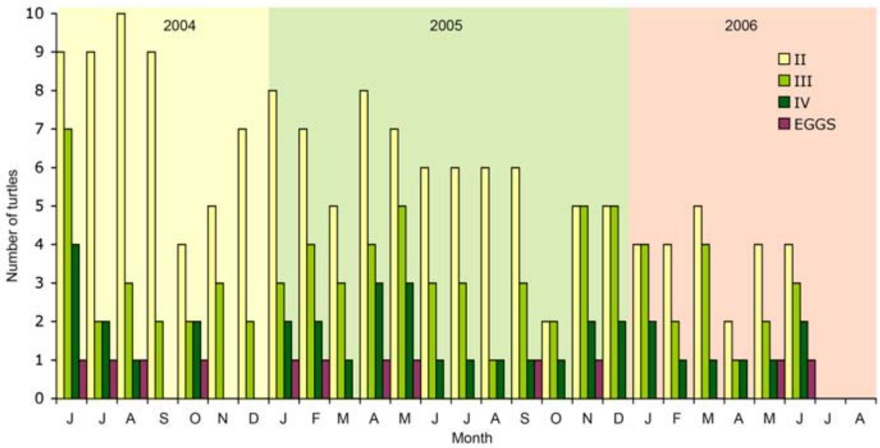


Figure 3.10 Stages of follicles and oviducal eggs found in specimens caught at a) Eco-lake and b) Bedok reservoir.

At Eco-lake, oviducal eggs were found in the months of June to August and October of 2004, January, February, April, May, September and November of 2005 and May and June of 2006. Follicles of ovulatory size (stage IV follicles) were found in all months except for September, November and December of 2004. The highest proportion of females (40%) bearing stage IV follicles occurred in June 2004, and 30% in April to May 2005, which is coincident with higher atmospheric temperatures (figure 3.8). During the first year of this study, the proportion of females bearing stage II follicles dipped from 90% in June to September to 40% in October. After that there was a steady increase to 80% in January and a decline to 50% in March. April had 80% with stage II follicles which dropped to 60% in June (figure 3.11a).

The trends in the second year of this study loosely followed the first year, with a decline in proportion bearing stage II follicles in October and April (instead of March). However, the proportions were lower than what had been observed in the first year.

(a)



(b)

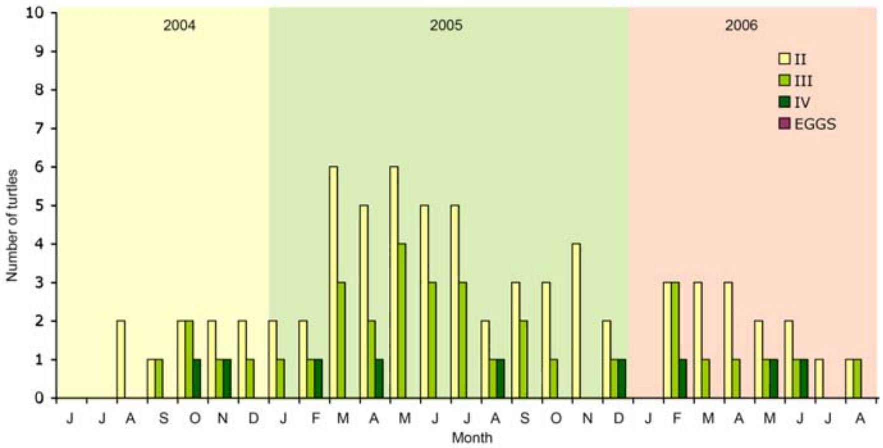


Figure 3.11 Number of females at a) Eco-lake and b) Bedok reservoir with Stage II, III, IV and oviducal eggs. Eco-lake was sampled from June 2004 to June 2006 and Bedok reservoir was sampled from August 2004 to August 2006. Sample size for each month was ten.

At Bedok reservoir, in either year, none of the 250 specimens examined contained oviducal eggs. Stage IV follicles occurred only in the months of October and November of 2004, February, April, August and December of 2005, and February, May and June of 2006 (with asterisks (*) indicating months that coincided with the presence of stage IV follicles at Eco-lake) (figure 3.11b). The proportion with stage II follicles only exceeded 40% during the period of March to July 2005, other than which most months only had 20% to 30% with stage II follicles.

Regression analyses showed no significant relationships between carapace length and number of oviducal eggs, stage IV follicles and stage II follicles. However, larger female sliders did seem to carry more stage III follicles ($R^2 = 0.12$, $P < 0.0005$) (figure 3.12).

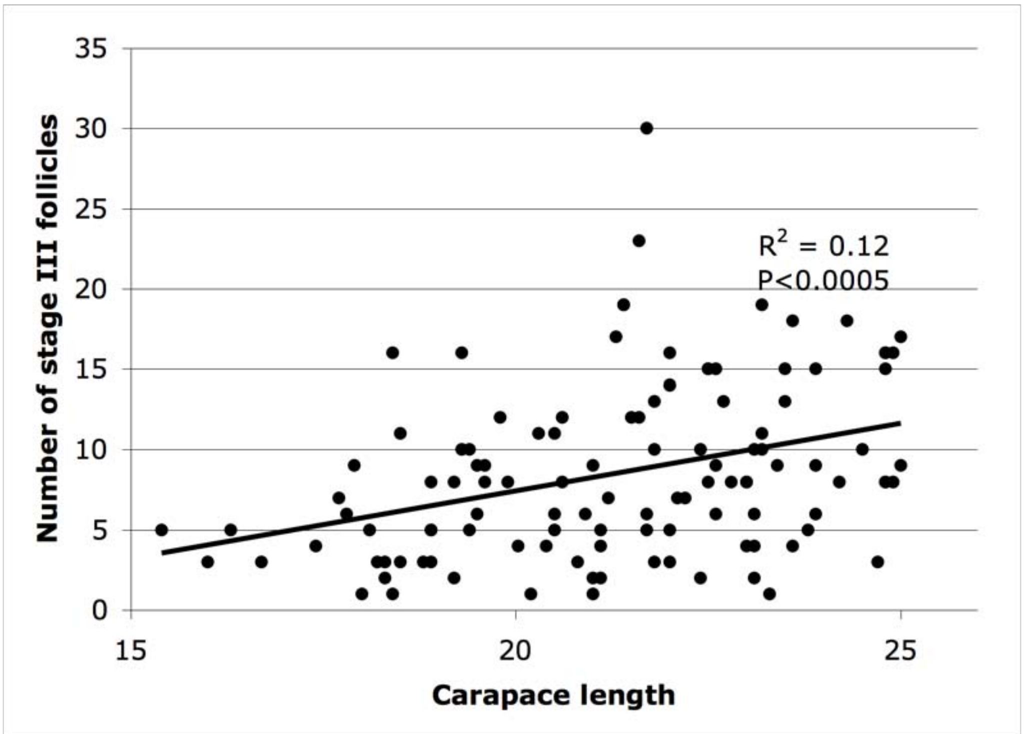


Figure 3.12 Linear regression of carapace length and stage III follicles.

The number of oviducal eggs found within one individual varied from two to seven and the average number found among the 12 females was 5. The modal number of oviducal eggs, stage IV follicles and stage III follicles was between 5 and 8, indicating that the clutch size of red-eared sliders in Singapore is between 5 and 8. None of the specimens examined had between 13 and 17 stage IV follicles and there were two individuals with 18 and 19 stage IV follicles each. Of the females bearing size III follicles, 71% had between 1 and 10 follicles. Of the females bearing stage II follicles, 81% had between 10 and 39 follicles (figure 3.13).

3.3.4 Temperature

Mean monthly atmospheric temperature data were cyclical with lowest temperatures during the period of November to January, the rest of the months were distinctively warmer (figure 3.8). 2004 appeared to have the warmest months (April to June) but declined in the months after. 2005 had lower maximum temperatures but high temperatures lasted longer (from February to June). 2006 appeared to be the coolest, with the maximum mean temperature being 28.4˚C compared to 28.8˚C in 2005 and 29.0˚C in 2004. The warm temperatures were more prolonged though, lasting from March to October and declining only in November.

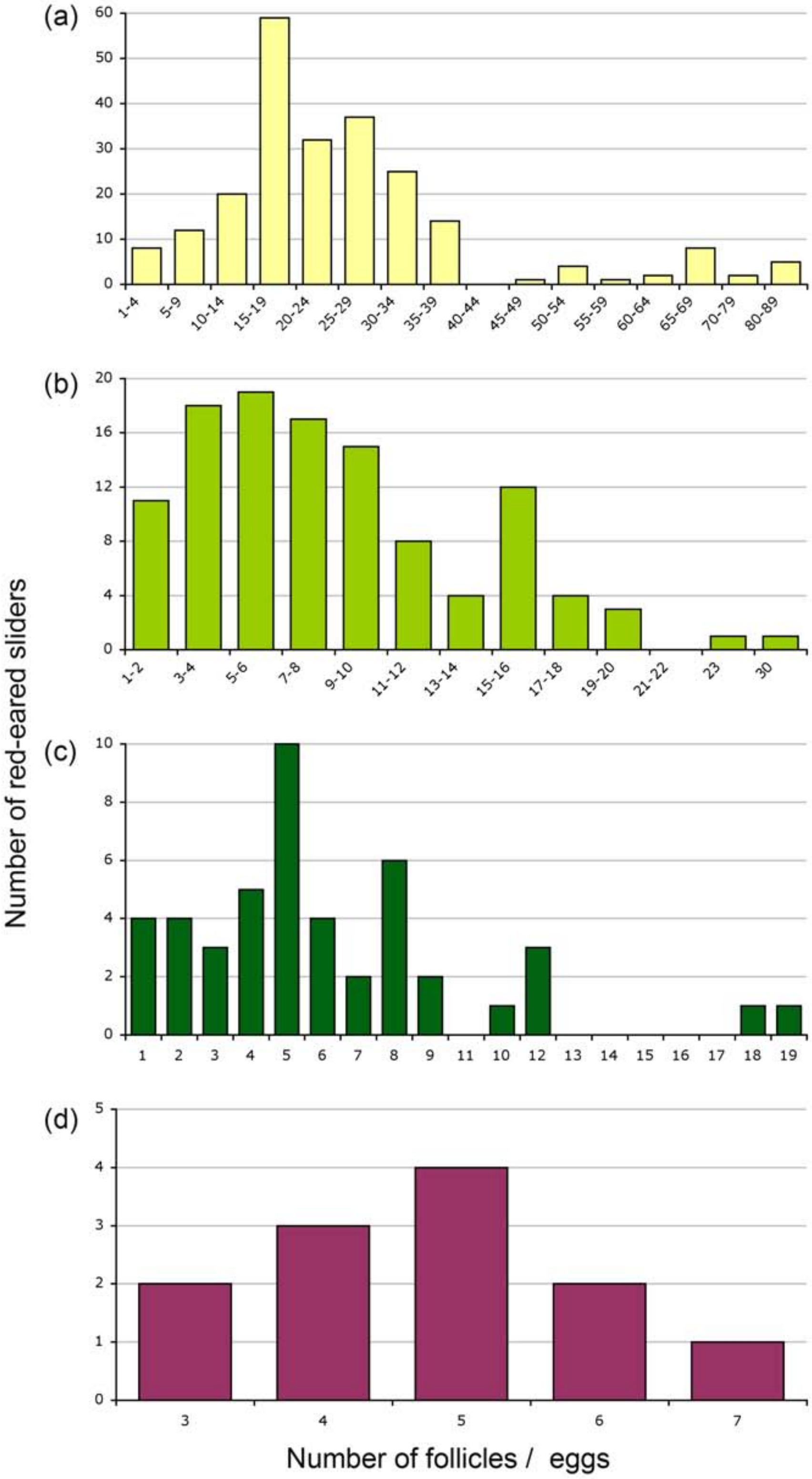


Figure 3.13 Frequency of a) stage II follicles, b) stage III follicles, c) stage IV follicles and d) oviducal eggs found.

3.4 Discussion

3.4.1 Sexual maturity and sexual dimorphism

Gibbons and Greene (1990) defined sexual maturity in female turtles as "the capability for producing eggs during the next breeding season and can be confirmed by the presence of oviducal eggs, corpora lutea in the ovaries, or enlarged pre-ovulatory follicles of sufficient size to be ovulated during the nesting season". Because the size at sexual maturity of females can vary greatly between sites and locations and no prior studies have been conducted in the region, in the present study female red-eared sliders of sizes ranging from 15cm to 25cm were caught. Gibbons and Greene (1990) suggested that size is the defining factor for the attainment of sexual maturity in males whereas age is more critical in females. Their studies at a thermally altered pond further suggests that with faster growth rates at high temperatures, males attain sexual maturity earlier, but females attain sexual maturity at a larger size. Based on the definition provided by Gibbons and Greene (1990), the smallest sexually mature female caught in at Eco-lake had a carapace length of 16.3cm and 18.1cm at Bedok reservoir. Only sexually mature males were caught in this study, identified by their distinctive secondary sexual characteristics such as longer foreclaw and tail length. Sometimes tail length alone was not sufficient to confirm the sex and from the results of this study, pre-anal tail length appeared to be a more defining character.

3.4.2 Testes and epididymides

The cyclical (and loosely temperature-related) increases in size and weight of the testes and epididymides of the red-eared sliders in this study suggest that spermatogenesis and sperm transfer follow a seasonal pattern in Singapore. In sliders, the increase in size and weight of testes are known to be coincident with the start of spermatogenesis and maximum size is achieved during the peak of spermatogenic activity. The testes quickly regress in size and weight at the end of the reproductive(Moll and Legler, 1971). The epididymides usually enlarge later than the testes and can remain enlarged even after the testes have regressed. Enlargement of epididymis coincides with the transfer of new sperm from the testes and the regression occurs when sperm is released during mating (Moll and Legler, 1971).

The increase in testes size and weight coinciding with the warmer months in Singapore are typical of the spermatogenic activity of red-eared sliders in general as spermatogenesis usually occurs during the hottest months of the year or immediately following the nesting season (Miller and Dinkelacker, 2008). The epididymis of red-eared sliders has been observed to contain sperm throughout the year and had little fluctuation even though testis weight changed according to sperm production throughout the year (Gist et al., 2002).

3.4.3 Ovarian cycle

Follicular enlargement and ovulation did not follow any distinct pattern in the sliders observed at either site in Singapore. This is in contrast to the red-eared sliders in their native range which exhibit clear seasonality in their reproductive cycles (Mitchell and Pague, 1990; Moll and Legler, 1971). In Panama, follicular enlargement occurs from August to May and no stage IV follicles were observed after April. Reproductive quiescence in females was also reported to last from June to July (Moll and Legler, 1971). In this study, follicular enlargement occurred in all months of the year at both

Eco-lake and Bedok reservoir represented by the presence of stage III follicles. This is also the first study to demonstrate the presence of pre-ovulatory follicles almost throughout the year as shown in Eco-lake.

3.4.4 Clutch frequency and clutch size

Red-eared sliders and many other species of turtles have the ability to produce more than one clutch per year or breeding season (Cagle, 1950). In this study, the presence of follicles of ovulatory size (stage IV) occurring in all 12 females that contained oviducal eggs suggests this to be true for red-eared sliders in Singapore. Furthermore, mid-sized developing follicles (stage III) could be found in all specimens that contained stage IV follicles, and sometimes all three stages were found in the same individual. This is an indication that while ovulation is occurring, other follicles from the next smaller size class are being enlarged to become pre-ovulatory as described by Moll and Legler (Moll and Legler, 1971). The presence of a number of individuals which had 15 to 30 stage III follicles and 18 to 19 stage IV follicles (roughly double the maximum clutch size observed in this study) suggested that the different clutches might be developed very close to one another. Limited conclusions can be drawn from the presence and numbers of stage II follicles since follicles this small may not necessarily enlarge to be ovulated and can be retained for the next breeding season (Moll and Legler, 1971).

The modal clutch frequency for most species of turtles in general is two or three clutches per season (Ewert, 1979), and red-eared sliders have been known to lay up to five clutches per year (Moll and Legler, 1971). The lack of a clear breeding season for the red-eared sliders in Singapore and the presence of ovulatory sized follicles in almost all months of the year suggest that the clutches may be spread out over the year as opposed to being restricted to a specific period.

Gibbons et al. (1982) reported that the mean inter-nesting period for red-eared sliders at South Carolina to be 26 days (ranging from 21 to 36) but this can be highly variable between sites (Tucker, 2001). The absence of oviducal eggs in females caught at Bedok reservoir does not preclude successful reproduction instances, especially since nesting has been observed previously (Grace Leng, pers. comm.). It might be interpreted as longer inter-nesting period because oviducal eggs are found less often, and in this case, not at all. Instead, it might be a case of higher clutch frequency (Tucker, 2001), i.e. sliders at Bedok reservoir may be nesting more often and the monthly captures coincides with their post egg laying period.

The other important aspect of reproduction in female turtles is clutch size. Clutch size has been known to increase with body size (Moll and Legler, 1971; Iverson, 1977; Tucker et al., 1998b; Gibbons et al., 1982; Gibbons and Greene, 1990), which might account for the smaller clutch size in the turtles at Eco-lake (between three and seven) than those reported from their native range (table 3.3). The carapace length of the specimens examined in this study was 20.1cm, and the average plastron length is estimated to be 17.9 cm (mean plastron length of females with carapace length 15.0 cm to 25.0 cm found at Eco-lake. See chapter 2). However, there were too few specimens found with oviducal eggs in this study to carry out regression analyses for more accurate information on clutch size. The only indication that clutch size has a relationship with maternal body size is the increased number of stage III follicles in large females. Although not all enlarging or enlarged follicles proceed to be ovulated, in general, a larger number of follicles will lead to a larger number of eggs (Miller and Dinkelacker, 2008).

Table 3.3 Maternal plastron length and clutch size of red-eared sliders from North and Central America arranged in decreasing latitude (Tucker et al., 1998b).

Location	Mean plastron length (cm)	Mean clutch size	n	Source
Illinois	21.4	14.0	440	Tucker et al. (1998b)
Illinois	20.2	13.3	10	Tucker et al. (1998b)
Illinois	21.4	13.4	238	Tucker et al. (1998b)
Illinois	21.4	13.2	111	Tucker et al. (1998b)
Illinois	21.0	11.3	34	Tucker et al. (1998a)
Illinois	21.1	12.5	16	Thornhill (1982)
Illinois	20.2	11.1	21	Thornhill (1982)
Illinois	20.3	9.2	67	Cagle (1950)
Missouri	21.8	16.4	5	Tucker et al. (1998b)
Oklahoma	19.5	8.8	6	Webb (1961)
Tennessee	20.0	10.5	47	Cagle (1937)
Virginia	23.2	9.7	21	Mitchell and Pague (1990)
Virginia	23.4	10.7	23	Mitchell and Pague (1990)
South Carolina	23.0	8.8	10	Congdon and Gibbons (1983)
South Carolina	18.5	6.1	73	Gibbons et al. (1982)
South Carolina	23.0	10.2	48	Gibbons et al. (1982)
South Carolina	19.3	5.9	15	Congdon and Gibbons (1983)
South Carolina	20.9	7.4	10	Congdon and Gibbons (1983)
South Carolina	20.5	7.1	88	Congdon and Gibbons (1985)
South Carolina	26.4	11.1	5	Congdon and Gibbons (1983)
South Carolina	24.2	9.5	8	Congdon and Gibbons (1983)
Louisiana	19.1	7.6	59	Cagle (1950)
Florida	21.0	9.7	30	Jackson (1988)
Mexico	26.6	12.0	31	Vogt (1990)
Costa Rica	37.8	20.0	24	Moll (1994)
Panama	30.8	17.4	38	Moll and Legler (1971)

Clutch size is also known to decrease with the number of clutches an individual turtle has laid during the same breeding season (Tucker, 1999). Over a study period of four years, Tucker (1999) observed that subsequent clutches tended to be smaller than the first clutch produced for the breeding season. This was also suggested by Gibbons et al. (1982) for populations of red-eared sliders in South Carolina.

Moll (1979) recognised two different types of reproductive strategies. In Pattern I, turtles produce large and multiple clutches of smaller soft-shelled eggs. Nesting occurs during a distinct season and nesting areas are well defined. The nests are carefully constructed and sealed. Red-eared sliders and many other sliders adopt this strategy (Moll, 1979). Pattern II involves turtles laying smaller clutches of larger hard-shelled eggs. Reproduction is non-seasonal and nesting areas are not defined nor are nests well constructed. Many native batagurines such as *Cuora* and *Cyclemys* adopt this strategy.

The ability to produce multiple clutches and the lack of seasonality in ovipositioning in this study suggests that sliders in Singapore may have a modified reproductive strategy in which smaller clutches are produced at a higher frequency and possibly throughout the year.

3.5 Conclusions

This is the first research on the reproduction of this non-indigenous species of turtle in Asia. Over a two-year period, this study showed that the reproductive patterns of female red-eared sliders differed between the two sites in Singapore, and from those in their natural range. Red-eared sliders in Singapore exhibit a smaller clutch size, and potential for nesting throughout the year with a lack of a distinct seasonality in reproductive output. The reproductive cycles (or lack of it in females) were asynchronous between males and females, which is common in many turtles (Miller and Dinkelacker, 2008). Miller and Dinkelacker (2008) suggest that this is due to the relative cost of the gonadal cycles of males and females. Spermatogenesis is considered to be relatively cheap and can occur quickly at whenever it is most energetically feasible. Vitellogenesis, on the other hand, is more expensive energetically and may require a longer period. Furthermore, female red-eared sliders have been known to be able to store sperm (Gist and Congdon, 1998) and this allows the female to mate at any time of the year (even before vitellogenesis is complete). Furthermore, high variability in clutch size and timing of egg laying is common even within a single individual. This and the variation in the proportion of reproductively active females within a year suggest that there are many extrinsic environmental factors which might govern reproductive output that may vary among individuals and also among populations (Gibbons and Greene, 1990). Microhabitat conditions can be extremely important in influencing the reproductive output (Gibbons and Greene, 1990).

Chapter 4: The diet of red-eared sliders in Singapore

4.1 Introduction

4.1.1 The red-eared slider's diet

In their native habitat, red-eared sliders are known to be opportunistic feeders. Their diet typically consists of a variety of vegetation including algae and various parts of vascular plants. Invertebrates and vertebrates are also found to be part of the sliders' diets. Invertebrates are consumed either intentionally or incidentally, such as when they are consumed together with aquatic plants. Smaller vertebrates like small fish and tadpoles are sometimes preyed upon but larger ones e.g. larger fish and birds are likely to be carrion (Parmenter and Avery, 1990).

In their native habitat, sliders exhibit seasonal patterns in their diet composition. Studies using both stomach flushing and dissection of guts show that in summer, their diet consists of a range of vegetation and animal prey while in winter, their diet is composed largely of vegetation (Parmenter, 1980; Schubauer and Parmenter, 1981). It is also typical of juvenile sliders to consume more or less equal amounts of vegetation and animal prey but change their diet habits to be composed mainly of vegetation when they reach maturity (Hart, 1983; Moll and Legler, 1971).

Red-eared sliders are known for their versatility in coping with a wide range of habitats. Their ideal habitat are areas with large, slow-moving bodies of water with large amounts of submergent vegetation and abundant basking sites (Moll and Legler, 1971). In Bermuda, leaves and stalks of plants and both terrestrial and aquatic insects were frequently found in the guts of red-eared sliders, with the less frequent occurrence of small fish, snails and bird feathers and bones (Outerbridge, 2008). However, in Panama, populations of sliders have been found in a muddy pond lacking in aquatic vegetation or basking sites (Moll and Legler, 1971). These sliders apparently used mud as a primary food source. When food in the water bodies where they live is scarce, sliders have been reported to forage terrestrially and returning to the water to consume their food (Cagle, 1944b).

The consumption of animal prey is likely to be opportunistic. Supporting evidence exhibiting the extreme versatility in food choices includes the active preying of waterfowl by a population of *Pseudemys scripta callirostris* (Pritchard and Trebbau, 1984). These sliders bite the legs of swimming waterfowl and proceed to drown them by dragging them underwater. This record illustrates behavioural modification that corresponds with the versatility in procurement of food. Another observation is the development of abnormally enlarged heads (macrocephaly) in *Pseudemys scripta chichiriviche* associated with the consumption of high concentrations of mollusks.

4.1.2 Physiology

Being ectotherms, the rate at which physiological processes occur is temperature dependent. One such process is food digestion where body temperature of a turtle appears to be positive correlated to gastric acid and enzyme secretion (Anderson and Wilbur, 1948; Wright et al., 1957), rate of stomach evacuation times (Fox and Musacchia, 1959), movement in the intestines (Studier et al., 1977), protein digestion, sugar absorption and energy assimilation (Riddle, 1909; Fox and Musacchia, 1959;

Fox, 1961). Cagle (1950) suggested that basking is an important behaviour for sliders (Chapter 5) as it allows for the regulation of body temperature and studies by Parmenter (1980) found 29 °C to be the optimal temperature for ingestion rate for sliders, with the rate of feeding being a function of body temperature

This optimal ingestion rate presumably occurs only in summer in the temperate regions, but may occur throughout the year in a climate like Singapore's (temperature range 20 °C to 32 °C). The effects of higher body temperatures in sliders are faster growth rates and earlier attainment of maturity (Dunham and Gibbons, 1990).

Food quality is also a factor that has to be taken into account when studying the effect of food and temperature on the growth and success of the sliders. However, there is currently very little information on their nutrient requirements. Laboratory studies by Pearse et al. (1925) showed that a mix of protein, carbohydrates, vitamins and essential nutrients promoted faster growth than diets consisting of only one type of food. This result is more relevant for captive or pet sliders as individuals in the wild are unlikely to consume a single food type. In Singapore it is not uncommon for pet sliders to be fed only a certain type of food such as leftover rice or only vegetables e.g. water convolvulus (*Ipomoea aquatica*), all of which are inexpensive and easily obtained. The feeding of feral populations of turtles is also very common and the most popular choice of food item used is stale bread. Avery (1987) experimented with various concentrations of protein in the diet of sliders and found that 10% crude protein in their diet is too little for normal growth. The sliders that were given foods containing 10% crude protein also had a curling abnormality of the posterior plastron (as seen in specimen collected from a Singapore water body shown in Chapter 2, figure 2.8).

While optimal nutritional requirements are not known, there are many deformities and ailments of pet sliders caused by dietary deficiencies or excesses (Frye, 1973). Some of these include: body emaciation and muscle atrophy due to the lack of protein, as well as the degradation of body tissues due to the lack of vitamins A and B_1. Typical vitamin deficiency-related conditions have also been recorded in reptiles and these include rickets (vitamin D deficiency), goiters (iodine deficiency), and steatites (vitamin E deficiency), although scurvy (vitamin C deficiency) seems rare in reptiles. Calcium deficiencies are however, extremely well documented, possibly due to the obvious effects on the shell, leading to a variety of shell deformities. The ideal calcium to phosphorus ratio should be within 1:1 and 1.5:1, an imbalance of which usually leads to osteodystrophy (abnormal bone growth) (Frye, 1973).

4.1.3 Objectives of the study

This study aimed to ascertain the general feeding patterns of the red-eared slider in Singapore waterbodies. The main questions asked were:

1. What is the red-eared sliders' diet composed of?
2. Is there seasonality in the quantity or composition of food consumed?
3. Are the diets of males and females the same?

4.2 Materials and methods

4.2.1 Fieldwork

Between July 2005 and July 2006, a total of 195 red-eared sliders were caught and euthanised. Each month, five females each of two carapace length classes (15.0 cm – 19.9 cm, 20.0 cm – 24.9 cm) and five males (15.0 cm to 24.9 cm) were captured from Eco-lake at the Singapore Botanic Gardens within the same day between 1300 hrs and 1500 hrs. The turtles were lured with bread from a bridge and consequently scooped up using dip nets. The sliders were transported back to the laboratory where they were euthanised within 24 hours and kept frozen until dissection.

4.2.2 Laboratory work

Upon dissection, length of the gut from the stomach to cloaca was measured. Gut contents were collected and preserved in 10% formalin for analysis. Prey items were sorted into four categories, (1) vegetation (including algae), (2) invertebrates (3) vertebrates and (4) non-food items. Prey items were dried in a drying cabinet at 40°C for 72 hours and dry weight of the various components was recorded. Identifiable parts of animals and plants were also noted (Ng, 1992). Bread (identified as white mush) in the gut was excluded from the analysis because it was used as bait during the capture.

Stomach flushing as described by Legler (1977) was carried out on 10 red-eared sliders as part of a trial to assess the feasibility of this technique for examination of gut contents in native turtles. The trial was carried out one animal at a time. Each animal was fed five leaves of water convolvulus five minutes prior to the start of the flushing. It was held in position while a catheter and large syringe was inserted through the mouth to introduce water into its stomach. The animal was then tipped suddenly to induce involuntary regurgitation of stomach contents together with the water. This method is ideal in retrieving recently ingested food items, which are therefore more easily identified. It is also non-destructive and would not require any animals to be sacrificed.

4.3 Results

4.3.1 General gut content

Of the 195 red-eared sliders examined, about half were found without evidence of foraging (i.e. guts were either empty of contained only bread). For the purpose of this dissertation guts found in this condition are referred to as 'empty' guts. Samples were grouped into three groups:- males, smaller females and larger females according to their size. Significantly more males ($\chi^2 = 6.06$, df = 2, p = 0.05) were found to have empty guts (60.0%) compared to smaller females (carapace length 15.0 cm – 19.9 cm) (50.8%) and the larger females (carapace length 20.0 cm – 24.9 cm) (38.5%) (figure 4.1).

Throughout a one-year period, the highest frequency of empty guts was found from January – March 2006, which corresponded with the period of lowest temperatures. July 2005 and June – July 2006 had the lowest percentage of animals with empty guts, which corresponded with periods of higher temperatures (figure 4.2).

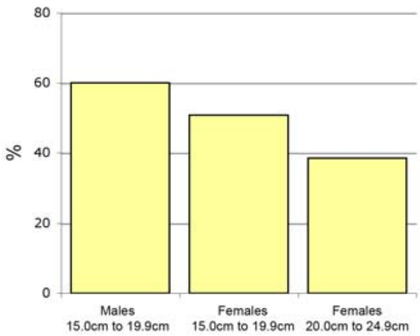


Figure 4.1 Percentage of males and small and large females found with empty guts.

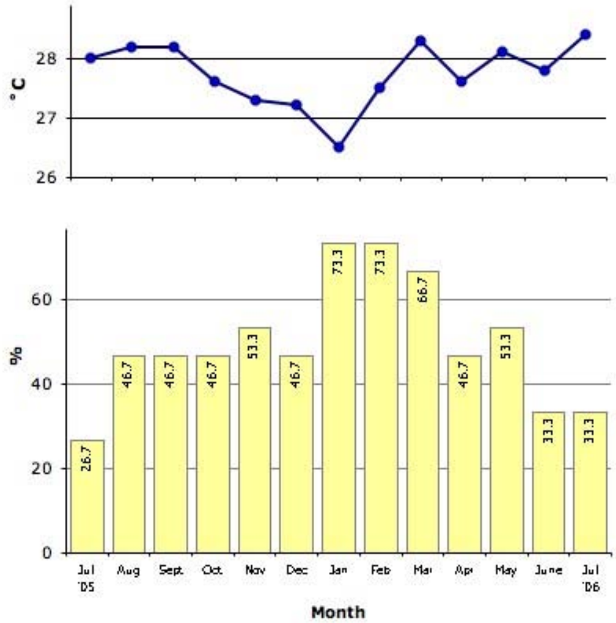


Figure 4.2 Percentage of animals found with empty guts and mean monthly temperature from July 2005 – July 2006.

4.3.2 Gut content composition

Table 4.1 shows the range of items found within the guts of the red-eared sliders. The food items are grouped according to vegetative and animal sources and the non-food items are grouped according to their likely sources.

Table 4.1 Items found in the dissected guts of red-eared slider from July 2005 to July 2006.

Food		Non-food
Vegetation	Animal	
Plant	Invertebrates	Non-anthropogenic sources
leaves	insect wings and legs	gravel
twigs	mollusc shells	sand
seed	crustacean shells	mud
	whole small invertebrates	wood
Algae		turtle scutes
unicellular	Vertebrates	
filamentous	feathers	Anthropogenic sources
	fish scales and bones	plastic
		glass
		fabric
		styrofoam

Among the animals found with contents in their gut, 66.5% – 90.5% of their total gut contents consisted vegetation and animal matter (figure 4.3). The remaining percentage was made up of non-food material such as gravel, sand, plastics and glass. The proportion of various items in the guts of all three groups was very similar (figure 4.3).

Of the organic material, a very high proportion (85.3% – 97.8%) consisted of vegetation (figure 4.4). Vegatation ingested composed mainly of filamentous green algae. Plant parts such as leaves and twigs were also found within the gut though it was not possible to identify these to taxa level due to the stage of digestion. The percentage composition of invertebrates ranged from 0.9% – 8.8%, which included

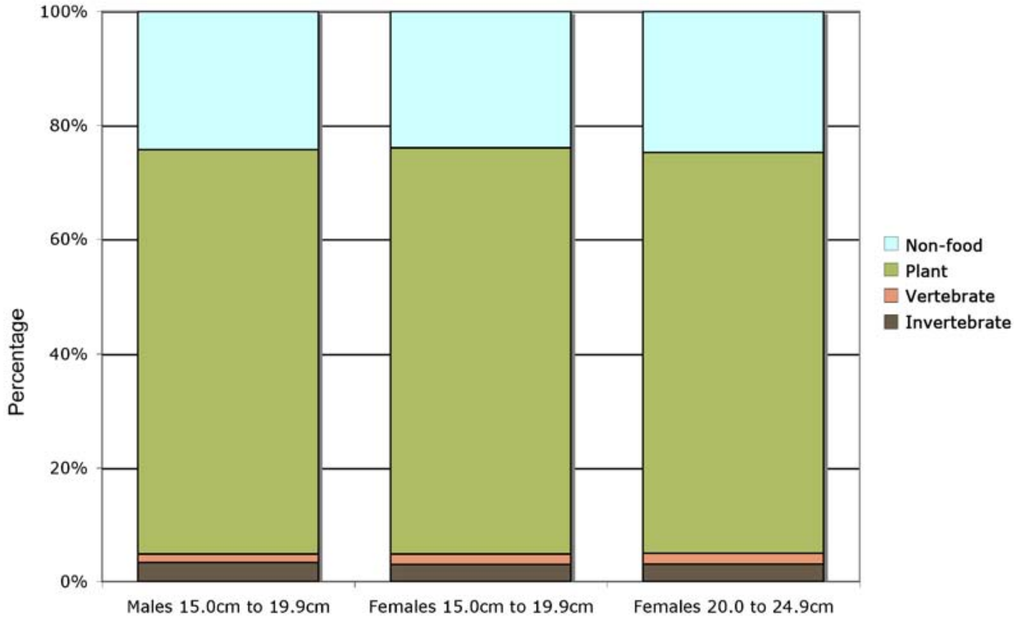


Figure 4.3 Gut content composition by percentage of three groups of red-eared sliders.

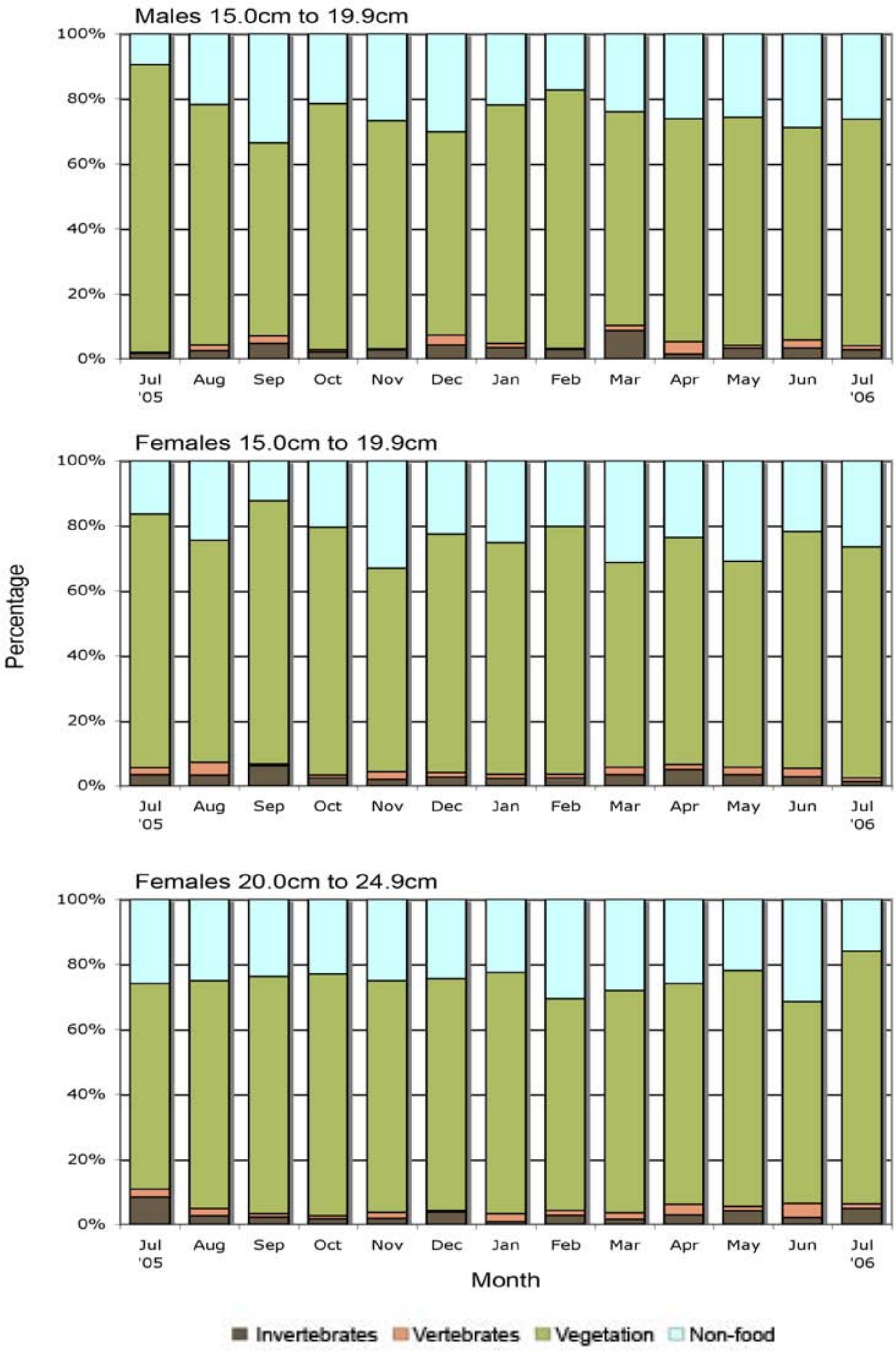


Figure 4.4 Monthly composition by percentage of the gut contents of three groups of red-eared sliders from July 2005 – July 2006.

arthropods (both insects and crustaceans), and gastropods (evidenced by their calcareous shell). Vertebrates made up 0.2% – 4.4% of total gut contents and consisted mainly of fish scales and bones and feathers. The other items found included glass pieces, plastic (both shredded and whole pieces), pebbles and sand. These non-food items made up 9.5% – 33.5% of the contents found in the guts, with pebbles and sand being the most common. The composition of the gut contents did vary greatly over the year and there was no discernible seasonality in food choice.

4.3.3 Gut content by dry weight

Analysis of gut content by dry weight using the Mood median test (Minitab 13) showed no significant difference amongst the three groups of red-eared sliders for total gut contents (figure 4.5). No significant difference was also found for the non-food, food, vegetation and animal matter amongst the three groups.

There was, however, significant difference among the months from the period of July 2005 to July 2006 for total content ($P < 0.005$), non-food ($P < 0.005$), food ($P < 0.0005$), plant ($P < 0.0005$) and animal content ($P < 0.0005$). Non-food and food weight did not have any observable patterns throughout the year (figure 4.6) while it appeared that peaks in vegetation and animal matter consumption loosely occurred in opposing months (figure 4.7). None of the various components appeared to have any trends associated with the fluctuations in temperature.

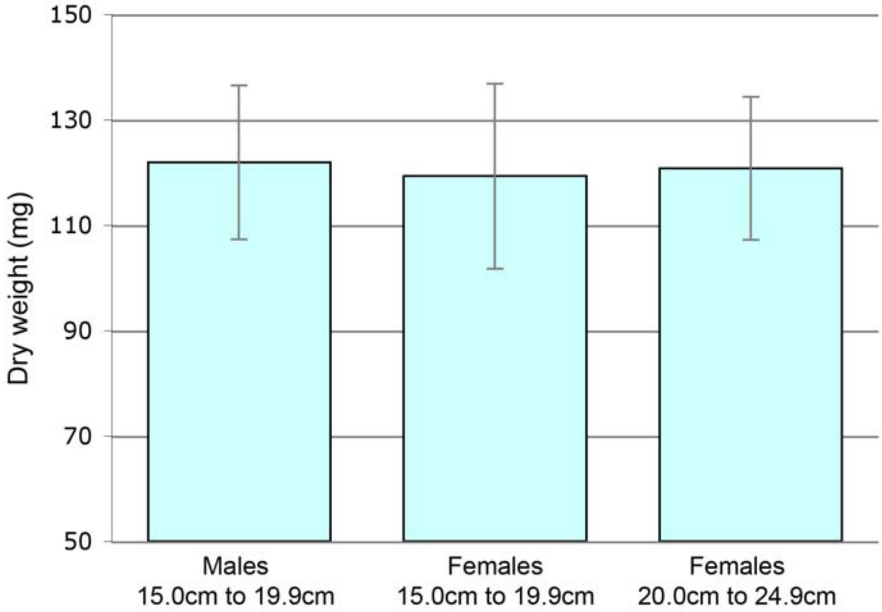


Figure 4.5 Mean dry weight of total gut contents found in the three groups of red-eared sliders.

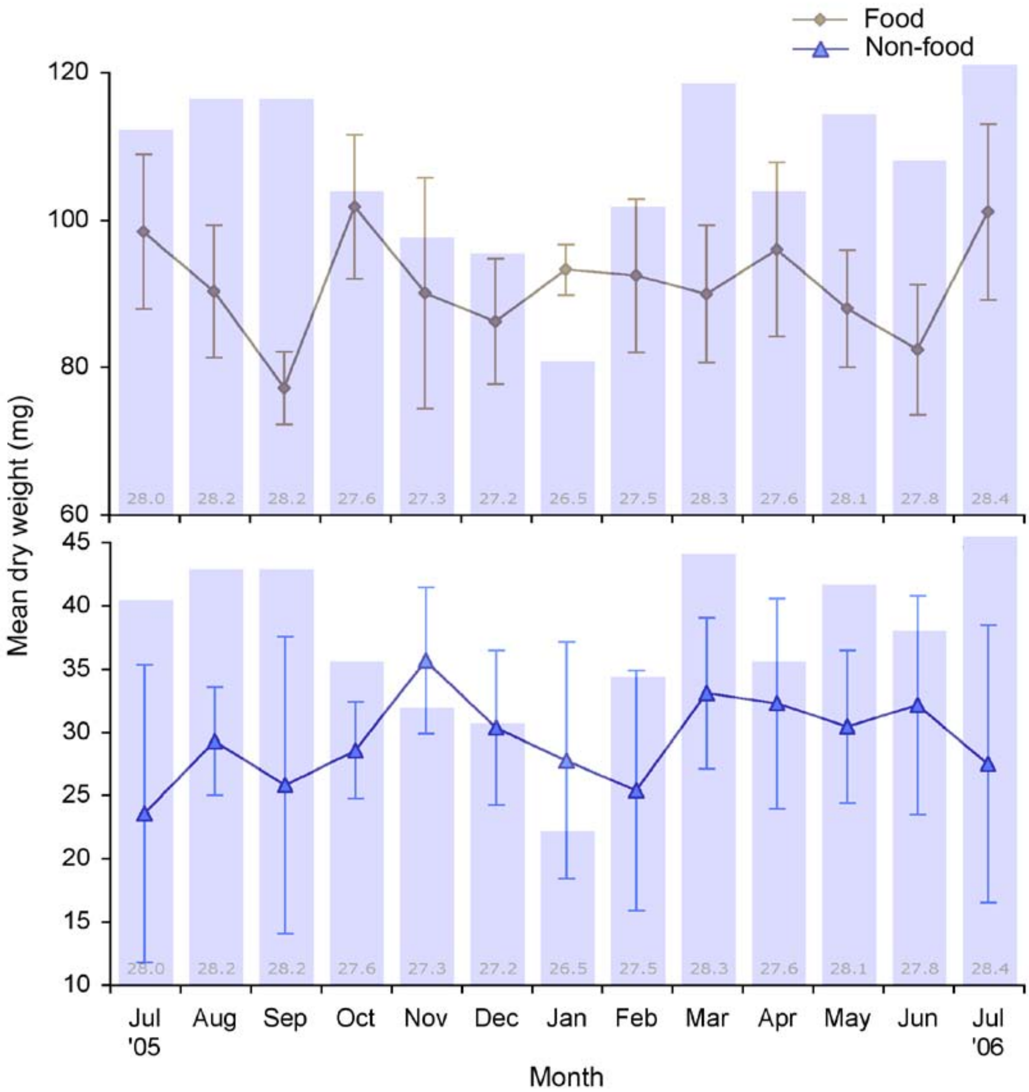


Figure 4.6 Monthly weights of food and non-food content found in red-eared sliders with bars representing monthly temperature (˚C).

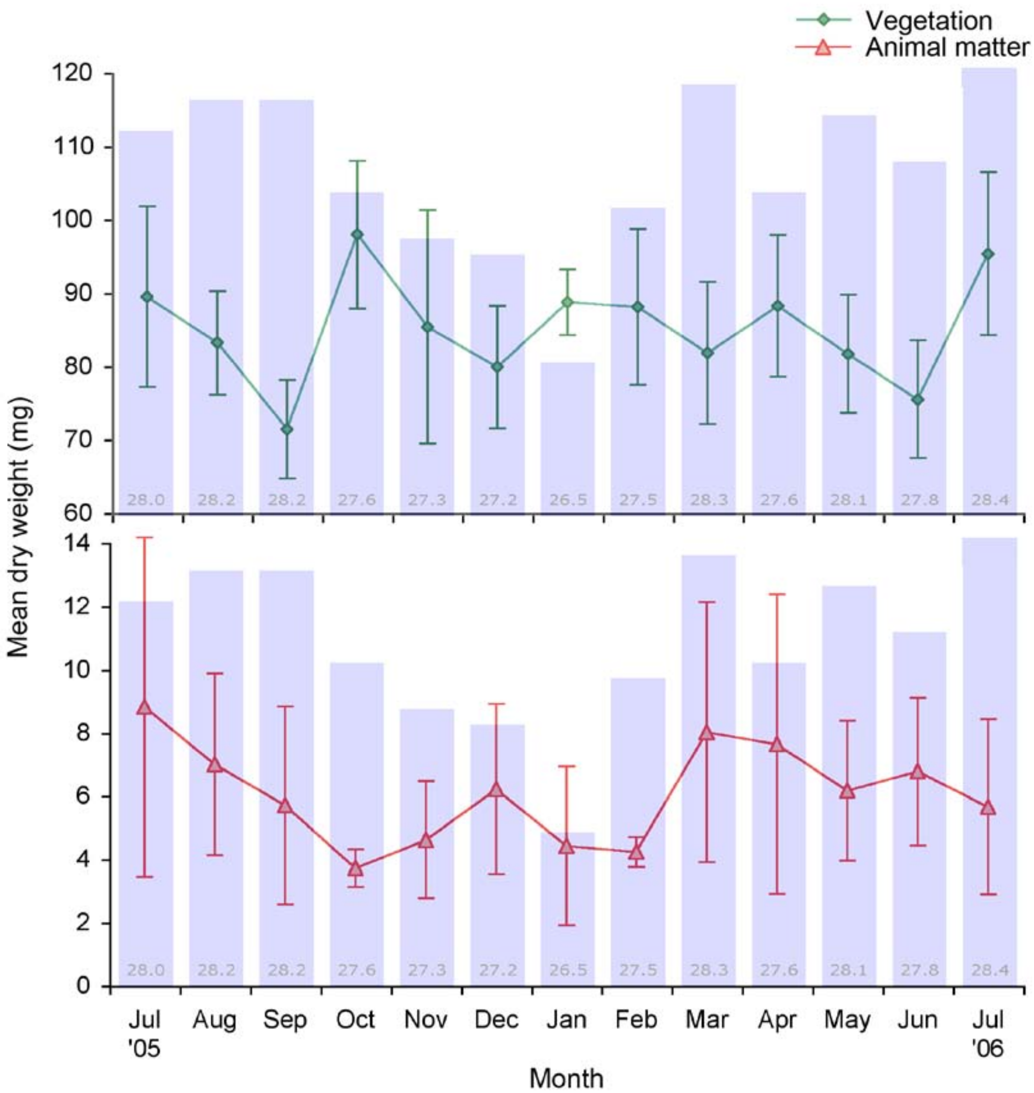


Figure 4.7 Monthly weights of vegetation and animal content bars representing average monthly temperature (˚C).

A substantial proportion of gut content (9.5% – 33.5%) was made up of non-food material. The dry weight of non-food material showed no significant relationship with the dry weights of either vegetation or animal matter (figure 4.8).

4.3.4 Gut length

Of the 195 red-eared sliders that were dissected, the gut length ranged from 17.2 cm – 164.5 cm for males ranging from 10.0 cm – 19.2 cm in carapace length and 45.5 cm – 196.0 cm for females ranging from 10.0 cm – 25.6 cm in carapace length. Both linear regression of carapace length to gut length showed a significant relationship ($P < 0.0005$) for both male and females for the range of sizes examined (figure 4.9).

4.3.5 Stomach flushing

Because of the stage of digestion upon dissection, it was difficult to obtain ingested items in a state that is easily identifiable. Stomach flushing, a method described by Legler (1977) would be a preferred method to obtain whole items before they are digested. Unfortunately, attempts at flushing the stomachs of 10 red-eared sliders were unsuccessful. During trials, the catheter could not be inserted deep enough into these sliders and it is also possible that insufficient quantities of water were introduced to cause regurgitation. The sliders also became progressively aggressive throughout the trial and were difficult to handle.

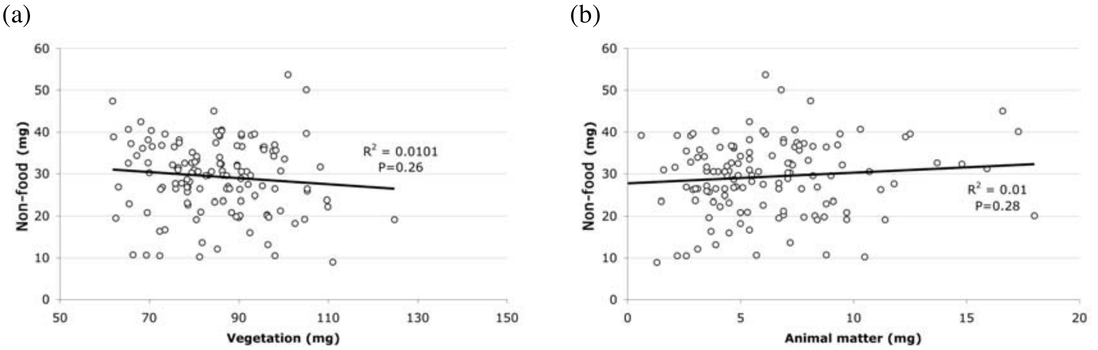


Figure 4.8 Relationship of non-food dry weight with a) vegetation dry weight and b) animal matter dry weight in all red-eared slider guts dissected.

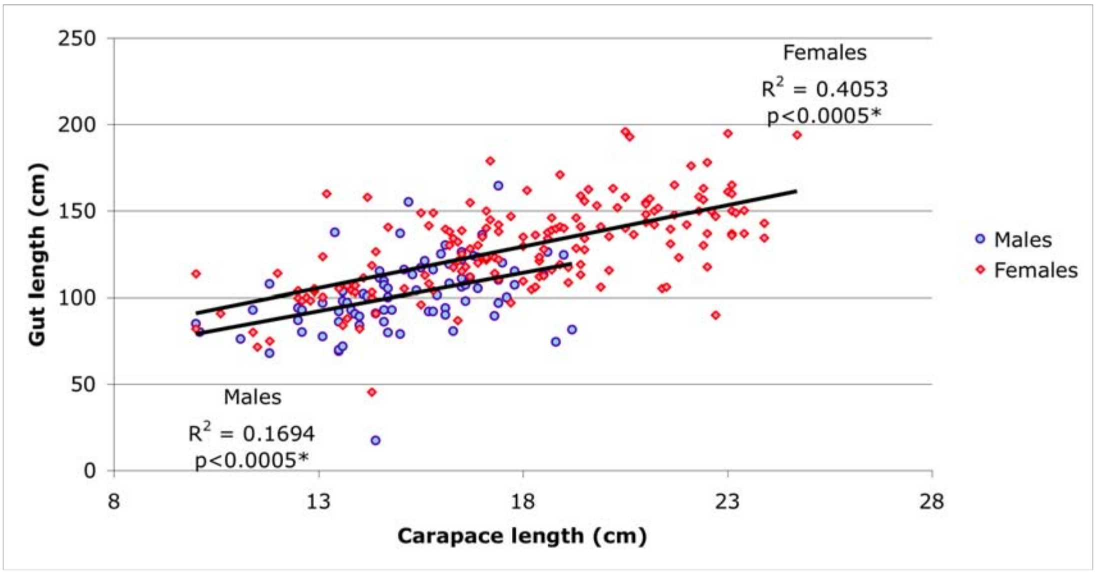


Figure 4.9 Relationship of carapace length and gut length of male and female red-eared sliders from 10.0 cm – 25.6 cm carapace length.

4.4 Discussion

4.4.1 The diet composition of red-eared sliders at Eco-lake

The contents of the guts of red-eared sliders at Eco-lake were consistent with a list compiled by Parmenter and Avery (1990) as well as a study by Outerbridge (2008), showing sliders to consume a variety of algae, grasses, fruits, seeds, gastropods, amphipods, arachnids, insects (of many genera including from the orders Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Odonata, Orthoptera, Homoptera and Lepidoptera), decapods, isopods, bryozoans, ostracods, fish, amphibian eggs, waterfowl and other items such as wood, turtle scutes, watermelon rinds, detritus, mud, pebbles, sand and paper. However, it should be noted that soft-bodied organisms such as annelids and larval stages of arthropods as well as fruit and meat leave behind very little residual material (Parmenter and Avery, 1990) and can be digested relatively quickly. While stomach flushing would have been a more effective method in retrieving these items, the method was unsuccessful in this study. Furthermore, the success of stomach flushing has been reported to be inconsistent in retrieving all items from the gut when later verified by dissections (Hart, 1983).

It is known that the composition of the sliders' diet is greatly influenced by the prey availability, with the most common items making up the greatest proportion of their diet (Cahn, 1937; Parmenter, 1980). This appears to be the case in the present study since the items found in the contents of the sliders at Eco-lake are similar to the flora and fauna that can be found at Eco-lake or other ponds in Singapore (pers obs.).

It is possible that the non-food items were consumed by accident, either being mistaken as food, or taken in together with the targeted prey item especially since foraging along the bottom of the Eco-lake was observed (see chapter 6). "Unidentified sediment" was also observed in the guts of 70% of 600 red-eared sliders in Bermuda (Outerbridge, 2008). However Parmenter and Avery (1990) suggested that sliders might exhibit geophagy, which is the deliberate consumption of stones or pebbles to assist in the mechanical grinding of food items to accelerate digestive rates. Although geophagy has not yet been observed for sliders, it has been reported in other species of chelonians, for example *Terrapene ornate* (Skorepa, 1966) and *Gopherus agassizii* (Sokol, 1971). While was no significant relationship between the amount of non-food items and either of the food groups (vegetation or animal matter), the presence of gravel in almost all of the guts that were not empty might be an indication that geophagy exists in *Trachemys scripta elegans* as well.

4.4.2 Seasonality in diet

The present study shows that while diet composition and volume was not constant throughout the year, there are no discernible patterns in food choices with regards to temperature. There was, however, a distinct pattern in the number of sliders found with empty guts at the point of dissection, implying that sliders foraged more frequently during warmer months of June and July (mean monthly temperature: 28.1˚C) than the cooler months of November to March (mean monthly temperature: 27.1˚C).

In their native range, sliders typically exhibit a change in diet composition with the seasons. In South Carolina, their diet shifts from including a range of vegetation and animal prey in summer months, to being almost completely composed of vegetation in winter. Parmenter and Avery (1990) attributed this to a few reasons. Firstly, it could be due to the decrease in availability and abundance of prey during the winter months. Secondly, the sliders might have decreased hunger levels during winter, and hence a decrease in the need to forage, being sufficiently satiated by vegetation alone. Indeed, it has been observed that trapping success is lower during winter months even when using meat or fish as bait (Cagle, 1950; Ernst, 1972).

Elevated temperatures in Singapore compared to temperate and neotropical climates suggest that ingestion and digestion rates are kept at an optimal level throughout the year as suggested by Parmenter (1980). Furthermore, the consistent capture success and relatively consistent numbers observed at the same pond from January 2007 to January 2008 (see chapter 6) indicate that slider activity does not fluctuate significantly in the Singapore climate.

Empty guts do, however, indicate the interval between foraging periods of red-eared sliders. A short study by Chia (2005) found the gastric emptying time of the red-eared slider in Singapore to be 87.4 ± 3.4 hours under laboratory conditions. It can be inferred from both the results from her data and that of the current study that, in general, half of the animals examined did not have any vegetation, animal or non-food material as part of their meal in roughly three and a half days. Foraging frequency has not been discussed in literature and this finding offers paradoxical evidence to seasonality in foraging frequency but not quantity in red-eared sliders.

4.4.3 Diet differences between size/sex groups

There were no significant differences among the quantity of food consumed or percentage composition of food items between males and females of the same size classes and between females of two different size classes. However, there was a distinct pattern in that males had the largest proportion of empty guts, followed by smaller females and larger females, which had the smallest proportion of empty guts, indicating that males fed less often than females, and larger females foraged more often than smaller females.

The one-year study suggests that the size groups do not differ in the amount of food they consume which is in contrast to existing literature that the diet of sliders shifts towards being more herbivorous with increasing size (Clark and Gibbons, 1969; Hart, 1983). Hart (1983) found a linear relationship between size (plastron length) and the percentage of plant content in red-eared sliders. Although Hart (1983) reported a high residual variance in his data, this can be attributed to the opportunistic feeding nature of the sliders. Indeed, when given a choice, sliders do prefer animal material, e.g. meat and insects, to aquatic vegetation (Parmenter, 1980) and this is supported by the successful use of prawns as bait in this study as well as in the literature (Burke et al., 1995; Close and Seigel, 1997; Moll, 1990; Tucker and Moll, 1997; Tucker et al., 1995). The rationale for the shift from carnivory to herbivory as turtles increase in size is that it is energetically less feasible for a larger turtle to pursue an animal prey item due to a greater amount of energy expended in the pursuit, as well as the lower proportion of potential energy gained by a larger turtle compared to a smaller one (Parmenter and Avery, 1990). The lack of difference in diet composition or volume in the various groups of red-eared sliders might be accounted for by the constant availability of foods that satisfy the needs of the turtles without having to alter their diet to maximise their gain per foraging effort.

In an effort to investigate further the shift (or lack of shift) in diet in response to the size of turtles, the current study also measured gut lengths and carapace lengths upon dissection. The study was based on the fact that herbivorous animals have longer intestinal tracts than carnivorous animals (Stevens and Hume, 1995). The relationship between gut lengths and carapace lengths for both adult males and females was linear which was not unexpected since no juveniles were examined.

4.4.4 Public provisioning of food

An interesting observation made during the course of this study is the extensive public feeding of freshwater turtles in Singapore. The main food item used for feeding is bread and occasionally vegetables such as water convolvulus (pers. obs.). It is estimated that up to 90 turtles (red-eared sliders and sometimes other species of turtles mentioned in chapter 3) gather to feed on the bread that is thrown into the water by members of the public. Bread may be an energetically feasible alternative to vegetation as it does not require foraging or pursuing of prey.

Laboratory studies on sliders have shown that diet preferences in mature individuals are influenced by early feeding experiences. The majority, if not all, of the sliders found at Eco-lake were released after spending their juvenile, adolescent and even a part of their adulthood in captivity. These individuals may have grown accustomed to and possibly prefer foods like bread, which they are unlikely to have a taste for in the wild. The effective use of bread as another type of bait to capture sliders for this study further suggests that sliders in Singapore are attracted by either the bread or the motions of bread dropping into the water.

Perhaps another indication that the diets of sliders are not typical of sliders from their native range is the presence of individuals exhibiting the symptoms of nutritional deficiency (see chapter 3). Fifteen of 640 animals (2.3%) were found to have curling or flattening of the carapace which is indicative of osteodystrophy. However, without further research on the nutrition of sliders both in captivity and feral populations, conclusions cannot be drawn as to whether the feral sliders prefer to and/or continue to subsist on unnatural dietary sources that they are used to consuming in captivity.

4.4.5 Feeding habits of native turtles

Native terrapins such as the Malayan box terrapin (*Cuora amboinensis*), black marsh terrapin (*Siebenrockiella crassicollis*) and the river terrapin (*Batagur baska*) were also observed to consume the bread that is fed by humans. This is not surprising, as they are known to be omnivorous (Ernst and Barbour, 1989). The actual diet of these species in the wild in Singapore is unknown but a few studies have been conducted on their feeding efficiencies with respect to red-eared sliders.

A comparative study on the bite speed of the red-eared sliders, Malayan box terrapin and black marsh terrapin showed that the sliders had a significantly faster biting speed compared to the two native turtles over a range of temperatures (Bels et al., 2008). A short study comparing the feeding rates of red-eared sliders and black marsh terrapins suggested that red-eared sliders were more aggressive when feeding (Chia, 2005). Sliders not only approached food items up to ten times faster than black marsh terrapins, they also finished consuming a fixed quantity of food faster (Chia, 2005). Furthermore, the minimum time a black marsh terrapin required to consume one unit of food was longer than the maximum time a red-eared slider took to finish the same unit (Chia, 2005). Not only are red-eared slider quicker to respond to food, they are also able to feed effectively over a wider range of temperatures than the native species (Bels et al., 2008). Should food resources be limited, the sliders would have a competitive advasntage. However, there is no evidence suggesting that resources are limited in any of the sites surveyed within Singapore during the course of this study. However, should the sliders reach forest streams, where there would be no provisioning by the public, they may then compete with native species for food.

4.5 Conclusion

The generalist and opportunistic feeding habits of the red-eared slider and the versatility of their feeding habits have allowed the slider to successfully inhabit a great variety of habitats in Singapore. These same traits that have allowed the red-eared sliders to thrive out of their natural range appear to be the same ones allowing them to become established in Singapore. Two factors that might have further contributed to their success here is the adaptation of feeding behaviour and the elevated temperatures in Singapore throughout the year. The latter allows for higher body temperatures and consequently optimal rates for physiological processes which translates to faster growth and earlier attainment of maturity. The high incidence of non-food matter in the guts of the sliders sampled from this Singapore water body suggest that geophagy may occur in this species, which has not been documented before.

Chapter 5: The behaviour of red-eared sliders in Singapore

5.1 Introduction

5.1.1 General behaviour

In its native range, the red-eared slider is known to be a diurnal aquatic turtle that typically emerges from sleep at daybreak and is active throughout the day (Cagle, 1950). Foraging activity typically occurs in the morning and evening and the rest of the day is usually spent basking (Morreale and Gibbons, 1986; Cagle, 1950; Boyer, 1965; Moll and Legler, 1971).

Winter months in temperate areas are periods of inactivity for aquatic turtles (Bury, 1979). Although sliders have been reported to be able to tolerate temperatures as low as 2˚C and have also been observed to bask on clear sunny days in winter (Schubauer and Parmenter, 1981). The optimal body temperature range for peak activity is between 25˚C and 30˚C and slider activity is believed to be reduced when the body temperature falls out of this range (Spotila et al., 1990). The most important factor determining the body temperature of turtles is light intensity (Boyer, 1965) while air and water temperatures affect how fast or slow heat is gained depending on the difference in temperature upon the turtle's emergence from water and the temperature to which it emerges. Wind velocity also affects heat gain rates especially when light intensity is low (Boyer, 1965).

Higher body temperatures achieved by basking have a direct effect on feeding and digestion rates (Parmenter, 1981). In temperate areas, foraging rates are suggested to be reduced during winter months (Parmenter and Avery, 1990) based on dramatically reduced trapping success of sliders during those months (Cagle, 1950).

Gibbons and Greene (1990) commented that the courtship behaviour of red-eared sliders in the wild has not been studied quantitatively. However, courtship has been observed to occur throughout the year in neotropical sliders in Panama, with peaks during the reproductive season (Moll and Legler, 1971).

Intra- and inter-specific aggressive interactions in the wild have not been well documented. Lindeman (1999) observed instances of aggressive interactions during basking among four species of emydid terrapins (including red-eared sliders) in an impoundment of the lower Tennessee River. Behavioural experiments have been conducted in captivity in France to assess competition between red-eared sliders and native European pond turtles (*Emys orbicularis*). The results of that study showed that red-eared sliders managed to secure better basking sites than the native turtles, an important element to aid in obtaining the body temperature for optimal physiological and digestive processes.

Nothing is known about the behaviour of the red-eared sliders in tropical Asian water bodies even though they are becoming more prevalent in many countries in Asia (Ramsay et al., 2007).

5.1.2 Objectives

This chapter aims to

a) Determine the daily activity pattern of the red-eared slider in Singapore, and to investigate further whether this daily pattern of activity changes throughout the year;
b) Compare the time and proportion of male and female sliders involved in courtships and feeding behaviour;
c) Document courtship behaviour in the wild; and
d) Document any inter- or intra-species interactions among freshwater turtles.

Ultimately, this present study seeks to ascertain whether this temperate turtle retains its behavioural patterns when introduced to the tropics.

5.2 Materials and methods

5.2.1 Preliminary studies

Preliminary observations were carried out in the month of December 2007 on three separate days. These observations were aimed at establishing an appropriate observation point, describing their ethogram (table 5.1) and to choose an appropriate time interval for focal sampling during which the majority of the behaviour could be observed.

5.2.2 Sampling methodology

Observations were carried out on one population of red-eared slider at Eco-lake at the Singapore Botanic Gardens from the period of January 2007 to January 2008. This location was chosen as information on demography, reproduction and diet had already been collected on this population. The layout of the site was also suitable for behavioural observations from the main bridge as red-eared sliders engaging in a wide range of activities could be observed (figure 5.1).

Both focal and scan sampling methods (Altmann, 1974) were used to record behaviour of these terrapins. For each hour from 0700 hrs to 2000 hrs (i.e. from sunrise to sunset), four samples were recorded using the scan sampling method; and focal observations were made of random individuals during the intervals in between scan sampling (see below for details). Three such hours were recorded within each month giving a total of 24 hours of day-time data each month, and 312 hours of data in total throughout the 13 month period. To take into account potential variation in behaviour

(a)

(b)

Figure 5.1 Eco-lake at Singapore Botanic Gardens showing a) the bridge and b) the area demarcated for behaviour observations.

with different weather conditions, sampling only took place in relatively fair weather (regarded as “normal conditions”) where the sun was out and sky was partially cloudy. When sampling was underway and rain occurred, sampling was suspended immediately until weather returned to normal again. The data for such hours were discarded.

The area surveyed was estimated to be 4 m by 4 m and consisted of a partially sandy bank, floating algal mats, shallow water with visible substrate (depth ~ 0.5 m) and wooden bridge pilings (partially submerged and approximately at a 35° angle to the surface of the water). Observations were made using a pair of binoculars from the bridge – from a fixed location for scan sampling, and a range of locations for focal sampling. The survey area was demarcated by visual markers and the presence of other species of terrapins and other fauna was also noted.

Scan sampling

Four times each hour, all red-eared sliders within the demarcated area involved in the activities defined in Table 5.1 were counted and recorded.

Table 5.1 The description of the various behaviours and their respective codes for recording when conducting a scan. See figure 5.2 for photographs of these behaviours.

Code	Description of behaviour
SS	Swimming slowly just below the surface of the water
SF	Swimming quickly just below the surface of the water
ST	Remaining stationary just below the surface of the water, head emerging. Usually interrupting SS or SF
SB	Swimming along the bottom of the water, usually a foraging behaviour
B	Basking (out of the water on a stable substrate, may be partially submerged)
CS	Courtship behaviour defined as any point in time where a male SF towards a female followed by typical courtship sequence of using claws to titillate female. A female is also counted as a participant as long as she responded to the male, whether remaining still, pushing him away or swiping a forelimb or hindlimb. In the case where a female has swum away after a sequence and the male was in pursuit, only the male was counted as exhibiting this behaviour
D	Dived underwater

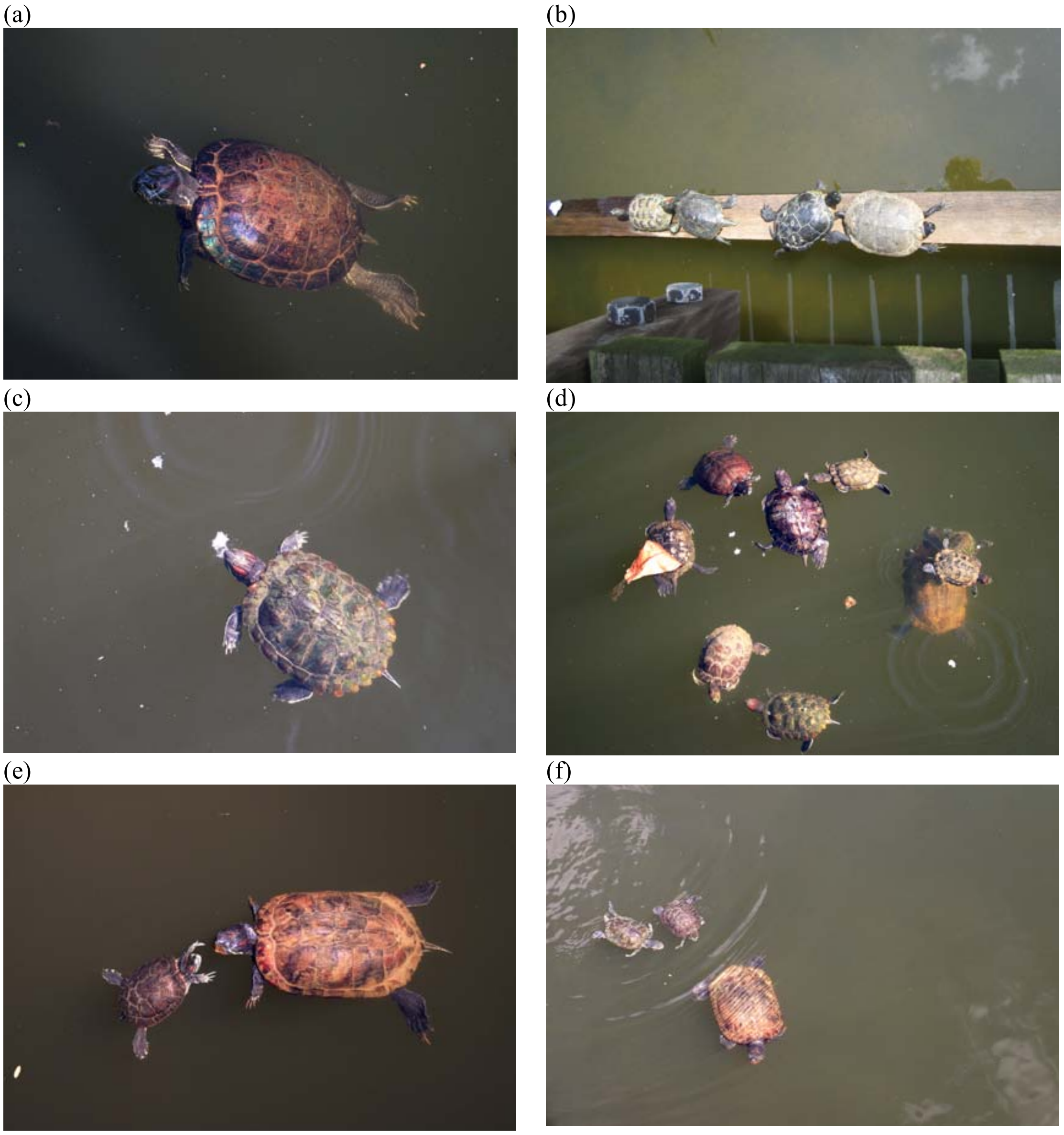


Figure 5.2 Photograph of the following behaviours exhibited by red-eared sliders: a) swimming slowly/stationary; b) basking; c) feeding; d) feeding (nine red-eared sliders); e) courtship (male using claws to stimulate female's face) and f) two males swimming fast in an attempt to court the larger female.

Focal sampling

Adult male and female red-eared sliders were randomly selected for observation for a continuous period of 10 minutes each time. All behaviours exhibited (defined in Table 5.2) were recorded to the second. A brief description of the individual was also recorded, including the sex, estimated carapace length and any visible distinguishing features such as shell deformities. Because many observation subjects went out of sight by either swimming out of visible range or diving underwater before the 10 minutes had passed, samples under 10 minutes (600 seconds) but at least 8 minutes (480 seconds) were used and time spent performing each behaviour was analysed as percentage of either 600 or 480 seconds.

Table 5.2 The description of the various behaviours and their respective codes for recording when conducting a focal observation.

Code	Description of behaviour
General behaviours	
SS	Swimming slowly just below the surface of the water
SF	Swimming quickly just below the surface of the water
ST	Remaining stationery just below the surface of the water, head emerging. Usually interrupting SS or SF
SB	Swimming along the bottom of the water, usually a foraging behaviour
CD	Change direction abruptly
Aggressive behaviour	
FS	Foreleg swipe towards another terrapin with claws extended
HS	Hindleg swipe towards another terrapin with claws extended
P	Any pushing with other parts of body
CT	Climbed atop partially or fully the carapace of another terrapin
Basking behaviours	
B	Basking (out of the water on a stable substrate, may be partially submerged)
CB	Climb atop a substrate for basking
Courtship behaviours	
FF	Manoeuver body or direction such that subject is face to face with another individual
MC	With forelimbs extended forward, male uses foreclaws typical titillating sequence. Occurs only after FF.
SN	Sniffing of cloacal region carried out by male on female
Terminating behaviours	
D	Dived underwater
Non-behaviour codes	
OOS	Out of sight

Night sampling

On nine occasions from January to March 2007, attempts were made to see whether the red-eared sliders showed any nocturnal behaviour, by sampling from 0600 hrs – 0700 hrs and from 0700 hrs – 2200 hrs. Observations were made using a HID headlamp and/or flashlight and infrared binoculars. No nocturnal activity was observed despite the use of infrared binoculars. All the turtles were out-of-sight after night fell and before daybreak, so no further nocturnal sampling was carried out.

Visitorship during the sampling period

The number of people who walked on the bridge that bounded part of the observation area was recorded for each hour of scan and focal sampling to investigate if visitorship had an effect on the behaviour of the red-eared sliders.

Climate information

Monthly mean air temperature and monthly mean number of sunshine hours were obtained from the National Environment Agency of Singapore's meteorological service. Over the study period, a total of nine Tid-Bit Stowaway temperature loggers were deployed to measure air and water temperature. However, within the first three months of the study, all were either stolen or the ropes which were used to secure them were severed.

Data analyses

All scan and focal sampling data were recorded in "Rite in the Rain" journal notebooks (J.L. Darling Corporation) with a 2B pencil and using a digital Casio (LW-201) watch. Data were transcribed to and compiled in Microsoft Excel. Statistical analyses were performed using JMP® (SAS Institute). Data were tested for normality using the Kolmogorov-Smirnov Test for scan sampling data (sample size > 2000) and the Shapiro-Wilk Test for focal sampling data (sample size ≤ 2000). Non-parametric Wilcoxon Rank-Sums Test and Mann-Whitney Test were used to compare the number of participants and length of time spent in activities among and between the hours, months and sexes.

5.3 Results

5.3.1 Number of turtles observed by scan sampling

Throughout the period from January 2007 – January 2008, the maximum number of red-eared sliders observed in one scan sample was 116. Only three samples contained zero-counts, all of which occurred between 1900 hrs and 2000 hrs. Red-eared sliders were most numerous from 1700 hrs – 1900 hrs and least numerous from 0800 hrs – 1000 hrs (figure 5.3). Red-eared sliders appeared to be more numerous later in the day from the period of September 2007 – January 2008 (with more turtles from 1800 hrs – 1900 hrs) compared to January 2007 – August 2007 (with more turtles from 1700 hrs – 1800 hrs). The period from 1900 hrs – 2000 hrs had the most variable number of turtles, ranging from 24 ± SD 24.6 in February to 56 ± SD 39.3 in September.

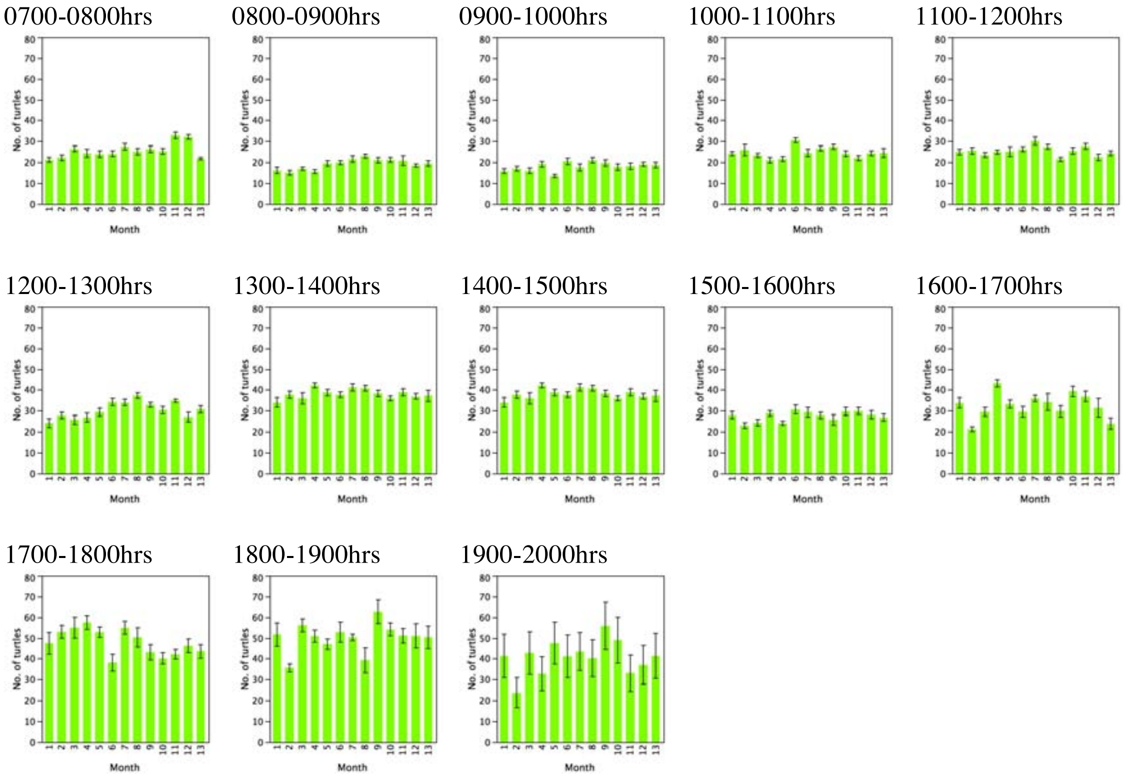


Figure 5.3 Monthly changes in mean number of turtles observed for each hour with standard error bars (Month 1 refers to January 2007 and Month 13 refers to January 2008).

All behaviours described in table 5.1 were observed although it was sometimes difficult to distinguish between turtles swimming slowly, swimming quickly and remaining stationary at the surface of the water while performing a scan sample. Therefore, all data recorded as these three behaviours were collectively termed "swimming along the surface" for analysis to avoid a bias in results due to a misidentification of the behaviours.

5.3.2 Summary of activity by scan sampling

January 2007

For the month of January 2007 (figure 5.4), there were clear changes in the proportion of red-eared sliders numbers participating in the four main activities over 13 hours of daylight. From 0700 hrs – 0800 hrs, 55.7% of the red-eared sliders were swimming along the surface (12 ± SD 3.8), followed by 28.8% basking (8 ± SD 4.5). Only 4.7% of the red-eared sliders observed were participating in courtship and about 1% was swimming along the bottom. In the following hour, the proportion of basking turtles increased to 75.8% and proportion of red-eared sliders swimming along the surface decreased to 22.2%. From 0900 hrs – 1400 hrs, basking peaked and remained fairly constant (between 81.9% and 88.4%) while swimming on the surface remained low from 10.5% – 17.5%. During this period, courtship and swimming along the bottom accounted for less than 2.5% of turtle activity. From 1400 hrs – 2000 hrs, the proportion of red-eared sliders swimming on the surface increased steadily from 17% – 80.6%, while the proportion basking dropped steadily from 75.6% – 7.7%. During this period, the proportion of red-eared sliders in courtship fluctuated between 2.2% and 9.5%, with the largest proportion occurring between 1700 hrs and 1800 hrs. Swimming along the bottom peaked at 4.6% between 1900 hrs and 2000 hrs.

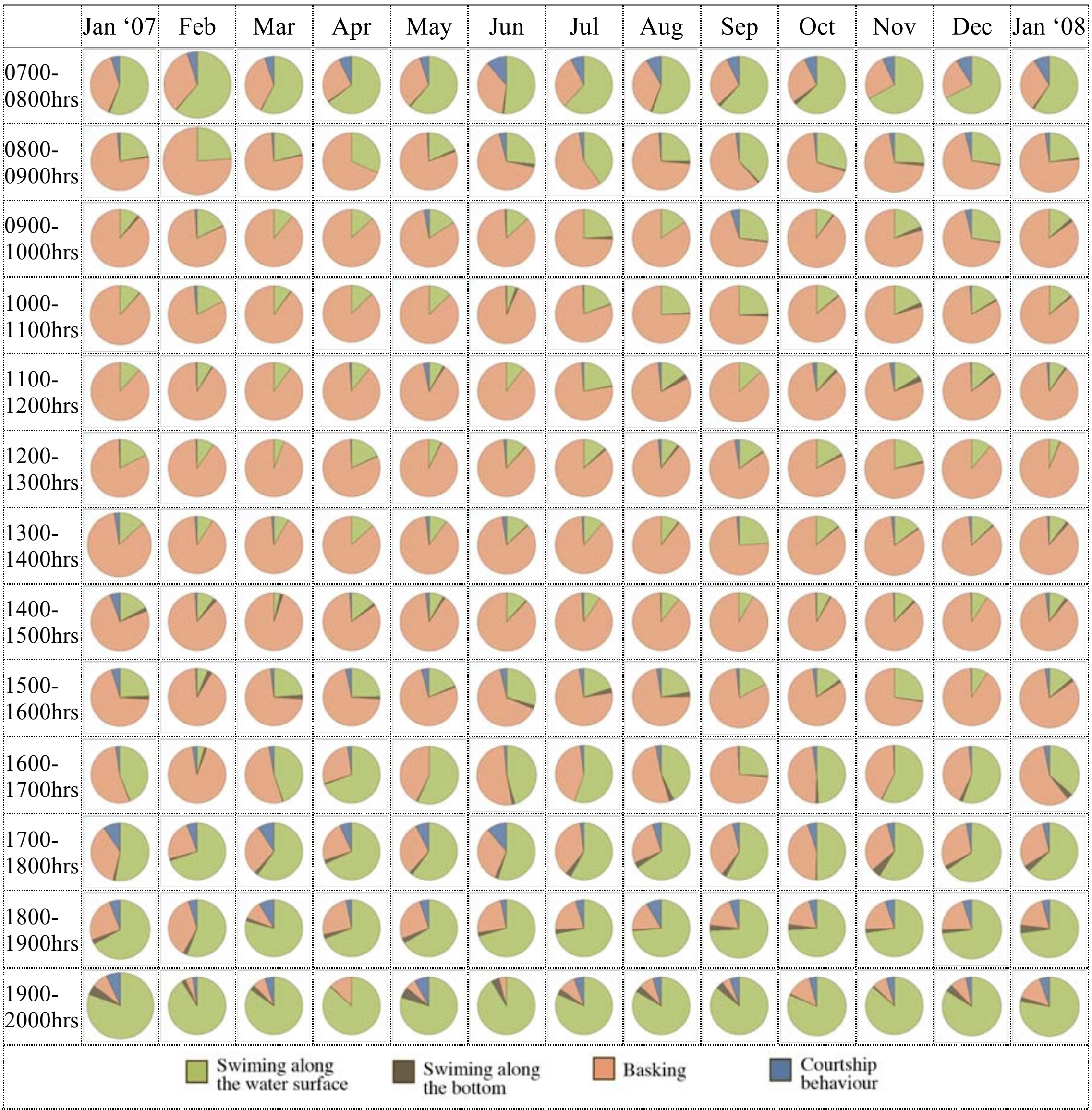


Figure 5.4 Percentage composition of turtles participating in the four main activities for every hour from 0700hrs to 2000hrs for 13 months from January 2007 to January 2008.

February 2007 to January 2008

The daily pattern of behaviour from February 2007 to January 2008 was similar to January 2007, the proportion of red-eared sliders swimming on the surface remained the major activity from 0700 hrs – 0800 hrs with between 51.4% and 67.2%, and the proportion basking was between 23.6% and 36.7% for the rest of the year. The mean proportion of red-eared sliders taking part in courtship was 7% for all months except for June, when 11.5% were taking part. Swimming along the bottom was minimal, ranging from 0% – 2% for this time period.

Red-eared slider activity remained fairly consistent across the months for the period between 0800 hrs and 1200 hrs except for July and September, during which a greater proportion of red-eared sliders appeared to be swimming along the surface and less basking compared to the other months. There was also a greater proportion of red-eared sliders were also observed swimming along the surface in August and October to December compared to the other months (excluding July and September) but to a less obvious extent.

Nevertheless, basking was still the major activity for most red-eared sliders from 1000 hrs – 1500 hrs across the year. Basking and swimming along the surface accounted for roughly 50% (± 1.7%) of the red-eared sliders observed throughout the year except for the months of February when 91.8% of the them were basking, April (69.5% were swimming along the surface) and September (72.7% were basking).

As described for January 2007, the proportion of red-eared sliders observed decreased steadily from 1400 hrs till dusk, with a corresponding increase in red-eared sliders swimming along the surface. February was an exception, with the proportion basking drastically from 91.8% – 23.3% within between 1600 hrs and 1800 hrs.

In general, throughout the months, swimming along the surface was the most observed activity first thing in the morning while the red-eared sliders spent most of their time basking between 0800 hrs and 1600 hrs. From late afternoon to dusk, the number of red-eared sliders swimming along the surface increased again to be the most prevalent activity, although some basking, courtship and swimming along the bottom also occurred.

5.3.3 Comparing among months and hours for number of turtles

a) Swimming along the water surface

A Wilcoxon-Rank-Sums test showed that there were significant numerical differences in the numbers swimming along the water surface among months for all hours of the day ($P < 0.05$) except for 1300 hrs – 1400 hrs and 1900 hrs and 2000 hrs (table 5.3). There were also highly significant differences among hours for all months (all $P < 0.0001$) (table 5.4).

b) Swimming along the bottom

There were only significant differences in the number of red-eared sliders swimming along the bottom among months for the periods 1100 hrs – 1200 hrs ($P < 0.005$), 1400 hrs – 1500 hrs ($P < 0.05$) and 1900 hrs – 2000 hrs ($P < 0.005$). There were no significant differences at all other times of the day (table 5.3). There were significant differences among hours for all months ($P < 0.005$) except for February and October (table 5.4).

c) Basking

There were significant differences in the number of red-eared sliders basking among months for 0800 hrs – 0900 hrs ($P < 0.005$), 0900 hrs – 1000 hrs ($P < 0.005$), 1000 hrs – 1100 hrs ($P < 0.005$), 1300 hrs – 1400 hrs ($P < 0.005$), 1600 hrs – 1700 hrs ($P < 0.05$), 1700 hrs – 1800 hrs ($P < 0.05$) and 1800 hrs – 1900 hrs ($P < 0.005$). There were no significant differences among months for the other hours of the day (table 5.3). The number of turtles basking had highly significant differences among hours for all months (all $P < 0.0001$) (table 5.4).

d) Courtship

There were no significant differences among months for all hours of the day except for the period 1400 hrs – 1500 hrs ($P < 0.05$), 1700 hrs – 1800 hrs ($P < 0.005$) and 1900 hrs – 2000 hrs ($P < 0.005$) (table 5.3). The number of turtles participating in courtship was significantly different among hours for all months (all $P < 0.005$) (table 5.4).

Appendix I shows figures of the numbers of red-eared sliders participating in the four main activities by hour (figure 1) and month (figure 2)

Table 5.3 $\chi 2$-values (P-values in brackets, d.f. = 12) for Wilcoxon Rank-sums test among months for the 13 hours of the day. Asterisks (*) indicate significant P-values at a 95% confidence interval. See Appendix I figure 1.

	Swimming on the surface	Swimming along the bottom	Basking	Courtship behaviour
0700-0800hrs	45.59 (< 0.0001)*	12.50 (0.4061)	10.51 (0.5716)	11.55 (0.4825)
0800-0900hrs	38.38 (0.0001)*	10.81 (0.5453)	29.02 (0.0039)*	10.52 (0.5703)
0900-1000hrs	22.98 (0.0279)*	15.07 (0.2377)	28.90 (0.0041)*	16.36 (0.1753)
1000-1100hrs	27.57 (0.0064)*	10.29 (0.5907)	31.13 (0.0019)*	13.58 (0.3282)
1100-1200hrs	26.85 (0.0081)*	30.96 (0.0020)*	14.29 (0.2823)	13.05 (0.3655)
1200-1300hrs	38.46 (0.0001)*	17.25 (0.1404)	20.49 (0.0584)	20.03 (0.0665)
1300-1400hrs	16.81 (0.1571)	14.21 (0.2873)	32.42 (0.0012)*	10.07 (0.6097)
1400-1500hrs	25.68 (0.0119)*	22.80 (0.0295)*	13.54 (0.3311)	28.11 (0.0053)*
1500-1600hrs	42.38 (< 0.0001)*	12.64 (0.3960)	20.37 (0.0604)	13.05 (0.3654)
1600-1700hrs	77.40 (< 0.0001)*	18.57 (0.0994)	26.39 (0.0095)*	7.52 (0.8220)
1700-1800hrs	26.45 (0.0093)*	16.76 (0.1589)	26.85 (0.0081)*	32.16 (0.0013)*
1800-1900hrs	32.04 (0.0014)*	14.47 (0.2719)	34.36 (0.0006)*	15.56 (0.2122)
1900-2000hrs	8.06 (0.7800)	32.23 (0.0013)*	15.97 (0.1926)	36.78 (0.0002)*

Table 5.4 $\chi 2$-values (P-values in brackets, d.f. = 12) for Wilcoxon Rank-sums test among hours for 13 months. Asterisks (*) indicate significant P-values at a 95% confidence interval. See Appendix I figure 2.

	Swimming on the surface	Swimming along the bottom	Basking	Courtship behaviour
Jan '07	94.72 (< 0.0001)*	34.22 (0.0006)*	82.74 (< 0.0001)*	55.86 (< 0.0001)*
Feb	90.61 (< 0.0001)*	18.29 (0.1070)	121.44 (< 0.0001)*	29.66 (0.0031)*
Mar	107.26 (< 0.0001)*	37.04 (0.0002)*	116.11 (< 0.0001)*	83.56 (< 0.0001)*
Apr	110.92 (< 0.0001)*	44.99 (< 0.0001)*	118.00 (< 0.0001)*	62.31 (< 0.0001)*
May	109.99 (< 0.0001)*	65.60 (< 0.0001)*	122.81 (< 0.0001)*	75.87 (< 0.0001)*
Jun	100.71 (< 0.0001)*	30.88 (0.0021)*	125.12 (< 0.0001)*	65.93 (< 0.0001)*
Jul	101.56 (< 0.0001)*	48.11 (< 0.0001)*	124.85 (< 0.0001)*	38.14 (0.0001)*
Aug	97.97 (< 0.0001)*	33.33 (0.0009)*	127.80 (< 0.0001)*	48.60 (< 0.0001)*
Sep	101.09 (< 0.0001)*	53.97 (< 0.0001)*	105.31 (< 0.0001)*	53.43 (< 0.0001)*
Oct	104.66 (< 0.0001)*	14.46 (0.2721)	101.03 (< 0.0001)*	46.03 (< 0.0001)*
Nov	96.26 (< 0.0001)*	28.99 (0.0039)*	112.92 (< 0.0001)*	53.89 (< 0.0001)*
Dec	103.52 (< 0.0001)*	32.38 (0.0012)*	109.32 (< 0.0001)*	45.58 (< 0.0001)*
Jan '08	99.54 (< 0.0001)*	29.39 (0.0034)*	106.67 (< 0.0001)*	49.84 (< 0.0001)*

5.3.4 Summary of activity by focal sampling

The behaviours swim slow (SS) and stationary (ST) as described in table 5.1 often occurred concurrently and were grouped together as (SS/ST). Appendix II shows a typical SS/ST sequence. Behaviours such as clocal sniffing and interactions with other species / same species which were not recorded in scan samples were observed using the focal sampling method. However, during focal observation periods, subjects often went out of sight even before 480 seconds. Because of this, data were grouped into two-month periods for descriptive purposes, and months kept separate but the hours of the day grouped into three time periods to achieve a large enough sample size for statistical analyses.

From 0700 hrs – 0800 hrs

The proportion of time spent in the different activities (figure 5.5) was roughly similar to the number of turtles participating in the same or similar activities observed using the scan sampling method. Swimming slowly/stationary (SS/ST) and swimming fast (SF) were the main activities for both males and females from 0700 hrs – 0800 hrs. These two activities were grouped together as “swimming along the surface” for the scan data because it was difficult to differentiate between the two behaviours instantaneously. During focal observations, it was clear that SS and ST behaviours took place interchangeably. Swimming fast was a different sort of behaviour whereby the focal subject expressed a distinct interest in a subject which included another turtle, other species (black swans or white-breasted water hens) and people throwing bread from the bridge. Other cues, possibly olfactory, could also be in play as several incidences of several turtles of differing species and gender being attracted to a

Figure 5.5 Percentage compostition time spent by males and females participating in 9 activities for every hour from 0700hrs – 2000hrs for 6 2- month periods (January 2007 – June 2007).

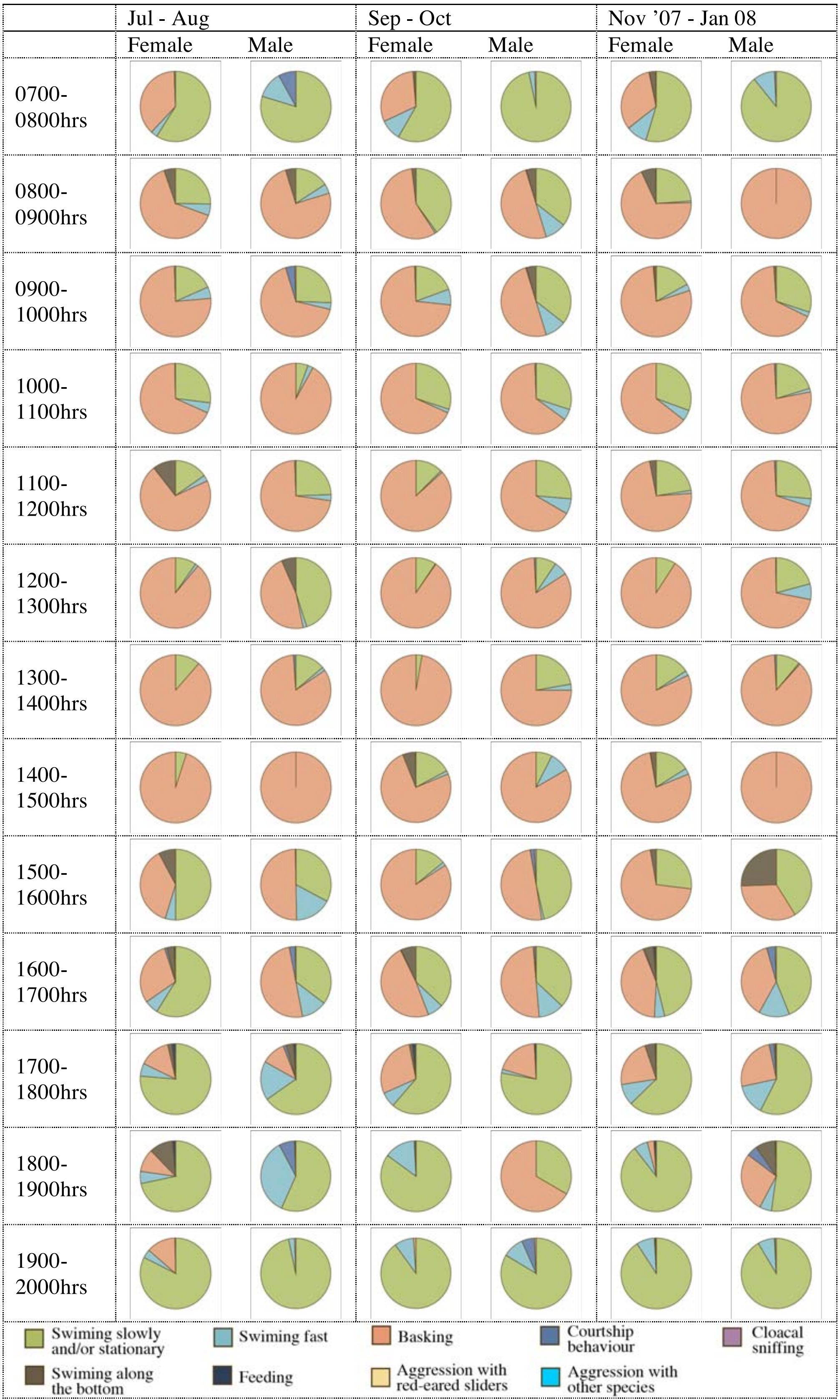


Figure 5.5 (continued) Percentage compostition time spent by males and females participating in 9 activities for every hour from 0700hrs – 2000hrs for 6 2- month periods (July 2007 – January 2008).

particular unknown object. These turtles turned their heads simultaneously in the same direction and following (swimming fast) towards them. Swimming fast was most commonly observed in males when pursuing females, followed by attempts to initiate courtship behaviour. Swimming fast was also a common behaviour of females in an attempt to avoid a courting male when they were not in a receptive state (vs remaining stationary while males performing courtship behaviour). Both males and females also observed swimming fast towards food being thrown into the water from the bridge (described in detail later).

Basking (B) activity was more prolonged in females than in males. Very few males were seen to bask at all during this hour, except for in May/June. Instead, males seemed to spend more of their time swimming fast along the surface or engaging in courtship (CS). Females spent a very small proportion of their time participating in courtship during this hour.

From 0800 hrs – 1500 hrs

More swimming along the bottom (SB) was observed from July – January 2008 compared to the first part of the year from 0800 hrs – 1000 hrs. In general, the proportion of time spent basking increased steadily from 0800 hrs to peak during the period of 1300 hrs – 1500 hrs. Turtles usually remained basking for the entire period of observation unless disturbed by the noise or vibrations made by people walking on the bridge above. While basking, some turtles exhibited a preference for moving higher up on the beams (further away from the water) while others stayed near the water surface with the edge of their carapace in the water. When basking, limbs of the turtles were stretched out and occasionally kicking movements were made. Some interactions were observed between turtles basking on the same beam when another tried to get higher up on the beam. This was achieved by either pushing against the turtle in front using the plastron, or attempting to climb over to get ahead. Interactions usually ended in one of two ways. In the first scenario, the initiator succeeded in causing the one ahead to move sufficiently forward or climbed over it. The other scenario resulted in either or both jumping into the water below.

For almost all months, males spend slightly more time in SS/ST than females. The only exception was the period from January – February 2007, where from 1200 hrs – 1500 hrs, all observed males spent 100% of their time basking. Males also spent more time swimming fast, a contrast with the females who hardly spent any time swimming fast during this period of time. Swimming along the bottom was not a common activity when basking activity was at its highest, although it was observed on a few occasions from July – January 2008 in females and May – October in males.

From 1600 hrs – 1900 hrs

In general, the proportion of time spent basking decreased and the proportion of swimming along the surface, swimming fast, swimming along the bottom and courtship increased for both males and females from 1600 hrs – 1900 hrs. For the same hours and months, males spent more time swimming fast and in courtship than females except for the months of September – October from 1700 hrs – 1900 hrs. From January – August 2007, only females were seen basking from 1800 hrs – 1900 hrs, while males spent more time basking during the same hour from September – January 2008.

Swimming fast during this period was also common in response to members of the public throwing food into the water from the bridge. The number of people that walked on the bridge was also highest during this period. When people pause along the bridge, the number of turtles in SS/ST and SF typically increase to up to 97% (scan observations). Feeding was usually a sort of frenzy with turtles pushing each other and sometimes chasing another that had obtained a piece of food. If people were walking slowly on the bridge, it was a common observation that the turtles that were in SS in the water nearby would follow them in the water with their heads pointed in the direction of the people.

From 1900 hrs – 2000 hrs

Both males and females spent most of their time during this hour swimming along the surface and the rest of their time was spent either swimming fast or in courtship (males more so than females). From July – August, basking was observed in some females. The number of turtles decreased drastically within the hour as the sun set. After sunset (about 1945 hrs), no turtles were observed with the exception of one or two individuals swimming along the surface on a few occasions. During these instances, the last visible individuals were followed using a torchlight. The turtle were typically swimming along the surface until they were out of visible range or they dived underwater and were out of sight. Some observations made between 2000 hrs and 2200 hrs saw an occasional turtle swimming in the water and at times, one or two turtles remaining stationary on the beams.

Other behaviours

Other behaviours that were observed but not described above were feeding, cloacal sniffing and intra- and inter-specific aggression. These behaviours were short-lived and are not represented well in pie charts. The time spent feeding ranged from three seconds – 89 seconds with a mean of 25.7 seconds and was observed 46 times throughout the 13 months.

Cloacal sniffing

Cloacal sniffing was observed 30 times and was carried out only by males. Of these, cloacal sniffing did not result in courtship behaviours in only eight instances during the 480 – 600 second observed. Cloacal sniffing lasted between two and 23 seconds but these are records of total time spent in each activity and each act of cloacal sniffing usually lasts only between two and four seconds.

Aggression

Aggression among red-eared sliders was observed in 17 individuals, of which only four were males. Time spent being involved in aggressive behaviour ranged from two seconds – 230 seconds with a mean of 31.5 seconds. Intra-specific aggressive behaviour consisted of snapping of jaws and pushing with either limbs or part of their carapace. Inter-specific aggression, with black swans, was recorded four times. The interactions lasted between six and 64 seconds with a mean of 22.3 seconds. The swans were always the aggressors, making attempts to bite the sliders. The turtles escaped by retracting their heads into their carapace or ducking and swimming away quickly.

Interactions with other species of turtles

Interactions between red-eared sliders and other species of turtles were noted but not included in the data, as these were not within the focal samples. Incidental observations of these instances are here included. Members of the public who participated in the feeding of turtles at reservoirs and ponds often did so from bridges, boardwalks or pond edges. Turtles gather at the areas below the bridges or near pond edges, swimming slowly and waiting for these feeds. Red-eared sliders were most abundant but other species of turtles such as the Chinese stripe-necked turtle (*Ocadia sinensis*), Malayan box terrapin (*Cuora amboinensis*), river terrapin (*Batagur baska*), pig-nosed river turtle (*Carettochelys insculpta*) and the Chinese soft-shell turtle (*Pelodiscus sinensis*) were also observed. Often, feeding frenzies ensue. In these instances, there were no observable differences in intra- and inter-specific aggressive interactions. There was one instance of a pig-nosed river turtle following a red-eared slider from a distance of about 1 metre for about four minutes.

Interactions with South-American sucker-catfish

There were 16 instances when red-eared sliders allowed the South-American sucker-catfish to feed off the algae on their carapace. The turtles would remain stationary while the fish moved slowly around it with some turning slightly on their side to facilitate the feeding. Sometimes the turtles swam away and the fish started to feed off the algae of another turtle nearby, and sometimes it was the fish that terminated the feeding first, moving on to another.

5.3.5 Comparing percentage time spent among months (males and females)

Non-parametric Wilcoxon Rank-Sums tests showed that there were no significant differences in the percentage of time spent in swimming slowly/stationary, swimming fast, basking, courtship behaviour, cloacal sniffing, swimming along the bottom, feeding, aggression within species and with other species among months for males and females (table 5.5).

Table 5.5 χ^2-values (P-values in brackets) for comparing turtle activities among months.

	SS/STAT	SF	B	CS	SN
Female	5.52 (0.938)	6.18 (0.907)	4.35 (0.976)	3.1 (0.995)	-
Male	4.64 (0.969)	8.16 (0.772)	2.97 (0.996)	10.43 (0.579)	5.77 (0.927)

	SB	F	AGG	AGG(SP)
Female	6.87 (0.866)	5.36 (0.945)	6.1 (0.911)	-
Male	11.36 (0.498)	12.45 (0.411)	8.61 (0.736)	-

5.3.6 Comparing percentage time spent among hours and between sexes

The hours of the day were grouped into three meaningful periods as shown in table 5.6. Wilcoxon Rank-sums tests were used to compare among periods and between sexes and when significant differences were found, the Mann-Whitney test was used to compare between periods.

a) Swimming slowly/stationary along the water surface (figure 5.6a)

Both females and males spent the most time in swimming slowly/stationary during period 3, followed by period 1 and they spent the least amount of time swimming slowly or being stationary in period 2 (table 5.6). Females spent significantly more time swimming slowly than males during period 3 but there were no significant differences between females and males during periods 1 and 2 (table 5.7).

b) Swimming fast (figure 5.6b)

Females spent the most amount of time swimming fast during period 3, followed by period 1 and then period 2. Males spent significantly more time swimming fast in period 3 than periods 1 and 2 (table 5.6). Males spent more time swimming fast (figure 5.6b) but it was only significant for periods 2 and 3 (table 5.7).

c) Basking (figure 5.6c)

Both females and males spent similar patterns of basking. Basking was carried out most in period 2, followed by period 1 and then period 3 (table 5.6). There were no significant differences in the amount of time spent basking between males and females throughout the day (table 5.7)

d) Courtship and cloacal sniffing (figures 5.6d and 5.6e)

Females spent more time participating in courtship during period 3 compared to the other 2 periods and no cloacal sniffing was observed on the part of females. Males spent more time in courtship and cloacal sniffing during period 3, followed by period 1 and then period 2 (table 5.6). Males spent significantly more time participating in courtship during all three periods (table 5.7).

e) Swimming along the bottom (figure 5.6f)

Females spent significantly more time swimming along the bottom during period 3 compared to period 1 and 2. Males did not spend significantly different amounts of time swimming along the bottom among the three periods (table 5.6). Females spent more time swimming along the bottom than males (figure 5.6f) but it was only significant during period 3 (table 5.7).

f) Feeding (figure 5.6g)

Females and males both spent significantly greatest amount of time feeding in period 3. There were no differences in the amount of time spend feeding during the other 2 periods for both sexes (table 5.6). There were also no significant differences between the amount of time spent feeding between females and males during all three periods (table 5.7).

g) Intra- and inter-species aggressive behaviours (figures 5.6h and 5.6i)

There were no significant differences in time spent participating in aggressive behaviours among all three periods for both sexes (table 5.6). There were also no significant differences in time spent in aggressive behaviour between sexes for all three periods (table 5.7). Only females were observed in inter-specific aggressive behavioural displays (black swans) but the lack of data from males could be due to the low density at Ecolake (Chapter 2, page 45).

Table 5.6 χ^2-values (P-values in brackets) for comparing turtle activities among three periods (period 1 – 0700 hrs – 1100 hrs; period 2 – 1100 hrs – 1600 hrs; period 3 – 1600 hrs – 2000 hrs).

Females	SS/ST	SF	B
χ^2(P-value)	201.52 (< 0.0001)*	54.28 (< 0.0001)*	204.48 (< 0.0001)*
Period in decreasing order of time spent (P-value)	3 > 1 > 2 (< 0.0001)*	3 > 1 > 2 (< 0.05)*	2 > 1 > 3 (< 0.0001)*
	CS	SN	SB
χ^2(P-value)	25.21 (< 0.0001)*	None observed	18.94 (< 0.0001)*
Period in decreasing order of time spent (P-value)	3 > 1, 2 (< 0.05)*	-	3 > 1, 2 (< 0.05)*
	F	AGG	AGG(SP)
χ^2(P-value)	69.37 (< 0.0001)*	3.00 (0.2234)	2.55 (0.2801)
Period in decreasing order of time spent (P-value)	3 > 1, 2 (< 0.0001)*	-	-
Males	SS/ST	SF	B
χ^2(P-value)	65.70 (< 0.0001)*	40.92 (< 0.0001)*	77.42 (< 0.0001)*
Period in decreasing order of time spent (P-value)	3 > 1 > 2 (< 0.005)*	3 > 1, 2 (< 0.0001) *	2 > 1 > 3 (< 0.005)*
	CS	SN	SB
χ^2(P-value)	38.91 (< 0.0001)*	18.09 (< 0.0001)*	0.60 (0.7406)
Period in decreasing order of time spent (P-value)	3 > 1 > 2 (< 0.05)*	3 > 1 > 2 (< 0.005* but only between 3 and 2)	-
	F	AGG	AGG(SP)
χ^2(P-value)	19.80 (< 0.0001)*	4.33 (0.1145)	None observed
Period in decreasing order of time spent (P-value)	3 > 1, 2 (< 0.005)*	-	-

Table 5.7 χ^2-values (P-values in brackets) for comparing turtle activities between males and females.

	Period 1 (0700hrs – 1100hrs)	Period 2 (11000hrs – 1600hrs)	Period 3 (1600hrs – 2000hrs)
SS/ST	0.061 (0.806)	0.438 (0.508)	10.210 (0.0014)*
SF	3.127 (0.077)	4.847 (0.0277)*	16.228 (< 0.0001)*
B	0.126 (0.723)	0.848 (0.357)	0.073 (0.788)
CS	23.438 (< 0.0001)*	18.285 (< 0.0001)*	45.157 (< 0.0001)*
SN	22.017 (< 0.0001)*	6.095 (0.0136)*	40.645 (< 0.0001)*
SB	3.505 (0.061)	0.108 (0.742)	6.969 (0.0083)*
F	1.264 (0.261)	0.992 (0.319)	3.498 (0.061)
AGG	2.551 (0.110)	0.0001 (0.993)	0.111 (0.739)
AGG(SP)	0.840 (0.359)	-	0.940 (0.332)

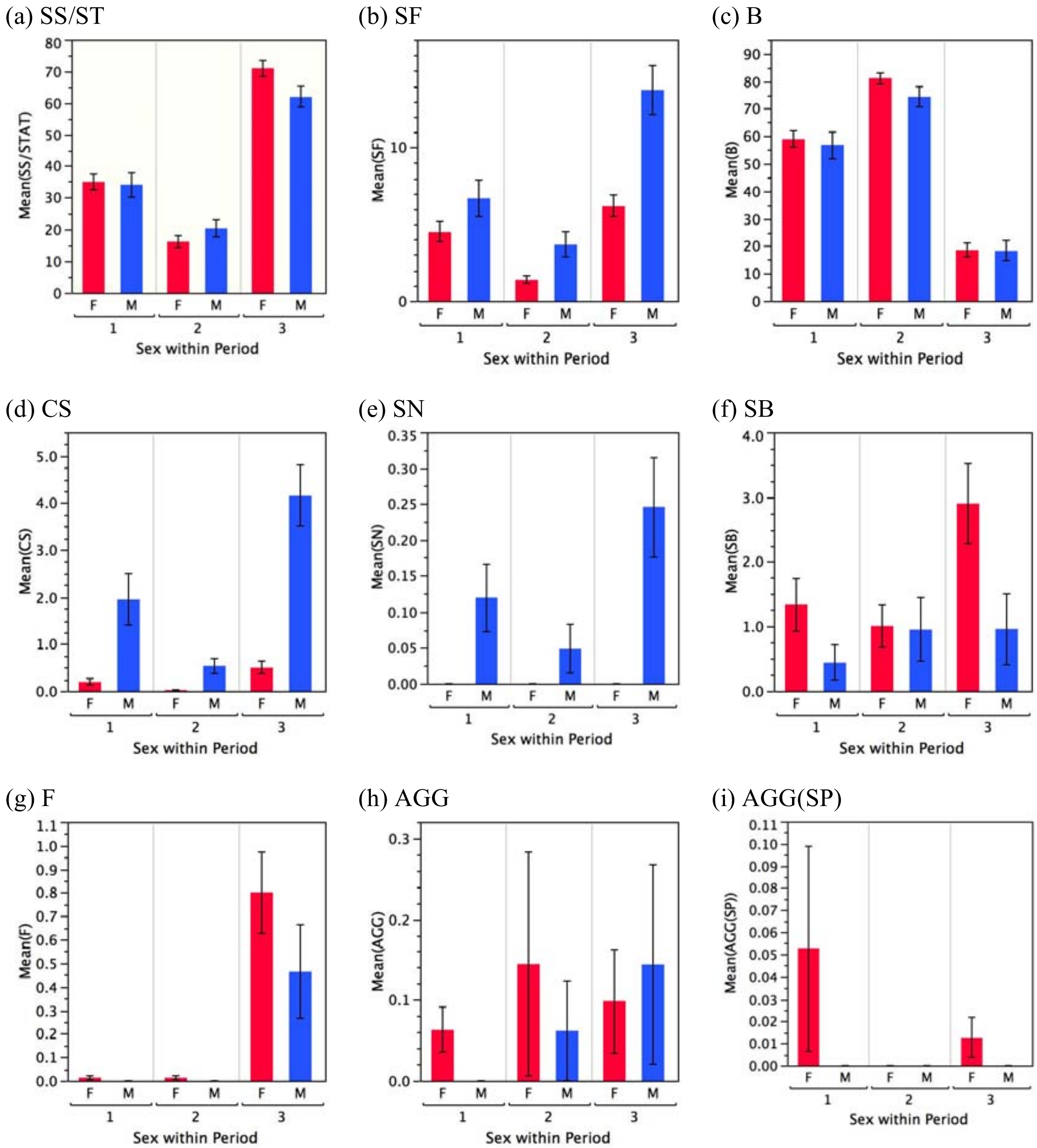


Figure 5.6 Mean percentage (with standard error bars) of time spent participating in a) swimming slowly and/or remaining stationary, b) swimming fast, c) basking, d) courtship, e) cloacal sniffing, f) swimming along the bottom, g) feeding, h) intra-species aggression, i) inter-species aggression.

5.3.7 Visitorship and environmental data

The number of people that walked on the bridge decreased from 0700 hrs (10 ± SD 3.6) – 1000 hrs (3 ± SD 2.9) and remained fairly low until 1500 hrs (figure 5.7). The number of people during the period of 1000 hrs – 1500 hrs ranged from 0 – 12 (with the mean ranging from 2 – 5). There was a slightly higher number of people at 1500 hrs (7 ± SD 4.9) than at 1600 hrs (5 ± SD 3.3). The number of people increased after 1700 hrs. The mean for 1700 hrs is 21 ± SD 7.8 and 1800 hrs had a mean of 25 ± SD 7.1 people. The number of people ranged from seven – 32 and 15 – 39 for the two hours respectively. During the period from 1900 hrs – 2000 hrs there were less people compared with the preceding two hours, with a mean of 16 ± SD 7.3. The months of May (22 ± SD 9.6), July (17 ± SD 5.6) and October (23 ± SD 6.4) 2007 and January 2008 (21 ± SD 7.0) appeared to have more people compared to the other months.

There was a positive relationship between the number of people that walked on the bridge and the total number of red-eared sliders ($R^2 = 0.532$, $P < 0.0001$, figure 5.8a) as well as with the number of red-eared sliders swimming along the surface ($R^2 = 0.729$, $P < 0.0001$, figure 5.8b). Although, a greater percentage of the data points (33%) can be accounted for by the relationship for the number of red-eared sliders swimming along the surface than the total number of red-eared sliders (17%). There was a negative relationship between the presence of people and the number of red-eared sliders basking ($R^2 = 0.0.278$, $P < 0.0001$, figure 5.8c).

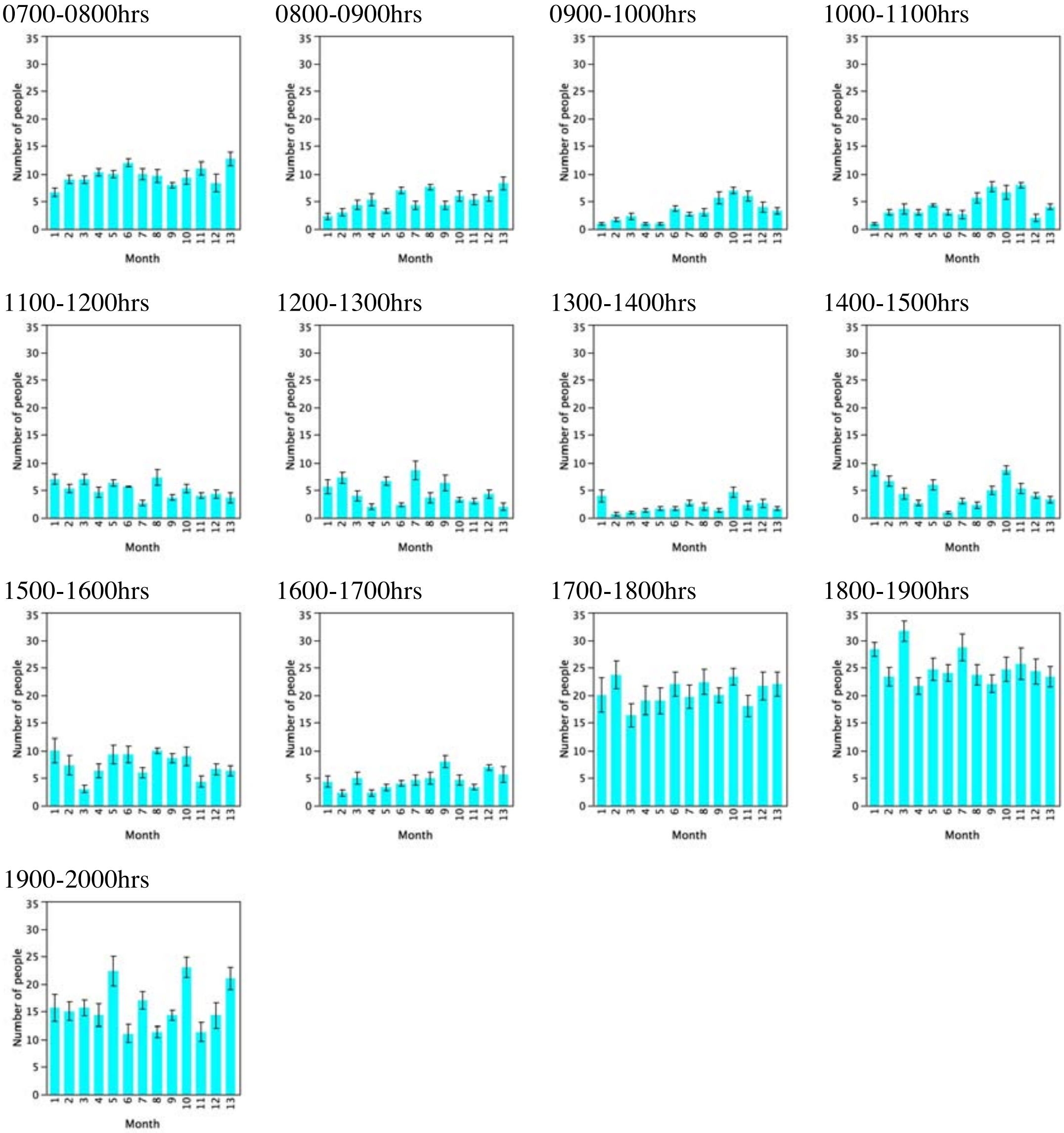


Figure 5.7 The mean number of people that walked on the bridge encircling part of the demarcated sampling area.

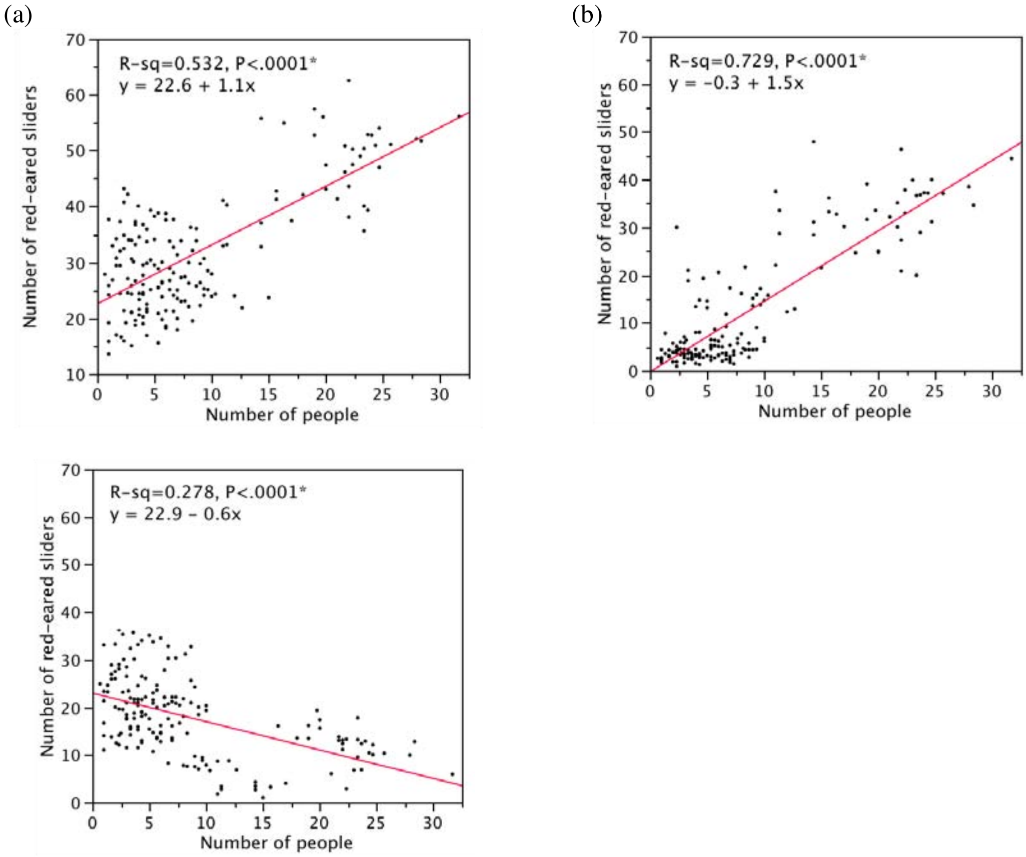


Figure 5.8 Regression analysis of the number of people that walked on the bridge with the a) total number of turtles observed per scan sample b) the number of turtles swimming along the surface and c) the number of turtles basking.

Average monthly air temperature (figure 5.9) increased steadily from 26.5°C in January 2007 to peak at 28.4°C in June 2007. It then dropped in July and remained around 27.7°C until October. The temperature dipped from October – December to reach its lowest (26.4°C) in December, after which it rose to 26.8°C in January 2008.

The total number of sunshine hours per month (figure 5.10) was the highest in February 2007 (213.7 hours) and January 2008 (189.8 hours). In between, the number of sunshine hours remained between 171 and 181 hours except for the months of July (119.3 hours), November (104.9 hours) and December (139.8 hours) when there were fewer sunshine hours.

Regression analyses showed that there was a significant relationship between the total number of red-eared sliders observed and the mean monthly temperature (figure 5.11) but regression analysis showed no significant relationship between temperature and neither basking nor swimming on the surface. Number of sunshine hours had no significant relationship with any of the above behaviours.

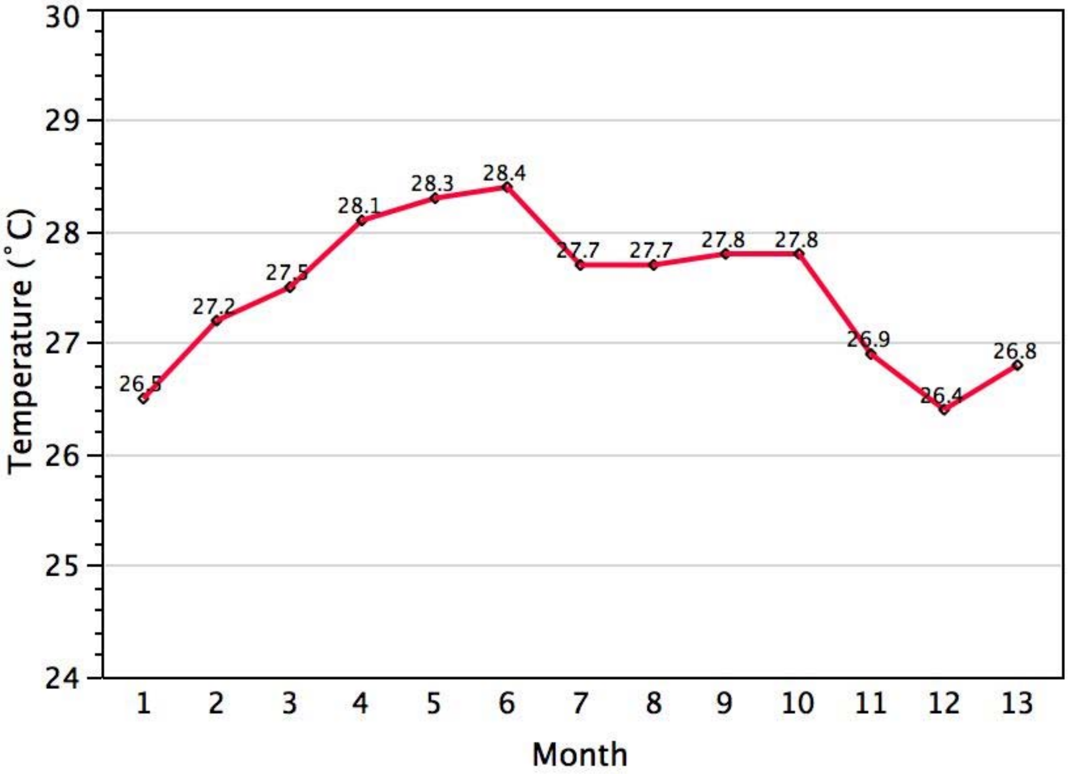


Figure 5.9 Mean monthly air temperature for the period of January 2007 (Month 1) – January 2008 (Month 13).

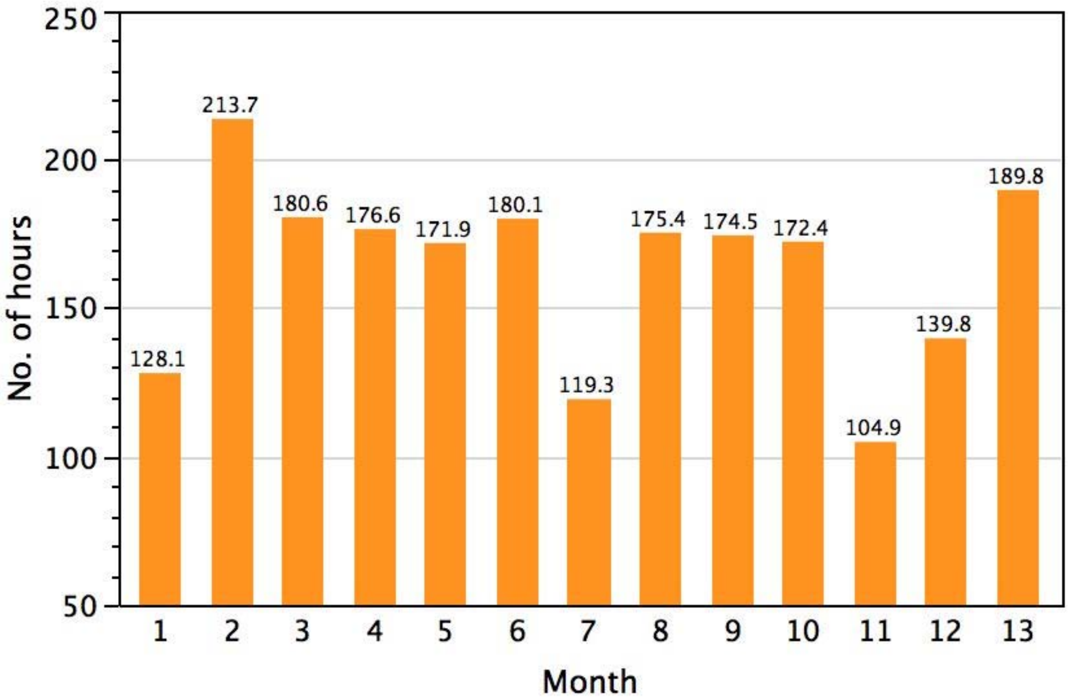


Figure 5.10 Total number of sunshine hours each month for the period of January 2007 (Month 1) – January 2008 (Month 13).

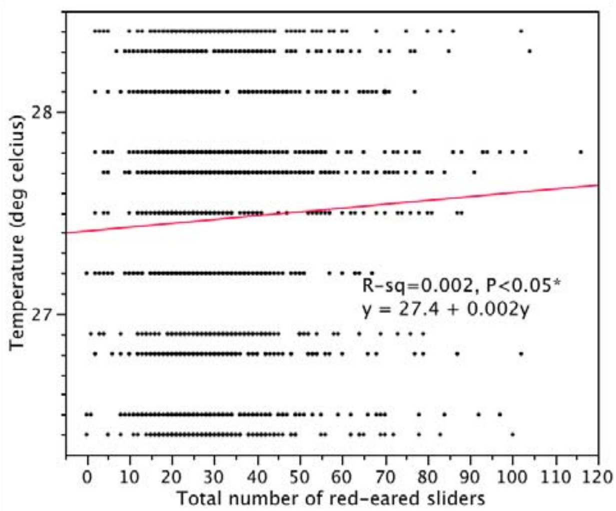


Figure 5.11 Regression analysis of mean monthly temperature with the total number of red-eared sliders.

5.4 Discussion

The daily activity cycle of red-eared sliders at Eco-lake was similar to that of other sliders reported in literature (Boyer, 1965; Cagle, 1950). Basking is predominant during the day and other activities such as courtship and feeding take place mostly in the mornings and evenings (Boyer, 1965; Cagle, 1950). The red-eared sliders at Eco-lake were active throughout the year with a clear absence of a dormant periods for specific behaviours, similar to the activity patterns observed in neotropical sliders (Moll and Legler, 1971). However, the total number of red-eared sliders observed seemed have a significant positive relationship with temperature. More red-eared sliders observed in the warmer months could be due to an in increase in overall activity.

5.4.1 Basking

Basking behaviour in red-eared sliders involves the individual emerging from the water to a position where it remains quiescent (Cagle, 1950). Support beams of the bridge at Eco-lake are angled at about 35˚ to the water surface. This allows the red-eared sliders to climb on easily and provides ideal spots for basking. Furthermore, the bridge spanning 100 m in length and three meters in width, provides ample shade during basking. Basking in direct sunlight for prolonged periods may be fatal to the turtles. The maximum lethal temperature of red-eared sliders has been found to be 44.4˚C (Moll and Legler, 1971) and 44.5˚C (Boyer, 1965). Interestingly, Boyer (1965) noted that red-eared sliders in Louisiana exhibited a preference for non-shaded basking sites. These same individuals, however, made no attempts to move or stop basking even when these spots became shaded later in the day. All basking sites at Eco-lake had similar coverage of shade by the bridge. No comparisons were therefore made on the preference of shaded versus non-shaded basking sites.

In the present study, basking red-eared sliders were often seen to have their limbs outstretched and occasionally making kicking motions with their limbs. This behaviour has been hypothesized to maximise the amount of soft skin exposed for heat absorption since blood flow is increased to the skin when there is heat (Spotila et al., 1990). Kicking motions have been observed in individuals that were basking for long periods and had been suggested to be related to high temperatures (Boyer, 1965). These same motions had been exhibited by sliders showing discomfort when forced to bask until their body temperatures reached 36.7˚C (Moll and Legler, 1971).

Emydid turtles were frequently observed to climb on top of each other to bask (Boyer, 1965). This was observed in red-eared sliders at Eco-lake, although not frequently. There might be two possible factors to explain the rarity of this behaviour. Firstly, the incline of the support beams may make it unfeasible and secondly, the abundance of available basking space may provide no motivation for "stacked" basking.

Partially-submerged or aquatic basking described by many authors (Cagle, 1944b; Boyer, 1965; Pope, 1949; Moll and Legler, 1971) was not observed in the present study. This behaviour involves the red-eared slider remaining submerged and floating on the surface of the water, or clinging to object just below the surface of the water. Aquatic basking also involves red-eared sliders resting on the bed of a shallow water pond or stream with part of the carapace exposed. Boyer (1965) noted that aquatic basking was mostly observed when there was a lack of basking sites. The absence of such behaviour at Eco-lake could indicate that basking sites are in abundance. Future studies could investigate if aquatic basking is prevalent in places with fewer artificial structures, such as at MacRitchie and Lower Peirce reservoirs, indicating a lack of suitable basking locations.

The basking patterns observed at Eco-lake are typical of red-eared sliders and other species of aquatic turtles (Boyer, 1965; Moll and Legler, 1971; Cagle, 1950). Basking commenced just after sunrise and ended after sunset. The number of turtles and the time spent basking increased gradually from sunrise to peak at about 1400 hrs, and decreased towards the evening. In Eco-lake, basking was often terminated when there were people walking on the bridge. These individuals jumped or slid off the basking spots regardless of distance from the water. This behaviour is a reaction to disturbance (Boyer, 1965). In Eco-lake, jumping off could either be a reflex when frightened or an anticipation of feeding. However, the act of returning to water voluntarily is described as either moving backward or turning around and going head-first back down the incline of the basking structure (Boyer, 1965). This suggests that the observed cessation of basking was due to disturbance, not in anticipation of feeding. At Eco-lake, turtles were seen (although extremely rarely) to be basking on beams long after sunset. Nocturnal basking was also reported from Louisiana (Boyer, 1965). It is suggested that nocturnal basking might function to dry the integument, presumably to rid themselves of algal growth on their shells and skin (Neill and Allen, 1954).

The main function of basking is believed to be thermoregulation (Spotila et al., 1990; Moll and Legler, 1971; Boyer, 1965). The increase in body temperature leads to increased rates of metabolism and physiological processes (Hammond et al., 1988).

Digestive turnover time was shorter and rate of food intake was faster at higher temperatures in the yellow-bellied slider (*T. scripta scripta*) (Parmenter, 1980; Parmenter, 1981). In Panama, sliders basked longer after ingesting food than when they had not fed (Moll and Legler, 1971). As observed in the present study, for most months of the year, males spent less time basking compared to the females during the peak basking periods at Eco-lake. Although the difference was not significant, it may indicate that males fed less than females (see chapter 5). Interestingly, Lefvre and Brooks (1995) found no significant differences in the period and frequency of basking between sexes.

Krawchuk and Brooks (1998) attempted to demonstrate that female painted turtles (*Chrysemys picta*) bask more than males before and during nesting to support egg development and aerobic activity respectively. However, increased frequency (with respect to known sex ratio of the population) and duration of basking in females only occurred during the nesting period.

The impetus for retaining long basking hours in Singapore deserves further investigations. Body temperature and the motivations for basking can provide more insight into the physiological adaptations of red-eared sliders in a tropical and non-seasonal climate.

5.4.2 Feeding

Food items were categorised into two components for this study; a) pieces of leaves and/or floating insects and b) pieces of food thrown by members of the public. Submerged foraging behaviour referred to turtles swimming along the bed and poking their heads into small crevices and between gravel, similar to foraging behaviour observed amongst algal patches (Parmenter and Avery, 1990). The substrata of all observable areas of study sites were completely covered with gravel. Submerged foraging behaviour can account for the majority of the geophagy content (between 9.5% and 33.5%) found in the guts of red-eared slider at Eco-lake from 2005 to 2006. Visibility and, consequently behaviour, of red-eared sliders were more apparent at the surface as opposed to those at the sub-surface and pond beds. Observations of submerged foraging behaviours were dependent on extent of light penetration. These observations were only made on days with moderately clear skies when the substrate was visible, lending confidence that the activities of individuals within the range are visible. However, turtles below the depth of 1 meter were completely not visible and were recorded as ‘out-of-sight’.

The turtles at Eco-lake were never observed to pursue any prey but there were indications that red-eared sliders were stimulated to feed by visual cues, as suggested by other published studies (see Moll and Legler, 1971). This is exemplified by an incident when the feet of a flying white-breasted waterhen touched the water surface. A stationary red-eared slider approximately one meter away, immediately swam vigorously and stopped at the point of contact. Another incident emphasising this point was when approximately 30 red-eared sliders swimming vigorously towards some saliva, spat by a lady from a bridge. Some of these turtles had jumped into the water from their basking positions while others swam from other nearby locations. Just prior to this incident, a scan sampling revealed only 15 red-eared sliders in the water. The turtles swam near the area for approximately two minutes, and all but two left after this duration when no food was present.

In general, both feeding on the surface and foraging along the bottom of the pond occurred mainly in the evenings. During this time, males and females spent similar amounts of time feeding on the surface (feeding on food thrown by members of the public), but females spent more time foraging along the bottom than males. Corroborating this difference in behaviour, analysis of gut contents found that males foraged less often than females and this study (Chapter 4, page 113).

Other species of turtles were observed to wait for food from members of the public together with the red-eared sliders (e.g. *Ocadia sinensis*, *Cuora amboinensis* and *Batagur baska*). It is not within the scope of this study to quantify the amount of food ingested by these other species. However, it is interesting to note that red-eared sliders have been shown to have a significantly faster bite time than the Malayan box terrapin (*Cuora amboinensis*) at 30˚C (Bels et al., 2008). If food sources were limited, it is likely that red-eared sliders would secure most of the food. In situ, the river terrapin (*Batagur baska*) and the pig-nosed river turtle (*Carettochelys insculpta*) were unable to seize hold of any food when members of the public threw food into the pond. However, the Malayan box terrapins had, on occasions, managed to procure the food thrown into the pond by members of the public.

Despite no clear observations during this present study, olfactory cues have been cited as a stimulant when feeding (Cagle, 1950). The high efficacy of traps baited with fishes, prawns and squids in this study indicates that olfactory cues are in play. However, red-eared sliders are known to be less responsive to olfactory cues when compared to other species such as the common snapping turtles (*Chelydra* *serpentina*), common mud turtles (*Kinosternon subrubrum*), chicken turtles (*Dierochelys reticularia*), common cooters (*Pseudemys floridana*) and common musk turtle (*Sternotherus odoratus*) (Cagle, 1950).

5.4.3 Courtship behaviour

According to Jackson Jr. and Davis (1972), courtship in red-eared sliders is stereotypical and unlike some reptiles, does not include biting. A typical courtship sequence commences when a male trails behind the female and sniffing her cloacal region. The male then moves to face the female, swimming backwards to maintain face-to-face position. The males then vibrate the long foreclaws in front of the female's head, a behaviour known as 'titillation' and then proceeds to move to her rear followed by mounting and intromission (Lovich et al., 1990; Cagle, 1950). The behaviours do not necessarily occur in this order. In this study, we observed repetition of some behaviours such as titillation and cloacal sniffing and at times, the females were not receptive to these advances and moved away. Courtship was observed to the point of mounting. Intromission was not observed during this study. Females displayed disinterest by either swimming quickly away or snapping their jaws towards the males. Interest in courtship translated to a passive behaviour, where a female remains stationary and allows a male to mount her. Courtship behaviour were observed to occur mostly between 1700 hrs and 1900 hrs. Lovich et al. (1990) were the first to record and describe 'blinking behaviour' which together with the initiation of titillation sequences by female red-eared sliders, they considered to be proceptive. The term 'proceptive' was coined by Beach (1976) to describe active performances by females to illicit attention from males. Proceptive behaviours were not observed during any part of this study.

It was observed in this study that males invested more time in pursuit of mating compared to females. This has been observed in other sub-species of conspecifics. For example, sexually active males of *Pseudemys scripta troostii* were described to “maintain a constant search for females during daylight hours” (Cagle, 1950). Males were also described as being extremely persistent. Cagle (1950) cited an example of a captive male courting a female for more than four weeks. Courtship cues recognized by the males were hypothesized to be either olfactory or behavioural in nature as males were able to distinguish and court small females that were sexually mature and not others of similar size but not yet sexually mature (Cagle, 1950). It was observed during this study hat certain females tended to attract more male attention compared to other seemingly large and presumably reproductively capable ones. It is possible that males are able to identify females that are receptive or at an appropriate stage of the reproductive cycle. The other possibility is that reproductively senile females do not produce olfactory cues but this has never been documented. Reproductively senile females were not found during the course of this study (Chapter 4).

At Eco-lake, courtship was observed throughout the year without distinct seasonality. More red-eared sliders participated in courtship behaviour from January – June 2007, usually between 1700 hrs and 1800 hrs. Although there were also individuals involved in courtship slightly later in the day (1800 hrs – 2000 hrs) during the other months (July 2007 – January 2008), the number of red-eared sliders participating were not as numerous as the preceeding months. Red-eared sliders in temperate areas mate throughout the year with peaks in spring and fall, coinciding with the reproductive cycle of males (i.e. emptying of the epididymes) (Cagle, 1950; Moll and

Legler, 1971). At Eco-lake, the peak in courtship behaviour occurred during the same months as the dip in epididymes weights in 2005 (Chapter 3, page 76) although the data were collected in separate years, suggesting but not confirming seasonality in mating in Singapore.

Nesting and egg-laying activity was not examined during the course of the study but evidence for nesting can be confirmed anecdotally by a video filmed by Wen Hwee Liew at a freshwater pond beside the Kandang Kerbau Hospital (figure 5.12).

5.4.4 Social interaction

Intra- and inter-specific social interactions of red-eared sliders had not been described in detail as they are regarded as solitary (Moll and Legler, 1971). Members of the same species are thought to seek each other for the purpose of mating (Moll and Legler, 1971). Juveniles of red-eared sliders have been observed to mutually feed on epizooic algae on each other's carapace (Moll and Legler, 1971). Instances of inter-specific mutual feeding were observed between the giant South American river turtle (*Podocnemis expansa*) and the Brazilian radiolated swam turtle (*Platemys radiolata*) as well as between the Indian roofed turtle (*Kachuga tecta*) and the three-striped roofed turtle (*Kachuga dhongoka*) (Moll and Legler, 1971). However the algal-cleaning interaction between red-eared sliders and the South-American sucker catfish observed in this study has not been reported elsewhere before.

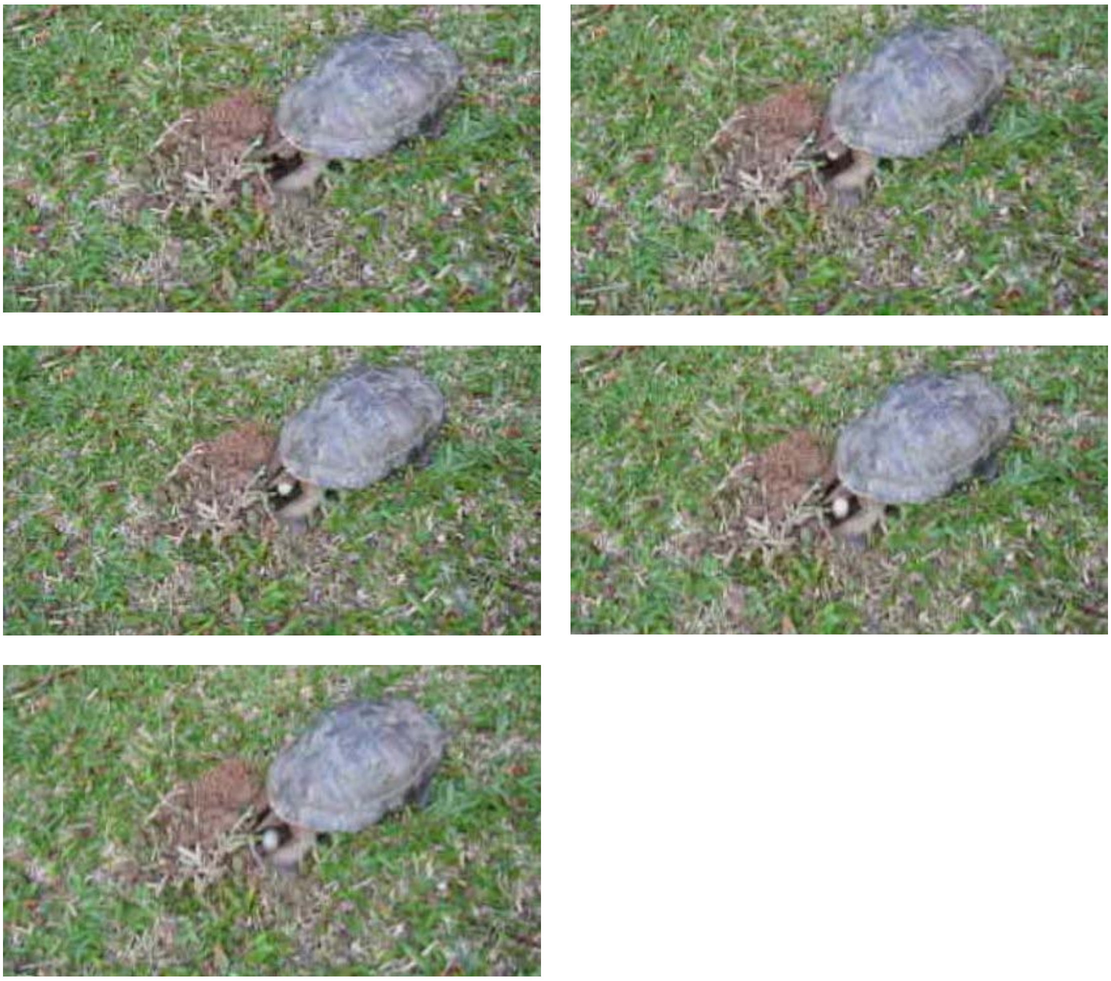


Figure 5.12 Red-eared slider laying egg.

Turtles have well developed olfactory structures in the central nervous system (Scott, 1979). Olfaction has been suggested to be an important sensory cue for mating (Cagle, 1950) and possibly nesting (Moll and Legler, 1971). Olfactory cues may therefore be the primary factor in peaking the interest of turtles to their surrounds and social interactions.

5.4.5 Conclusions

This study provided an outline of the daily and seasonal activity patterns for red-eared sliders in a small pond in Singapore. In Singapore, ponds like Eco-lake have very high turtle density (Goh, 2004) and the retention of their normal behaviour suggests that there is no lack of basking spots, food and mates in such habitats. The behaviour patterns with respect to basking, feeding and courtship lends support to these aspects of their ecology as described in earlier chapters. Though minimal, the interactions of red-eared sliders with other species of animals provide insight to their adaptations to new environment. It would be interesting to further investigate social interactions of red-eared sliders with endangered native turtles such as the Malayan box terrapin (*Cuora amboinensis*) and the river terrapin (*Batagur baska*). This is especially pertinent as laboratory studies have shown red-eared sliders to be more aggressive in feeding behaviour than *Cuora amboinensis* (Bels et al., 2008). Aggressive behaviours and interactions would hold further implications for conservation of these species.

Another area of interest that would be worth more investigation is the effect of feeding (by people) on the behaviour of introduced species of animals using red-eared sliders as a model. Red-eared slider behaviour in the current study suggests an anticipation of being fed. Although red-eared sliders left their basking locations in an abrupt manner, they stayed at the surface of the water closest to the locations of passers-by on the bridge. The extended basking time may also be an indication of modification of behaviour because of less need to forage due to feeding by humans. Research into this topic would also allow for better management of feral animals as well as provide more information for the facilitation of public education with regards to feeding of wildlife.

Chapter 6: Survey of pet ownership and attitudes towards releasing of pets

6.1 Introduction

6.1.1 The introduction of red-eared sliders in Singapore

The red-eared slider has been the only reptile species that can be legally sold as a pet in Singapore (Goh and O'Riordan, 2007) and are considered common pets in Singapore households (the Malayan box terrapin *Cuora amboinensis* has recently been approved for sale). Informal communications with pet-store proprietors and pet owners revealed that red-eared sliders are also often purchased to feed other pets such as large aquarium fishes. Red-eared sliders have also been purchased for release into various aquatic bodies as part of personal ethics code or religious rites.

Data from the Agri-food and Veterinary Authority of Singapore (AVA), the statutory board in charge of the import and sales of red-eared sliders, showed that more than one million juvenile red-eared sliders were imported in 2007, a 40% increase from 2001 (Lye Fong Keng, AVA personnel, pers. comm.). Information such as mortality rate when in transit, mortality rate while at pet shops, purpose of bought terrapins (pets, feed or release) are unknown. A survey of 27 pet shops showed that each juvenile red-eared slider was sold within the price range of S$3 to S$5 (Goh and O'Riordan, 2007) although some are known to be sold for as low as S$2 (pers. obs.).

Medium to large sized red-eared sliders were reported to be on sale at wet markets, presumably for the purpose of release during religious rites (Goh and O'Riordan, 2007). In Singapore, it has been assumed in local newspapers (Sulaiman, 2002), local publications (Lim and Lim, 1992; Ng, 1992; Lim and Chou, 1990; Tinsley, 1983; Tan et al., 2007) and by local authorities (Dr. Leow Su Hua, Head of Animal Welfare Education Branch, AVA. pers. comm.) that the release of unwanted pet red-eared sliders is the major source of feral population in local water bodies. The pet trade has also been the suspected route of entry of red-eared sliders to many countries such as Guam (Mariana Islands), Taiwan, Korea, Japan, Malaysia, Singapore, Thailand, Indonesia, Sri Lanka, New Zealand, Israel, Arabia, Bahrain, South Africa, Brazil, Panama, Bermuda, Italy, Spain, Britain, France, Guadeloupe, Guyana, Martinique, Polynesia, and Reunion, as well as in North America outside its natural range (Newbery, 1984; Bouskila, 1986; Uchida, 1989; Ernst, 1990; McCoid, 1992; Platt and Fontenot, 1992; da Silva and Blasco, 1995; Moll, 1995; Ota, 1995; Luiselli et al., 1997; Servan and Arvy, 1997; Chen and Lue, 1998; Thomas and Hartnell, 2000; Outerbridge, 2008). However, there is currently no quantitative information on how rampant release activity is and the motivations of the people who do so.

The only information that exists on the effect if humans on feral populations of red-eared sliders is a study done by Severinghaus and Chi (1999) on prayer animal release in Taiwan. Their survey found that 29.5% of 1040 households in Taipei had released animals for religious reasons, identifying the profile of those most likely to release animals to be "women with lower education, run their own business and are financially well-off and who believe that animals can survive after being released".

The religious background of those who released did not seem to have an effect on whether or not they released animals.

There currently exists no evidence linking the presence of red-eared sliders in local water bodies to mercy releases or releases by irresponsible pet owners. While there have been efforts by AVA and the National Parks Board to educate the public on responsible pet ownership and potential harm caused by releasing animals, there has been no information on the efficacy of these campaigns on the attitudes of the public.

6.1.2 Objectives

This survey was essential in the provision of baseline information on:

a) Red-eared slider ownership in relation to the ownership of other pets;
b) The extent of release of red-eared sliders by pet owners or otherwise;
c) The extent of feeding of turtles;
d) The current understanding among respondents on issues such as;
    a. The non-native status of red-eared sliders in Singapore;
    b. The laws opposing the release of animals into parks and nature reserves; and
e) The opinions of respondents with regards to release and feeding of pets and in particular, red-eared sliders.

The results of this study would provide quantitative data on the extent of animal release and the feeding of turtles in public ponds in Singapore; and also the motivations and attitudes driving such actions. The understanding of root causes of these actions is imperative in the management of current and future populations of red-eared sliders in Singapore.

6.2 Methodology

Between September and November 2008, 400 households were surveyed using a quota sampling technique (Hayes, 2000) for their past and current pet ownership, history of releasing animals, as well as their opinions and current understanding of feeding and releasing animals in nature areas in Singapore. The survey was administered in the form of a questionnaire and conducted door-to-door.

A pilot study was conducted prior to the actual survey. In August 2008, door-to-door visits were made to approximately 50 HDB flats in Bishan Town to assess the efficacy of the questionnaire and the surveyor. Only 12 of the 50 households responded to the survey and some modifications were made to the questionnaire for better flow and clarity. This pilot study also showed the need to prepare a Chinese-language version of the questionnaire. In October 2008, before surveys of the landed private properties commenced, the questionnaire was distributed into the postbox of each of the 50 households. Attempts to retrieve them after 2 days were unsuccessful as all but two of the households had either lost the survey, or claimed they did not receive it in the first place.

Consequently, a door-to-door survey was chosen to be the method for survey execution. This method is preferred over telephone surveys because of the need to survey differing demographic groups. Different housing types can be more easily ascertained when carrying out surveys door to door rather than over the telephone. Further, inherent issues in door-to-door surveys such as, travel time from one household and high transportation costs incurred, are of little concern in densely-populated Singapore.

6.2.1 Questionnaire

The final questionnaire (Appendix III) was comprised of the following sections:

Preamble – Introduction to the study and how to contact me.

Section 1 – Pet ownership;

Section 2 – Red-eared slider ownership;

Section 3 – History of purchasing red-eared sliders for the purpose of releasing;

Section 4 – History of feeding red-eared sliders/other turtles in public places;

Section 5 – Opinions and current understanding of issues to do with the release and feeding of animals in public places; and

Section 6 – General information on survey respondent.

6.2.2 Survey execution

Four hundred households were randomly selected based on the housing demography of Singapore in 2005 (Ministry of Trade and Industry, 2006). A similar percentage of each type of housing (e.g. public HDB estates and private estates such as landed property) was surveyed with the exception of condominiums (table 6.1). There were only two respondents residing in condominiums as entry was refused by most estates' security. In response to this limitation, the number of semi-detached and terrace houses was increased to compensate for the lack of respondents living in condominiums. Surveys were conducted at the following locations shown in figure 6.1.

a. Anchorvale Drive
b. Ang Mo Kio Avenue 1
c. Ang Mo Kio Avenue 4
d. Bedok Reservoir Road
e. Bedok South Avenue 2
f. Bukit Purmei Road
g. Clementi Avenue 2
h. Clementi Avenue 5
i. Commonwealth Avenue West
j. Commonwealth Close
k. Commonwealth Crescent
l. Mount Sinai
m. Serangoon Avenue 2
n. Tampines Avenue 4
o. Toa Payoh Lorong 5
p. Toa Payoh Lorong 8
q. Thong Soon Road
r. Thomson Hills Drive
s. Yishun Avenue 2
t. Yishun Ring Road

Figure 6.1 Locations of households surveyed for the opinions and current understanding of red-eared slider issues.

Table 6.1 Singaporean housing demography and the number of units (and percentage) of each housing type surveyed in this study

		Actual number[1]	Proportion of total housing (%)	Surveyed number	Proportion surveyed (%)
Public housing	1- and 2- room flats	46,017	4.4	22	5.5
	3-room flats	216,785	20.7	76	19.0
	4-room flats	341,057	32.5	136	34.0
	5-room and executive flats	281,674	26.9	117	29.3
	Others	2,460	0.2	2	0.5
	Other public flats	4,096	0.4	0	0
Private apartment	Condominium and private flats	98,178	9.4	2	0.5
Landed property	Bungalows	6,836	0.7	3	0.8
	Semi-detached bungalows	19,763	1.9	14	3.8
	Terrace houses	30,722	2.9	27	6.8
	Others	1,423	0.1	0	0
	Total	1,049,011	100	400	100

[1]based on the figures in report by the Ministry of Trade and Industry (2006)

Prior to conducting the survey, the seven surveyors involved were briefed on how to conduct the questionnaire. It was important that the opening line included information about the institution that this project is based at, the purpose of this survey (without revealing information such as the subject of the survey being non-native turtles) and also making it known to the respondent that participation was optional. It was also emphasised during the briefing that the questions should not be asked in a manner that hints the “correct” answer to the respondent. The surveyor’s personal stand on the issue cannot be made known to the respondent prior to obtaining the responses. This was especially important for section 5 of the questionnaire which seeks to understand current public opinion.

During the course of each survey, this study preferred that the surveyor fill in the responses whilst interviewing respondents. This ensured that all questions were answered and that the responses were obtained in a legible penmanship. In instances where there was a language barrier (e.g. non-Chinese-speaking surveyor and elderly non-English-speaking respondent) or when respondents preferred to fill the questionnaires on their own, the questionnaire was left with the respondent for a few minutes before being collected.

6.2.3 Data analysis

Data were compiled and statistical analyses were performed using Microsoft Excel. For open questions, responses were grouped based on the overarching sentiment.

6.3 Results

6.3.1 General pet ownership

Of the 400 households surveyed, 201 (50.3%) households are current pet-owners or had previously owned pets. Pets owned included dogs, cats, birds (including chickens), rabbits, guinea pigs, hamsters, rats, mice, chinchillas, fish, turtles, insects and molluscs. Dogs, fish and turtles were the most commonly owned pets (See figure 6.2). Of the 201 households that had pets, 71 had turtles of which all except one were red-eared sliders (i.e. 17.5% owned red-eared sliders). None of the households admitted having snakes or lizards.

Among pet owners, the number of pets of each type owned within one household ranged from one to 700. One respondent was a pet breeder who had reared 800 birds and 4000 fish (these data were excluded when calculating the average number of pets per household). The average number of turtles owned by one household was 2.8 ± SD 2.5, which is the third highest after fish and birds (table 6.2).

Table 6.2 Average number of each type of pet owned by each household

	Dogs	Cats	Rodents and lagomorphs	Birds	Fish	Turtles
Mean ± SD	1.5 ± 0.79	1.9 ± 1.20	2.7 ± 2.44	3.5 ± 4.37	20.2 ± 80.66	2.8 ± 2.6
Minimum	1	1	1	1	1	1
Maximum	4	5	12	20	700	14
Sum	137	53	105	73	1516	199
Count	93	28	39	21	75	71

Of the 94 households that had previously owned pets (not including red-eared sliders), several explanations were given for not owning the pets currently: 60 were due to death, 19 were re-adopted, 5 were lost, 2 were released, 8 were due to other reasons (e.g. given to the SPCA, stolen, confiscated or unknown) (figure 6.3).

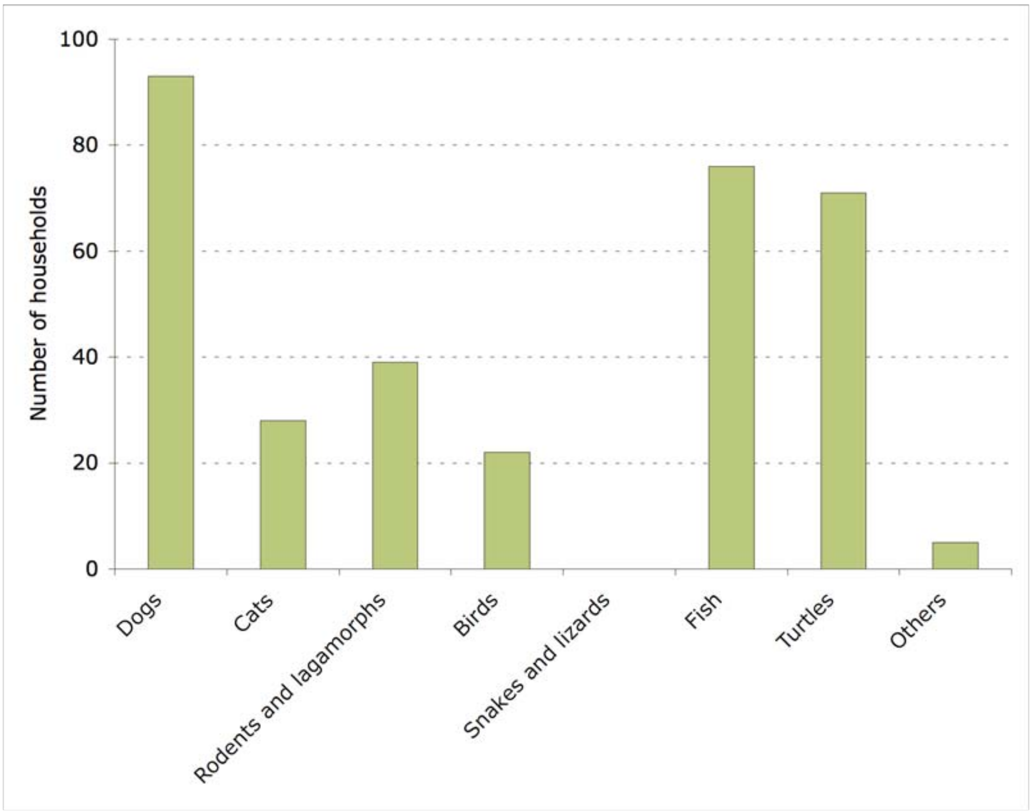


Figure 6.2 The number of households that own/owned the various animals as pets.

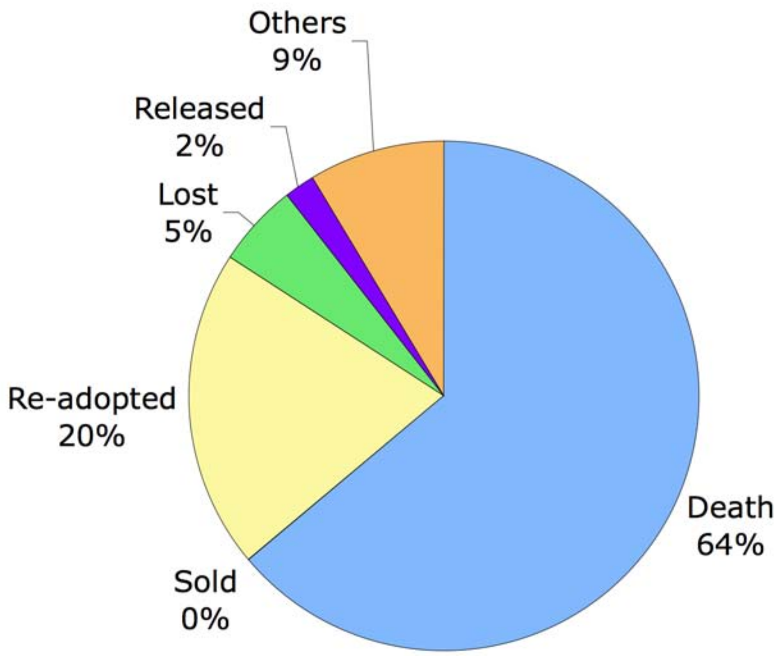


Figure 6.3 Explanations by previous pet owners for not owning pets (not including red-eared sliders) currently.

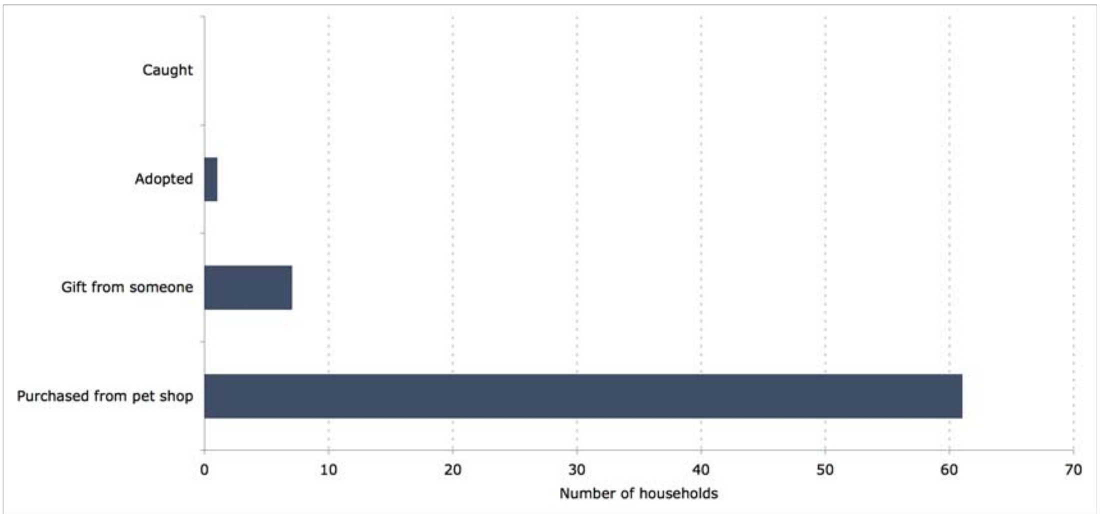
6.3.2 Red-eared slider ownership

Among the 70 households that currently own or have owned red-eared sliders, 61 (88.4%) households purchased theirs from pet shops while seven (10.1%) received theirs as gifts. Only one household had adopted their two red-eared sliders from another owner. No households owned sliders that they had caught themselves (figure 6.4a). Majority of the households (53 households) reared their pet red-eared sliders for a period of three months to five years (figure 6.4b).

Among those who no longer owned their red-eared sliders (64 households), the most common reason was release (44%), followed by death (25%), re-adoption (23%) and lost (5%). Two households had forgotten or were not aware of the fate of their red-eared sliders (figure 6.5). This proportion was significantly different from that of non-red-eared slider owners ($\chi^2 = 48.63$, df = 4, p = 0.05).

Among the 28 households that had released their pet red-eared sliders, park ponds was found to be the most frequent choice of location for release (10 households). Four households released their sliders into reservoirs such as MacRitchie, Bedok and Peirce (not specified whether it was Upper or Lower). Temples were also a popular choice (5 households) for release. One household chose to release their red-eared slider into the sea, and some of the other locations cited included private ponds in schools and restaurants (figure 6.6).

(a)



(b)

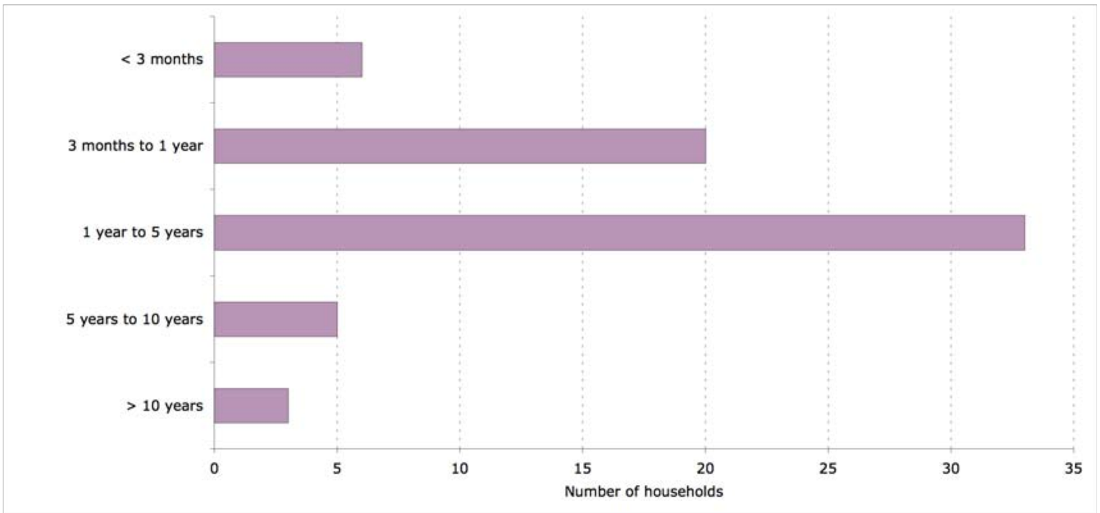


Figure 6.4 Number of households with red-eared sliders with a) their sources and b) length of time kept.

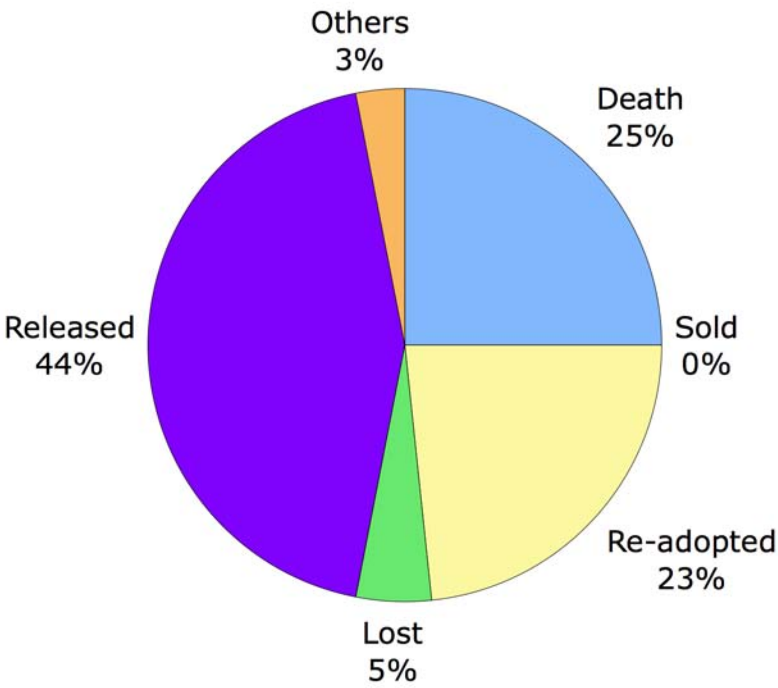


Figure 6.5 Explanations by previous pet owners for fate of pet red-eared sliders.

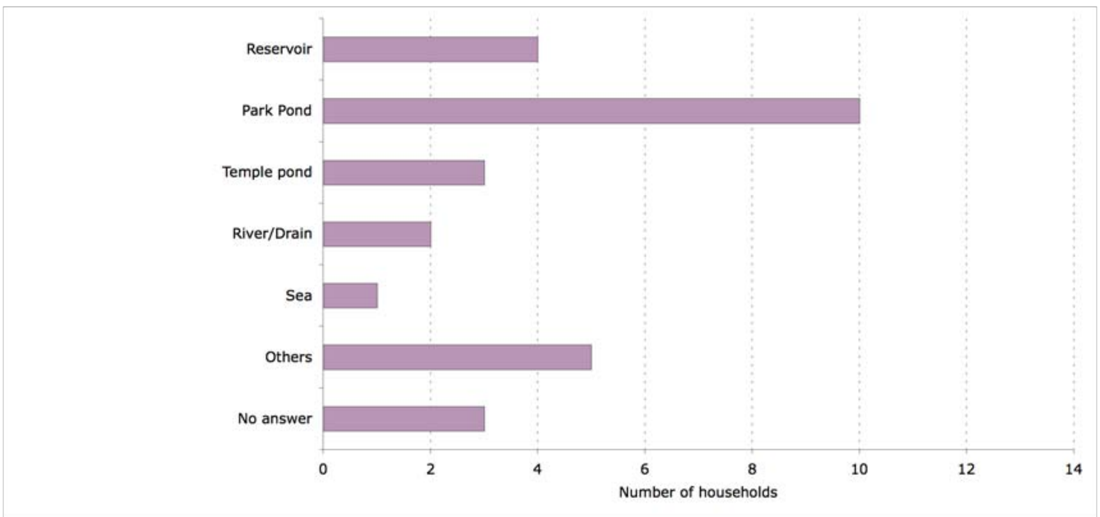


Figure 6.6 Choice of locations for the release of pet red-eared sliders

The most common reason offered for the release of pet red-eared sliders was that the sliders had grown too big for the house (42.9% of 28 households). That the sliders belong in the wild was cited 9 times (32.1%) and that the pet sliders were dirty and smelly was cited 6 times (21.4%). All other reasons were cited at least twice, such as, moving away and being unable to rear the slider in the new home, and that the recipient of these pets did not like their gifts (figure 6.7).

6.3.3 Red-eared slider release by non-pet owners

Of the 400 households surveyed, 16 (4%) had bought red-eared sliders for the purpose of releasing them. Of these, 11 were for religious purposes and three specified that they had done so on Vesak Day. One respondent said “there are too many in the pet shops” (1 household). The remaining four had forgotten or did not want to specify their motivation.

6.3.4 Current understanding of origin of red-eared sliders and legislation against the release of wildlife

Of the 400 households surveyed, four did not respond to whether they had ever released an animal. While it is possible that these respondents may not have understood the meanings of the terms “imported” and “native”, data from the pilot study revealed that these two terms were most widely understood. The definitions of the two words according the Merriam-Webster dictionary are:

Import (verb) : to bring from a foreign or external source; or to bring (as merchandise) into a place or country from another country (2009).

Native (adjective): grown, produced, or originating in a particular place or in the vicinity: or living or growing naturally in a particular region (2009)

The responses of the aforementioned four households were henceforth omitted from further analyses. Data from the remaining 396 households revealed that almost half (46.2%) knew that red-eared sliders were imported while 36.4% either did not know or did not answer the question. 15.4% believed red-eared sliders were native to Singapore while 2% (eight households) thought that the sliders are found both locally and from elsewhere.

Source of red-eared sliders in Singapore

The above responses were then sorted into two groups viz. households with a history of releasing a red-eared slider (a pet or otherwise) and households that did not have a history of releasing red-eared sliders (but may have released other animals). Fifty-eight per cent of the respondents who had released red-eared sliders are aware that red-eared sliders are an imported species, compared to 45% of those who had never released red-eared sliders (figure 6.8). Despite the responses being not significantly different from each other ($\chi^2 = 3.82$, df = 3, p = 0.05), it appears that respondents who had released red-eared sliders are slightly more aware of the origins of this species.

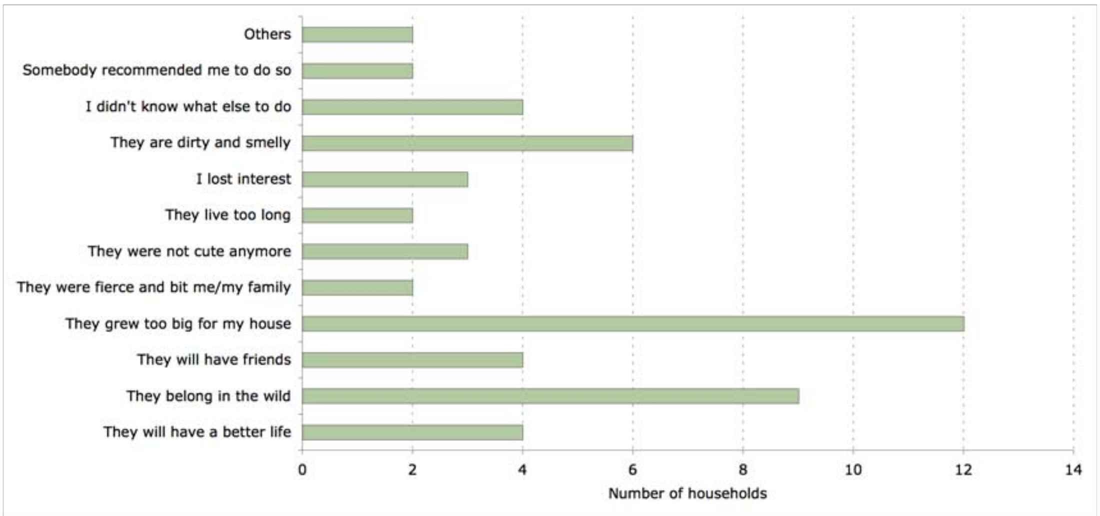


Figure 6.7 Reasons cited for releasing pet red-eared sliders

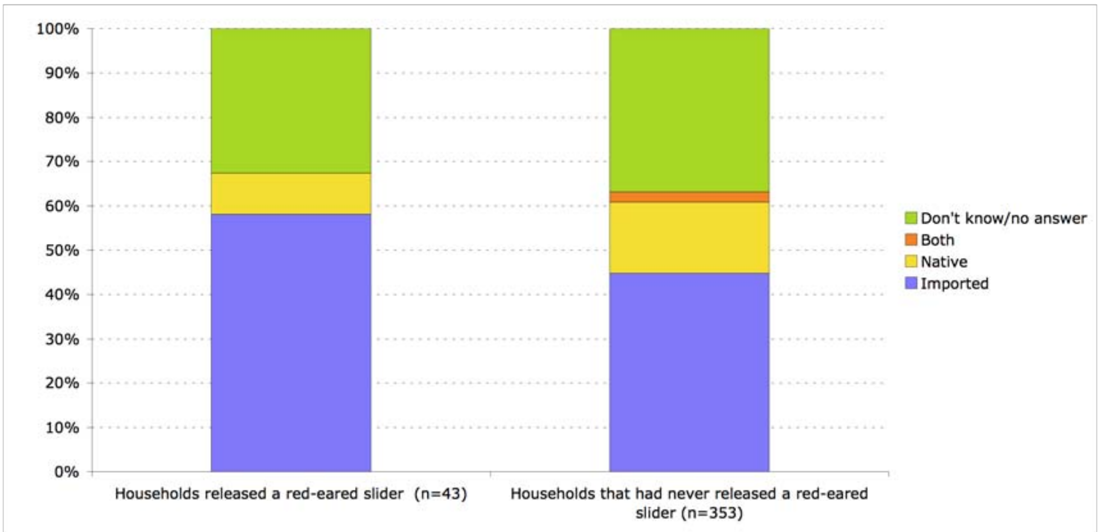


Figure 6.8 The origin of red-eared sliders in Singapore according to 396 households surveyed.

Legality of releasing animals in parks and reservoirs

Data collected on the perception of legality surrounding the release of an animal into parks and reservoirs are presented according to the responses from households that had a history of releasing an animal (regardless of species and whether it was a pet) and responses from households that had no history of releasing an animal.

Of the 396 respondents, 255 (64%) thought releasing animals into parks and reservoirs is illegal. Eighty-four per cent thought it is legal, with similar contribution percentages from respondents who had never released pets (21%) and from those who had (27%). Slightly more (66%) respondents who had never released an animal than those who had (56.3%), refrained from doing so because they knew that releasing animals into parks and reservoirs is illegal (figure 6.9) but the responses from both groups were not significantly different (χ^2 = 2.58, df = 2, p = 0.05).

6.3.5 Perspectives and opinions regarding the release and feeding of turtles in Singapore

Releasing turtles

Of the 400 households surveyed, 132 households (33%) liked or felt there was nothing wrong with releasing turtles, 172 households (43%) felt that it was wrong to do so and 74 households (18.5%) had no opinion or did not give an answer (figure 6.10). Twenty-two households had additional comments in response to the questionnaire (listed in Appendix IV).

The responses were further sorted into three groups – the first group comprised of the responses from households that had never released any animal before (n=349); the responses in second group were from households that had released a pet (red-eared slider or other animals) but had never bought an animal for the purpose of releasing (n=31); and those in the third group were from households that had released an animal that they had bought for that purpose alone (i.e. the animal was not regarded as a pet) (n=16).

A larger percentage of respondents who had bought an animal for the purpose of releasing (18.8%) liked the idea of releasing animals in parks and reservoirs as compared to the group who had previously released a pet (3.2%) (figure 6.11). A more common sentiment among pet releasers was that there was nothing wrong with releasing (45.2%) compared to those who had released an animal that they had bought for that purpose (25.0%). On the other hand, respondents who had never released a pet before most commonly felt that releasing animals into parks and reservoirs was wrong (45.3%) while 31.3% of them felt that they liked, or that there was nothing wrong with releasing animals. Of all the respondents that had previously released an animal (whether bought or was a pet), 27.7% felt that it was wrong. However, a comparison among groups showed that they were not significantly different from each other ($\chi^2 = 13.75$, df = 8, p = 0.05).

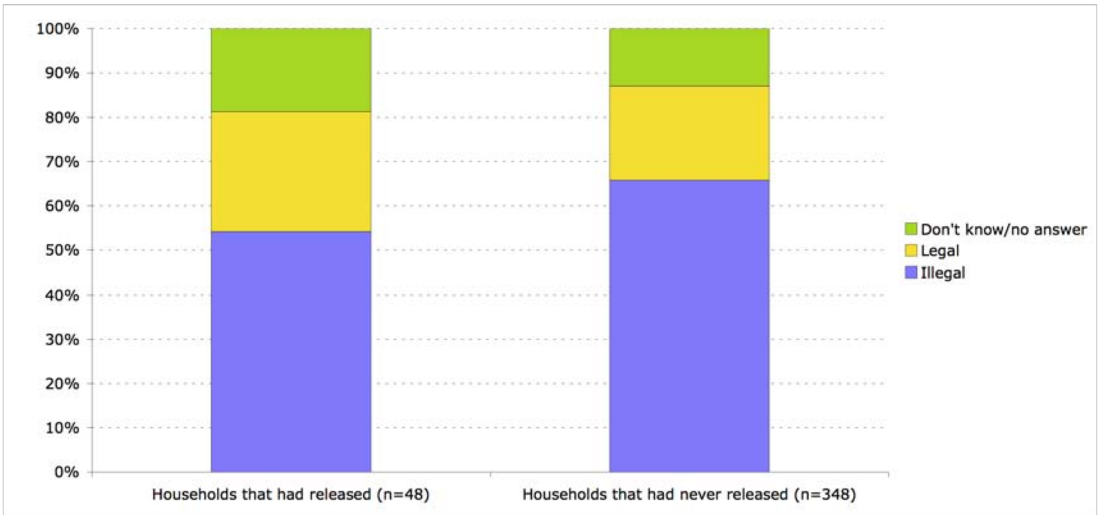


Figure 6.9 The status of legislation regarding the release of wildlife into parks and reservoirs in Singapore according to 396 households surveyed.

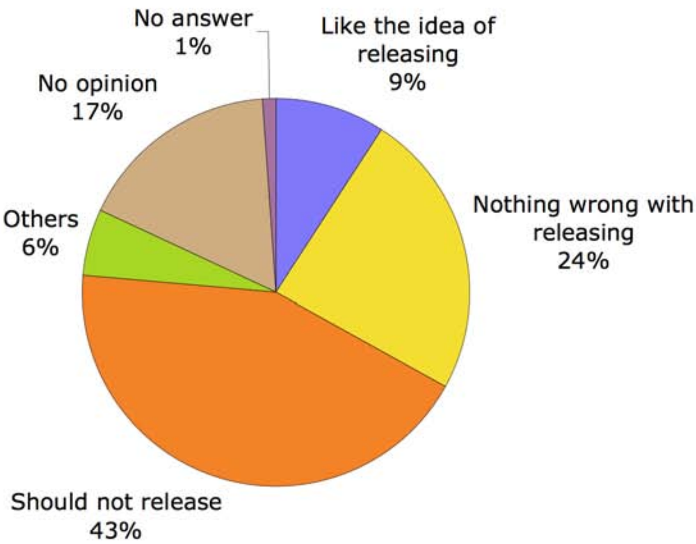


Figure 6.10 Opinions on the feeding of turtles in parks and reservoirs

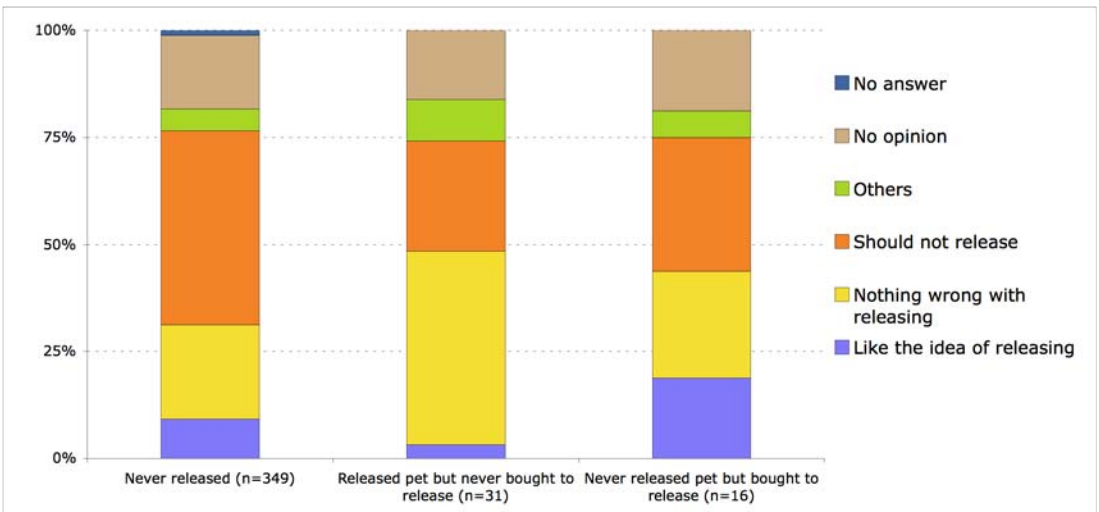


Figure 6.11 Opinions on the release of animals in parks and reservoirs sorted by history of past releases

Feeding turtles

Among the 400 households surveyed, 109 had fed turtles in public areas. Of these, 90% did not do so regularly. The other 10% fed turtles on a weekly, bi-weekly, monthly or bi-monthly basis. Only one respondent fed turtles in public areas on a daily basis (figure 6.12a). Based on this study, ponds in parks were the most frequent location where turtles were fed (54%), followed by private ponds such as those in temples and schools (22%) and reservoirs (16%) (figure 16.12b). Some respondents had fed turtles overseas and these responses were regarded as “not applicable” (n. a.) as these locations fall outside the geographical scope of the present study. Bread was predominant feed choice (60%) followed by vegetables (23%) and commercial turtle/fish feed (12%). Meat (prawns and squid) was fed by two respondents and three cited feeding tit-bits e.g. popcorn (figure 6.12c).

Most respondents (57%) cited “fun” as the main motivation for feeding turtles (figure 6.12d). Some respondents (14%) fed turtles during family outings, or when their childresn wanted to. Thirteen per cent of the respondents did so because they felt pity for the turtles. Other reasons cited included curiosity and the fact that they happened to be in the vicinity of these turtles.

Among all 400 households surveyed, 45% liked or felt that there was nothing wrong with feeding turtles in the parks and reservoirs, while 36% felt that it was wrong to do so (figure 6.13). The other 19% had either no opinion, did not give an answer or had other opinions (compiled in Appendix IV).

(a)

(b)

(c)

(d)

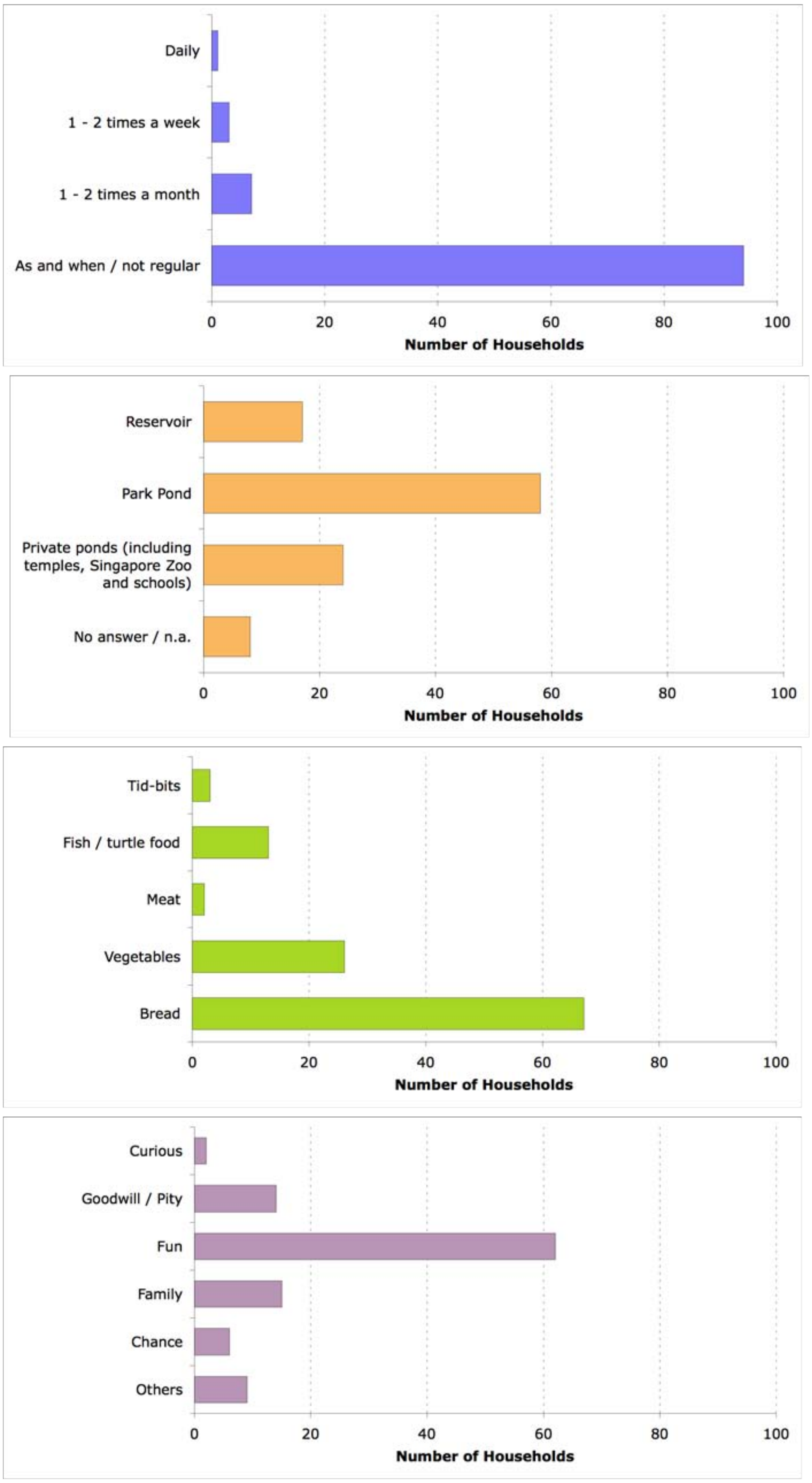


Figure 6.12 Feeding a) frequency, b) location, c) items and d) motivations.

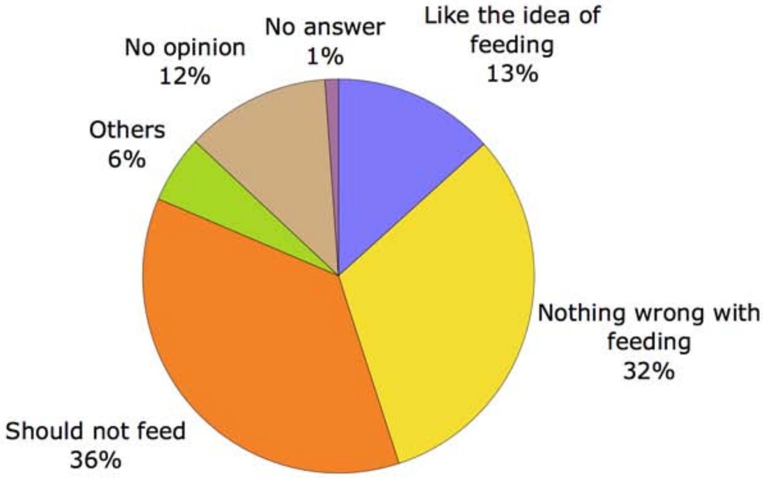


Figure 6.13 Opinions on the feeding of turtles in parks and reservoirs

6.4 Discussion

This is the first study in Singapore to provide an indication of the popularity of red-eared sliders as pets in Singapore in comparison to other common pets such as dogs, cats, fishes, birds, rodents and rabbits. The survey of 400 households provides an insight into the mindsets and actions of a representative sample of Singaporeans.

6.4.1 General pet ownership

Of the households that are or were pet-owners, 35% had or currently own red-eared sliders. The red-eared slider is the third most common pet, and evidently more common than cats, birds, rodents and rabbits. Further, the average number of red-eared slider per household (2.8) is more than those of cats (1.9), dogs (1.5) and rodents and lagomorphs combined (2.7, including hamsters, guinea pigs and rabbits). The popularity of red-eared sliders as pets could be due to both the widespread availability at pet shops and the low cost involved in their maintenance (Goh, 2004). Pet shop owners have been heard dispensing inaccurate information on the care for and lifespan of pet red-eared sliders. These could further perpetuate misconceptions within the community and potential buyers.

It was found that 99% of red-eared slider owners had either purchased or received these animals as gifts. The onus was then on them to find out information on providing the proper care for their pets. Most owners were seemingly unprepared to keep their red-eared slider since only three out of the 70 owners had kept their red-eared slider for more than ten years. The majority of red-eared slider owners (79%) kept their sliders for a period of three months to five years. Most of the sliders from this category (kept for 3 months to five years) had died and some pet owners indicated that had their sliders survived, it was probable that they would have been released.

Releases (44%) and deaths (25%) were the two most common fates of the red-eared sliders, further indicating lack of proper care and emotional attachment to their pets. In contrast, the most common fate of pets other than red-eared sliders was death (64%) and only 2% of respondents released pets other than red-eared sliders. It is evident that pet owners have a different attitude towards red-eared sliders as compared to other pets.

6.4.2 Red-eared slider releases

Forty-four per cent of 64 respondents who had red-eared sliders released the sliders at a variety of locations including reservoirs, ponds in parks and temples, rivers and drains and even the sea. While releases in the sea were not common (one in 28 releases), this choice is here included to highlight the lack of understanding of the habits and needs of their pets. The respondent in question emphasised the inherent merits of releasing red-eared sliders into the sea, which includes the cessation of "dirtying" reservoirs and parks. Some of the incidences of red-eared slider sightings in the sea (Chapter 2, pg 68) could be attributed to pet owners such as these, performing a misdirected act of compassion.

Further evidence of the lack of knowledge on the part of red-eared slider owners can be deduced from their responses to reasons for releasing their pets. Many cited that the sliders grew too large for their house, indicating that they were unprepared or unaware that these animals are capable of growing to large sizes. Respondents have indicated the loss of interest in these sliders as a reason for their release. This may have occurred as the sliders mature, losing the “cute” appeal as well as bright markings and colouration. Some respondents stated the longevity of the sliders as a reason for their release, indicating again the insufficient knowledge of these pets prior to purchase. Some respondents made additional comments such as “Releasing gives the animals freedom” and “The turtles will have friends after they are released” (Appendix IV) demonstrating an incorrect perception of wildlife.

These perceptions might have originated or reinforced by popular animated films such as Madagascar (2005) and Finding Nemo (2003) in recent years. The theme of both films revolved around captive animals in pursuit of their natural habitats. A survey done in the United States of America suggest that despite the general public being knowledgeable about matters regarding irresponsible pet ownership, there is still a great need for emphasis on the topic in the education system (Selby et al., 1979).

More than half (56%) of respondents with a history of releasing a pet were aware that red-eared sliders are an imported species. It is possible that pet shop owners market these turtles as “imported species” since exotic pets appear to be popular in Singapore (Goh and O'Riordan, 2007). However there is no available documentation on how red-eared sliders are being marketed or promoted by pet shop owners. Despite being aware that red-eared sliders are an imported species, 25 respondents still chose to release their sliders. This demonstrates that there may be a lack of understanding of basic ecology and the potential risks in the release of an animal to itself and its introduced habitat. Additional comments made by some of the respondents provided some insights into their idea of biodiversity. These comments included, “Releasing turtles add variety to the reservoir” and “It is good to release animals and cultivate life” (Appendix IV).

Another possible rationale for the release of red-eared sliders despite being aware that they are not native could be that these owners felt that there was no other solution when faced with aforementioned difficulties.

Some conveyed their frustration by commenting (or defended their actions), “What else can I do if I cannot take care of my turtle anymore?”, “Releasing should not be done but people have no choice if the turtles grew too big” and “Releasing an animal is better than killing” (Appendix IV).

Respondents who purchased one or more sliders with the intent of releasing them comprised of a small proportion of the all the households surveyed (4%). Eleven out of 16 did so due to religious reasons, although the religion in question was not requested to be stated. However, a study in Taiwan reported that showed that 63.4% of people who release animals in Taiwan, Republic of China, were either Buddhists or Taoists (Severinghaus and Chi, 1999). Three of the eleven respondents in this present study released red-eared sliders on Vesak Day, a celebration of Buddha’s birthday on the first full moon of the fourth lunar month, celebrated by Buddhists in many Asian countries including Singapore (Fowler, 1997). During the celebrations, captive animals such as fish, birds, turtles and insects are released to symbolise liberation and the gift of freedom to those who are imprisoned (Fowler, 1997; Severinghaus and Chi, 1999). Red-eared sliders in Singapore have been spotted with red paint markings on their carapace (Goh, 2004; Goh and O'Riordan, 2007) which serves as an indication that these were released for religious purposes.

Turtles might also hold special significance because of local folklore such as the legend of the formation of Kusu Island, a small island off the southern coast of Singapore. The folklore (as described on signages on the island) states that a giant turtle turned itself into an island to save two sailors from drowning when their ship sunk. Therefore Kusu Island is also known as Tortoise Island. A Malay shrine and a Chinese temple erected on the island attract thousands of devotees every year. The island also has enclosures for various freshwater turtles (including *Cuora amboinensis* and *Batagur baska*) as well a hawksbill turtle (*Eretmochelys imbricata*) in an enclosed lagoon (pers. obs.).

Respondents who had purchased sliders for the purpose of release favoured the idea of releasing animals more so than those who had bought, kept and later released their pets and those who had never released an animal before. Respondents who had released their pets were of the opinion in that there was nothing wrong with the act of releasing rather than being in favour of releasing their pets. Interestingly, almost 30% of respondents who had released an animal (both as pets or bought for release) felt that releasing should not be done. Of these, only one provided an additional comment suggesting that a sanctuary of sorts should be set up for people to release their pets (Appendix IV, “Call for Management” Point 14). There were more comments stating a similar point (Appendix IV). Slightly over 30% of the respondents who had never released an animal before were in favour or felt that there was nothing wrong with releasing animals into parks and reservoirs. If presented the chance, this group of respondents may release an animal into these public areas.

Releases on Vesak Day

To obtain an indication of the frequency of releases on Vesak Day (2nd June, 2006), counts were made of the number of visitors and incidents of release were noted at five locations in Singapore. This exercise was conducted at Eco-lake and Swan Lake at the Singapore Botanic Gardens, MacRitchie and Lower Peirce Reservoirs and Kent Ridge Park by five observers. On this single day, a total of ten releases were observed, 4 of which involved red-eared sliders (Table 6.3). Despite the short duration and limited localities, the number of releases is a cause for concern. It is not known how many more were released elsewhere and during other times.

Table 6.3 Total number of visitors, incidents of release and animals released at five sites over a period of one day.

	Total no. of Visitors	Total release instances (red-eared slider release instances)	Animals released
Lower Peirce Reservoir	218	1 (0)	4 snakeheads
MacRitchie Reservoir	569	2 (1)	2 red-eared sliders 5 fish
Swan Lake	306	4 (1)	2 red-eared sliders 4 Malayan box terrapins 2 frogs 50 goldfish
Eco-lake	296	3 (2)	1 red-eared slider 1 red-eared slider 20 shrimp
Kent Ridge Park	64	0 (0)	-
Total	1453	10 (4)	-

Phone interviews to Buddhist temples

Phone interviews were made to twelve Buddhist temples randomly chosen from a directory of Buddhist associations in Singapore. Five temples do not the practice release of animals. One had done so in the past but had since stopped the practice in the past five to six years, and four are still releasing captive animals. Two temples of the contacted temples declined to comment.

Article 9(3)a of the Parks and Trees Act (2006) states that "No person shall, except with the approval of the Commissioner granted under section 12 and in accordance with the terms and conditions of such approval bring or release or cause any animal to be brought or released into a nature reserve". Those in violation of this act are liable to conviction to a fine not exceeding $50,000 or to imprisonment for a term not exceeding 6 months or to both and, in the case of a continuing offence, to a further fine of $500 for every day or part thereof during which the offence continues after conviction (Parks and Trees Act, 2006). While majority of the respondents (64%) knew that releasing animals is an offence, it is not clear how many of these are aware of the penalty associated with the violation of this law. The other 36% of the surveyed households were unaware of such a law.

Among households that released their pet red-eared slider, the majority (50%) had chosen to do so in public parks and reservoirs. In other words, 3.5% of the 400 households surveyed had released one or more red-eared sliders into a park or reservoir. Based on the extrapolation of these results, it can be approximated that there had been 36,000 releases among the 1,024,458 households (Ministry of Trade and Industry, 2006) in Singapore.

6.4.3 Feeding of red-eared sliders in parks and reservoirs

A concern frequently cited among respondents that do not condone feeding of turtles in ponds and reservoirs (Appendix IV) was pollution of these water bodies. Words such as "pollute", "contaminate" and "unhygienic" were used to describe the effect of excessive feeding of turtles. Further, this group felt that feeding of turtles is unnecessary as they are able to find their own food. There were also concerns of feeding them the wrong type of food, or that the turtles might become too reliant on humans for food. In general, 36% of the 400 households surveyed felt that feeding should not be done, while 45% liked the idea or felt that there is nothing wrong with it.

About one quarter of the respondents had fed turtles before, the most frequent location being at ponds in parks, followed by private ponds (including those in temples and schools) and reservoirs. Parks (and ponds) are commonly found all around Singapore. Singapore has eight nature reserves and 42 parks (some parks are contained within the nature reserves) (National Parks Board, 2008b), many with freshwater ponds, lakes or reservoirs. The accessibility of these areas to members of the public allows easy access to nature areas but also makes it easier for unwanted pets to be released.

There was a marked increase in visitor-ship to Ecolake at the Singapore Botanic Gardens from 1700 hrs to 2000 hrs (please see Chapter 5). Feeding of the turtles living in the lake is a common event during these hours evidenced by the turtles "following" visitors as they walked on the bridge across the lake (pers. obs.).

Among the respondents who had fed turtles in this survey, the most popular choice of food item was bread, although the type and source are unconfirmed. It was observed that most people used old / stale bread or breadcrumbs, but occasionally some would use new loaves of bread to feed the turtles (pers. obs.). The motivations for feeding the turtles stemmed from it being a "fun" and wholesome family activity (71%), although 13% did so because they felt pity for the turtles.

6.5 Conclusion

This study has been successful in providing quantitative data that supports the previous chapters of this dissertation. Through comments made by the respondents, insights and issues surrounding the current understanding and attitudes of Singaporeans towards pet care and wildlife have come to light. The lack of basic knowledge of pets is evidenced repeatedly in the responses obtained from the questionnaire. A search of the website of the Singapore Society for the Prevention of Cruelty to Animals (SPCA) (2009) found that there were care sheets for a range of popular pets with the exception of turtles, despite the prevalence of these animals as pets in local households. The incidence of shell deformities in red-eared sliders observed in some of the ponds and reservoirs (Chapter 2, page 51) indicates malnutrition or incorrect diet while in captivity, prior to being released. The SPCA of Singapore does not accept red-eared sliders although they sometimes receive abandoned red-eared sliders in tanks at their gates (Chong, P.C., SPCA, pers. comm.). The large difference between the rate of release of pet red-eared sliders (44%) and other pets (2%) suggests that attitudes towards red-eared sliders may be different than attitudes towards other pets. Some respondents realized that releasing was wrong, but felt that they were left with no other choice. Many respondents commented on a need for a designated sanctuary for the release of red-eared sliders.

The lack of enforcement of the Article 9(3)a of the Parks and Trees Act (2006), a law which has been in place since 1997 is evident. It appears that members of the public are either unaware of the law, unaware of the consequences of violating it, or are simply disregarding it. Unfortunately, with many parks and water bodies dotted around the country, it would be extremely challenging for the National Parks Board to monitor and patrol for people releasing their pets.

The knowledge of basic ecology and environmental science introduced to the school syllabus and advertisement drives may change the perception regarding the favourable release of red-eared sliders (and possibly other non-native species of plants and animals). Misconceptions such as the animals having "friends" and "freedom" in the "wild", and "cultivating life" after being released, illustrate the lack of awareness of the potential effects of their release such as competition with native species and alteration of the ecosystem (Chornesky and Randall, 2003). Some respondents did not appear to know the difference between marine and freshwater turtles as evidenced by their comments and sightings of red-eared sliders in the sea (Chapter 2, page 59).

Hygiene appeared to be a main concern of respondents and may deter many Singaporeans from feeding or releasing red-eared sliders into the numerous water bodies in Singapore. Additional comments provided by a respondent alluded to the fact that it is acceptable for sliders to be released into ponds but not reservoirs. This could be tied to the issue of hygiene as water from the reservoir would eventually be consumed, and hence, many people might be more guarded when introducing agents into them. If this is a common sentiment among past and potential red-eared slider releasers, it could explain the lower density of sliders found in MacRitchie and Lower Peirce Reservoirs compared to the two ponds at the Singapore Botanic Gardens (Chapter 2, page 45) found in this study.

Interestingly, none of the respondents seemed aware or mentioned the chances of contracting Salmonellosis from turtles even though freshwater turtles are a known carrier of many *Salmonella* species (Hidalgo-Vila et al., 2007).

This study has been successful in achieving its objectives in establishing baseline data on the history, attitudes and views of red-eared slider issues in Singapore. The issues highlighted above deserve to be further investigated, as they are imperative to curbing the release of animals, and even plants, into various habitats in Singapore. Future more in-depth studies on various aspects of release of non-native organisms with the inclusion of more respondents should be carried out to further understand the psyche and attitudes of the general public.

Chapter 7: Conclusions and general discussion

7.1 Current ecological status of red-eared sliders and other turtles in Singapore

7.1.1 Population demography

Red-eared sliders are abundant at many freshwater bodies in Singapore. At four sites, which were studied in detail, — two reservoirs (MacRitchie and Lower Peirce) and two ponds (Swan Lake and Eco-lake at the Singapore Botanic Gardens), the population sizes of red-eared sliders ranged from 274 – 562 individuals. At the same sites, population densities ranged from 4 – 380 individuals per hectare. Populations were more than 30 times denser at the ponds than at the reservoirs, but do not exceed the densest documented red-eared slider population (see Chapter 2, page 57). Sex ratios at all sites were biased towards females, with females outnumbering males by 3.71 – 8.90 times. This differs from the sex ratio commonly encountered in their native range, which is 1:1. Both male and female turtles have larger carapace lengths at the reservoirs when compared to those at ponds. This may be indicative of older populations at the reservoirs. The total number of red-eared sliders caught and marked in this part of the study was 662, of which 33 were injured and 16 had shell deformities.

The reasons for such large populations of non-native red-eared sliders are unclear and difficult to determine. The large populations however, are most likely the result of the continual release of sliders from the pet trade or/and the successful reproduction of released sliders.

7.1.2 Reproduction cycles

Red-eared sliders in Singapore show a strong potential for successful reproduction. Observations on their behaviour at Eco-lake showed consistent courtship behaviour throughout a 13-month period. Although no actual mating was observed, nests have been found in a number of locations. There is no reason to suggest that the eggs would not have hatched. The present study found that males displayed increased spermatogenic activity during warmer months while females had no distinct patterns of follicular enlargement and ovulation. However, sperm storage is common in sliders and can account for the lack of dependency of male and females reproductive cycles (Pearse and Avise, 2001). There are also indications that sliders in Singapore are capable of spreading out the production of multiple clutches of eggs throughout the year, modifying their typical Pattern I reproductive strategy to produce smaller clutches of eggs at a higher frequency over the duration of the year (Chapter 3, page 92).

7.1.3 Diet composition and frequency

Known to be opportunistic omnivores, red-eared sliders in Singapore were found to eat a variety of food, feeding on available food material such as plants and algae, arthropods, molluscs and crustaceans. Fish scales, fish bones and avian feathers were found in the guts of the sliders but these are likely to be a result of scavenging on dead fish and birds rather than predation. Geophagy material such as glass, plastic and gravel made up 9.5% – 33.5% of gut contents. The persistent presence of gravel in the guts suggests that these items were deliberately consumed. Such behaviour, known as 'geophagy', had been thought to assist in the mechanical grinding of food items to aid in digestion (Skorepa, 1966; Sokol, 1971; Parmenter and Avery, 1990) in other animals, but had not previously been recorded in turtles. Based on the gastric emptying time determined by Chia (2005), the percentage of animals found with empty guts indicated that a proportion of animals had not fed within three and a half days prior to capture. Males were found to have the highest frequency of empty guts, followed by small females. This was corroborated by the behavioural data which showed that females spent more time foraging along the bottom substrate than males. The largest females had the lowest frequency of empty guts. While there were no seasonal trends in diet composition or volume, empty guts were most commonly encountered during periods of lower temperature.

7.1.4 Behaviour

At Eco-lake, the red-eared sliders exhibited typical diurnal activity, emerging at daylight and retreating back to their sleeping places at dusk. No seasonal behavioural patterns were observed throughout the 13-month observational period. These turtles spent most of the late morning to the late afternoon basking (on beams under the bridge at Eco-lake). Other activities such as swimming and/or remaining stationary on the surface, swimming along the lakebed, courtship and feeding were prevalent at other times of the day. Males spent more time in courtship than females. Females spent more time foraging along the bottom of the water only during the evenings. Only females were observed to participate in aggressive behaviour. On a number of occasions, turtles were observed to remain stationary while allowing another non-indigenous species, the South-American sucker-catfish to feed off the algae from their carapace.

There was a positive relationship between the number of people that walked on the bridge above the sampling area, the number of turtles observed in total and the number of turtles swimming slowly on the surface. There was a negative relationship between the number of people and the number of turtles observed basking. The turtles exhibited a learnt behaviour of following people around as they walked on the bridge and increased in numbers very rapidly whenever food (mainly bread) was being thrown into the water from the bridge.

7.1.5 Other species of turtles

During the course of the study, a number of species of freshwater turtles other than *T. scripta* were also observed. These species included the native Malayan box terrapin (*Cuora amboinensis*), black marsh terrapin (*Siebenrockiella crassicollis*), river terrapin (*Batagur baska*), Asiatic softshell turtle (*Amyda cartilaginea*) and Malayan softshell turtle (*Dogania subplana*). The black marsh terrapin was the most common, with 20 individuals found at Lower Peirce Reservoir. Non-native turtles such as Chinese striped necked turtle (*Ocadia sinensis*), American cooter (*Pseudemys* sp.), Pig-nosed river terrapin (*Carettochelys insculpta*) and Chinese softshell turtle (*Pelodiscus sinensis*) were also observed. Species such as pig nosed turtle (*Carettochelys insculpta*) and the Malayan box terrapin (*Cuora amboinensis*) were for sale in pet shops in Singapore (Goh and O'Riordan, 2007) although both are listed in the CITES Appendix II, along with a number of other non-native species.

7.2 The invasive status of red-eared sliders and other turtles

The red-eared sliders fulfill many criteria that characterise successful invaders. They have a generalised ecology and adapt well to almost any habitat. Red-eared sliders have overcome many of the obstacles to naturalisation and successful establishment in a non-native environment (figure 7.1). They were transported to Singapore for the pet trade and thereby, ensuring high survivability during this time.

The initial establishment of populations within Singapore was probably ensured by the regular release of red-eared sliders (Chapter 6, pages 177 and 180). Based on interviews of pet owners in Singapore, the release of animals is perceived by many as acceptable for both pets and the environment. Red-eared sliders, by modifying their reproduction cycle, diet and behaviour, have established local populations in their adopted habitats. Discussions with park managers in Singapore also revealed that the red-eared sliders have altered the habitats in ponds for example, defecation / excretion from the sliders coupled with poor pond drainage systems have made some ponds aesthetically unpleasant and leads to increased expenditure for maintenance.

One of the concerns of non-native introductions is the impact on local species due to interactions and competition. In Singapore, there are no direct evidences suggesting potential competition between red-eared sliders and native Malayan box terrapins or black marsh terrapins. However, this cannot be discounted. Red-eared sliders approach, bite and consume food faster than the two native species (Chia, 2005; Bels et al., 2008), suggesting competition for food and space resources. This is therefore, an area definitely warranting further research in Singapore.

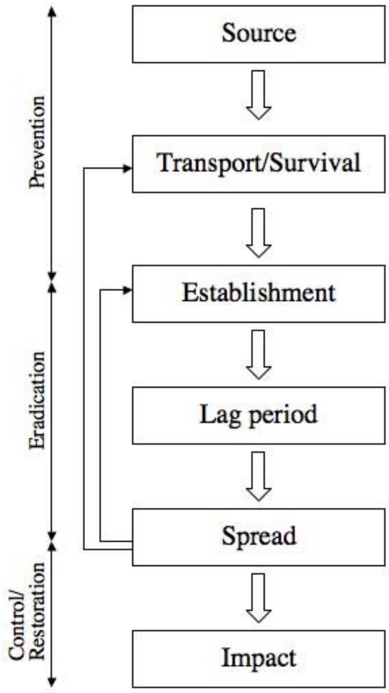


Figure 7.1 Flowchart of the generalised steps in invasions as well as the general management actions that can be taken based on Lodge (1993) and Sakai et al. (2001).

While there are currently no direct evidences on the negative impacts of red-eared sliders to the natural environments in Singapore, the potential for impact is great due to the high numbers imported yearly. There is an urgent need to manage present impacts of introduced sliders and prevent further introductions. Based on the current information gathered on this species, as well as literature on the management of invasive freshwater species, recommendations can be made towards impeding the possible effects of the invasion of red-eared sliders. It should be noted that these non-indigenous sliders are now the best-studied population in Asia and findings from this study will be of interest throughout the region.

Chapter 8: Recommendations for management

Management interventions for invasive species can take place at different stages of the invasion process (Chapter 7, figure 7.1). At the source level, reducing the supply of the invasive species might be one way of mitigating the continued introduction into the environment. The next level that intervention can take place is at the level of introduction, before the establishment of the species.

Identification of the pathway in which the red-eared sliders take from being imported to establishment in local bodies would indicate the various areas that can be controlled. Since red-eared sliders are not indigenous to Singapore it can be inferred that their route of entry into local water systems is via the pet trade (Ng, 1992; Rajathurai and Teo, 1997; Rajathurai and Teo, 1998; Lim and Lim, 2002). This is especially likely since large numbers of juveniles are imported into Singapore yearly (Lye Fong Keng, AVA, pers. comm.). Furthermore, a survey of 400 households in Singapore found that 28 had released one or more pet red-eared sliders (Chapter 6, page 177).

Red-eared sliders also enter local waterways by another pathway – the release by members of the public as an act of goodwill (for religious reasons or otherwise). Goh (2004) and Goh and O'Riordan (2007) reported the incidence of red-eared sliders with the Chinese word 生 (sheng) painted on the carapace. The word 生 indicates life or "release from captivity", thus indicating that the animal was a release. While these releases are usually in the form of juveniles purchased from pet shops, some medium to large red-eared sliders have been seen on sale in market stalls in Singapore, probably for this purpose (Goh and O'Riordan, 2007). Personal observation during the course of this study is that some of these turtles for sale were poached from parks and reservoirs locally. The release of red-eared sliders as an act of goodwill was further confirmed by 16 respondents to the survey (please see Chapter 6) and personal observations on Vesak Day, although it was not clear where they had purchased the animals.

Establishment of the red-eared sliders locally can be confirmed by their large numbers (Chapter 2) and completion of the reproductive cycles (Chapter 3). Intervention at this stage will be in the form of population control and management and possibly eradication. Figure 8.1 summarises the pathways for introduction and establishment of red-eared sliders in Singapore.

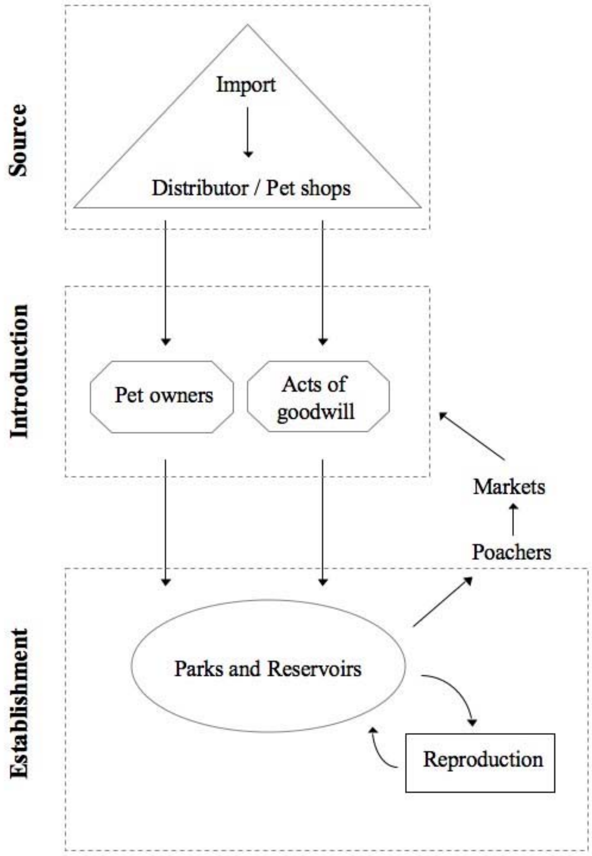


Figure 8.1 Introduction and establishment pathways of red-eared sliders in Singapore.

8.1 Intervention at the source stage

Recommendation 1: Impose a minimum size restriction on imports and introduce a regulation that requires red-eared sliders to be microchipped. All costs should be borne by the customer by advising pet shops to increase the price of red-eared sliders.

In the United States, the US Food and Drug Administration banned the domestic sale of turtles less than four inches (about 10 cm) in 1975 because children were putting small turtles into their mouths and it was estimated to cause 300,000 cases of salmonellosis each year (Williams, 1999). While cases of salmonellosis have not yet been attributed to reptiles in Singapore, allowing only red-eared sliders above the size of 10 cm carapace length to be imported and sold can potentially decrease the level of demand of this species as pets as they may not be perceived to be as cute as juveniles (Tangley, 1984).

The microchipping of dogs and dragonfish (arowanas) are already mandatory in Singapore. Extending this requirement to red-eared sliders by the AVA is another way in which impulsive purchases of red-eared sliders can be deterred. Microchips or passive integrated transponder devices (PIT tags) can be small and are based on RFID (radio frequency identification) technology. They can be implanted under the skin of an animal relatively painlessly and can be easily identified using an RFID reader. Originally required for the identification of lost pets and the spread of disease, microchipping can also be used to identify the owner of a pet that has been intentionally released. This would be especially useful in deterring pet owners from releasing their pets, knowing that they can easily be identified.

Microchipping red-eared sliders will however come at a cost. It costs between S$25 and $80 to microchip a dog in Singapore, which is normally borne by the owner. As it may be an uphill task convincing red-eared slider owners to microchip their pet at such a cost, the responsibility of microchipping these animals should fall upon the pet shop owners licensed to sell them. This makes it easier to ensure that all red-eared sliders have been microchipped and a possible side effect is that pet shops will be committed to providing better welfare for this species. The pet shops can be advised to increase the prices of red-eared sliders to compensate for their trouble and costs. Hatchling red-eared sliders are currently sold for S$3 – S$5 (Goh and O'Riordan,

2007) which is inexpensive compared to most other pets. Increasing and controlling the prices of red-eared sliders are also effective in preventing impulse buys.

The recommendations mentioned above are not as convenient as imposing a ban on the import of all red-eared sliders in an effort to eliminate the availability of this species. However, bans on imports require direct evidence of impact caused by red-eared sliders (of which there is currently none). However, a direct ban of a species may not be effective in overall management as the demand for an “illegal” pet may lead to smuggling of this species into Singapore, as observed by Goh and O’Riordan (2007) in their survey of illegal animals for sale in pet shops.

Recommendation 2: Stricter enforcement of regulation that pet shops licensed to sell red-eared sliders are required to display and disseminate accurate information regarding this species.

Currently, the import and sale of Malayan box terrapins requires that relevant documentation such as the CITES permit number and a detailed invoice and letter of purchase or transfer for each animal purchased. The retailer is also required to provide educational material to the customer to ensure proper care and maintenance of the animals (Import & Export Division Agri-food & Veterinary Authority, 2009). In contrast, there is no such requirement for the sale of red-eared sliders, although pet shops are advised to do so (Dr Leow Su Hua, Head of Animal Welfare Education Branch, AVA. pers. comm.). Stricter enforcement and harsher penalties for pet shops that fail to do so would be useful in ensuring that accurate information is passed on to new pet owners.

The provision of accurate information such as lifespan, size at maturity, housing and nutritional requirements are essential in allowing interested buyers to make an informed decision when choosing a pet. The most common reason cited for the release of pet red-eared sliders was that the sliders had grown too big (Chapter 6, page 180). This is an indication that owners may not be prepared for the growth of their pet.

8.2 Intervention at the introduction stage

Recommendation 3: Greater emphasis needs to be placed on creating public awareness of the consequence of releasing animals and responsible pet ownership.

The need for public education and creating awareness is a key step in mitigating the release of animals into parks and reservoirs. A survey of 400 households in Singapore showed that of these, one third either favoured the idea of releasing animals or felt that there was nothing wrong with it. The survey also indicated misconceptions about the welfare of released animals as well as the environment. The Centre for Animal Welfare and Control, AVA (2008) has spearheaded a recent campaign promoting responsible pet ownership by conducting roadshows, talks and publishing education materials among other efforts. Issues addressed are mainly the welfare of these animals after abandonment, and the responsibilities of owning a pet.

These topics as well as environmental issues can be covered on a greater scale, especially to young children, who are especially prone to wanting to own pets. Instilling values in children at the Primary school level has long term and potentially far-reaching effects as children often have an effect on their parents (Mol and Buysse, 2008). Below are some proposals on how this can be achieved.

a) **Provide teachers with materials and teaching tools** to use pet ownership as an example of how to be socially responsible and how to care for animals. Social responsibility is already part of the Lower Primary Civics and Moral Education (CME) syllabus (Ministry of Education, 2006) and the current example being used in the syllabus focuses on how to be socially responsible in school such as practicing good hygiene in school and taking care of school property. The topic of social responsibility can also include taking care of public property outside of school (e.g. parks and reservoirs) where vandalism, littering and releasing animals are undesirable behaviours. Caring for animals is also already part of the CME syllabus. The current examples on how students can care for animals include "not ill treating them" and "rendering help when necessary e.g. by calling relevant authorities like SPCA when I witness animal abuse". Students can be taught animal welfare topics such as giving pets suitable living conditions and nutrition and giving consideration to whether they can commit to owning a pet for its entire life before buying one. Red-eared sliders can be used as an example for these topics.

b) **Include ecology as part of the Upper Primary syllabus** for both CME and Science. The current Upper Primary CME syllabus includes a section on protecting the environment but topics discussed mainly revolve around recycling and saving electricity and water. Ecological concerns such as invasive species could be introduced to students at this stage. The subject of invasive animals and plants can also be incorporated into the Upper Primary Science syllabus under the topic of "Interactions with the Environment" (Ministry of Education, 2007b) where unfavourable habitats and organisms can be discussed.

c) **Instill a sense of pride for Singapore's natural heritage in the youth** by including the rich local flora and fauna (among the many other things that Singaporeans can be proud of) in the Lower Primary CME syllabus in the topic "Respect: Loving Singapore" (Ministry of Education, 2006). Local organisms can also be featured in co-curricular activities such as partnerships with the Singapore Science Centre's Young Scientist badge programme (e.g. introduce a Young Nature Ambassador badge), Community Involvement Projects as part of the National Education (Ministry of Education, 2007a) (e.g. projects centering around caring and creating awareness of local nature) and school clubs and societies such as Interact Club and Green club can focus on protecting local nature as an environmental issue.

d) **Include web presence in addition to organizing roadshows, exhibitions and school talks** emphasising the need for responsible pet ownership. The AVA has been conducting talks and roadshows as part of their responsible pet ownership campaign. The internet can be a valuable tool for creating awareness among children as the internet is one of the top three favourite activities of children aged 9 – 12 in Singapore (Majid and Tan, 2007). Although AVA provides some tips about pet care and responsible ownership on their website (Centre for Animal Welfare and Control Agri-food & Veterinary Authority, 2008), the information is rather brief. A portal with a separate domain can be created to not only provide information for new and potential pet owners, but also to facilitate discussion (such as a public forum) and provide resources such as reading material and useful information like contact numbers of veterinary clinics in Singapore. Pet care enthusiasts (found on local forums such as www.pets.com.sg, www.petschannel.com, www.sgclub.com and www.sgforums.com) and local animal welfare groups (e.g. SPCA, Animal Concerns Research and Education Society (ACRES), Cat Welfare Society

(CWS) and the House Rabbit Society of Singapore (HRSS) etc.) can be sought to be involved.

e) **Vigilance and the establishment of a standard operating procedure** in response to animals featured in mass media. Several instances have occurred where by the mass media has influenced the procurement of a particular animal as a pet [e.g. red-eared sliders in response to the cartoon series “Teenage Mutant Ninja Turtles” (Harrison, 2003) and increased anemone fish sales after the animated film “Finding Nemo” was screened (Teh, 2003)] or attitudes and behaviours towards pets [e.g. children flushing fish down the toilet in an effort to free them in response to “Finding Nemo” (The Argus, 2003)]. The SPCA voiced concerns over potential impulse buying of pets in response to movies such as “Beverly Hills Chihuahua” (Tan, 2008). The SPCA also worked with local cinemas to appeal to the public not to buy pets on impulse during the screening of “Bolt”, which featured an American white shepherd dog (Tan, 2008). Stakeholders such as AVA, the SPCA and the Media Development Authority (MDA) should work together to establish a standard operating procedure to monitor and respond to changes in the demand of the relevant animals.

Recommendation 4: Increase in legislative awareness and enforcement.

Red-eared sliders have been released into parks and reservoirs in Singapore by pet owners despite the knowledge that doing so is against the law (Chapter 6, page 183). Under the Parks and Trees Act (2006), violators face a fine of up to $50,000 or imprisonment of up to 6 months, or both. It appears that the blatant disregard for the law could be due to the lack of awareness of the severity of the penalty, or they may find it unlikely that they will be caught in the act. Potential offenders can be reminded or informed of the penalties faced if caught releasing by including the punishment on signs at parks and reservoirs (figure 8.2). Authorities such as AVA and the National Parks Board (NParks) are authorized to prosecute offenders if they have evidence. However in most cases, providing evidence is almost impossible (Dr Leow Su Hua, Head of Animal Welfare Education Branch, AVA. pers. com.). Furthermore, enforcement of this law would require constant and regular patrolling of parks and reservoirs, which may not even be effective in catching offenders since it is unlikely that anyone would release an animal in the presence of an officer. Microchipping (mentioned in recommendation 1) would eliminate the need for such manpower intensive operations as the previous owner can easily be identified by the microchip found in the released animals.

Figure 8.2 Sign in East Coast Park advising the public not to feed or release animals, but not including the penalty if caught.

Recommendation 5: Create awareness of alternatives to releasing unwanted pets.

It has to be taken into account that there may be red-eared slider owners who regret their decision to buy one in the first place. The welfare of the pets owned by these people is at risk because of the lack of interest in these situations coupled with the lack of a solution to the perceived problem. Temples have been cited as suitable "sanctuaries" and some Singaporeans have suggested that turtle sanctuaries should be set up as a collection point for these unwanted pets (Appendix IV). Although animal sanctuaries may seem like an ideal solution for unwanted animals to live out the rest of their lives, sanctuaries may present a plethora of problems. Some of the major concerns associated with sanctuaries include the lack of financial sustainability and animal welfare problems such as overcrowding. There is also a fear that sanctuaries might turn into a dumping ground. Pet owners may deem abandoning their pet as "acceptable" because it will be taken care of. Pet owners need to be made responsible for their actions. Should they have a pet and find themselves unable or unwilling to keep it, they should be educated on the available alternatives such as re-adoption via societies such as the SPCA, newspapers and Internet forums. If really unable to do so then they should be informed that euthanasia by a trained vet is the next best option instead of releasing. The procedure is available at about half of the 31 veterinary clinics in Singapore, 11 of which do not require consultation with the vet. The procedure costs between S$10 and S$80 depending on the weight of the animal (Appendix V). All this information can be made accessible to pet owners via the portal as discussed in recommendation 3d.

Recommendation 6: Suggest viable alternatives and guidelines for mercy releases.

Because the motivation for mercy releases is mainly religious, sensitivity has to be exercised when handling this issue. The need to preserve religious customs must also be appreciated. The premise for releasing animals is to perform a good deed in freeing an animal from captivity (Goh and O'Riordan, 2007). In order to tackle this problem, religious groups that are likely to release animals need to be educated on the potential harm to the environment and the released species that their actions might cause. The AVA currently conducts talks at temples and Buddhists associations in order to dissuade them from releasing animals such as birds, fish and turtles but this is not done on a regular basis (Dr. Leow Su Hua, Head of Animal Welfare Education Branch, AVA. pers. comm). An informal call made to ten Buddhist temples and associations in Singapore found four that currently continue to release animals but none claim they organise such activities. Golden Pagoda Buddhist Temple claims to have stopped releasing animals for more than five years and has since replaced releases with chanting more scriptures for merit. The flexibility shown by this particular group suggests that religious groups are open to new suggestions. Because the main intention is to do a good deed, it is likely that religious groups will also be compliant if guidelines are set up for the release of animals.

Suggestions for guidelines include a) requiring a license from AVA or NParks for each release event, including details such as the location, time, date and number of people involved; and b) creating a list of *native* fish with short life spans such as the Spanner barb (*Puntius lateristriga*), Avicennia fat-nose goby (*Pseudogobius* *avicennia*), Pygmy goby (*Pandaka pygmaea*) and Mangrove bumblebee goby (*Brachygobius kabiliensis*) that are acceptable for release.

8.3 Interventions after establishment and plans for the future

Recommendation 7: Control of established populations by culling.

Management of established populations already present in our parks and reservoirs is essential because the long lifespan and successful reproduction of red-eared sliders will continue to maintain, if not proliferate even if new introductions are curbed. Humane euthanasia can be carried out by injection of barbiturates combined with sedatives (Gartrell and Kirk, 2005). Selective culling can be targeted at large females as these are the individuals likely to be carrying the largest and most frequent clutches of eggs. They are also found to consume the greatest proportion of resources compared to the other demographic groups of red-eared sliders, and presumably generating the largest amount of excrement. The large female red-eared sliders have therefore the highest potential to alter the habitat and should be first in line for eradication. Hopefully with proper management of new introductions, culling would not be a long-term solution.

Recommendation 8: Further funded research is required to be able to better identify key areas of concern.

This dissertation has identified some areas of research that should be addressed in order to refine and develop new management strategies for red-eared sliders and pet abandonment.

1. The survey of public opinion on pets revealed that pet owners may have different attitudes towards their pet red-eared sliders and other pets. Motivations for purchasing a red-eared slider to keep as a pet in the first place are yet unknown although the pet owners lack of awareness and short attention span seem to indicate that these pets were bought on impulse. It would be useful to find out motivations for both purchase as well as release (as opposed to options such as re-adoption and euthanasia).

2. The sale of juvenile red-eared sliders smaller than 4 inches (10 cm) has been banned in America due to reports of children contracting salmonellosis after putting their pets into their mouths (Williams, 1999). *Salmonella* is commonly found in reptiles not exhibiting any symptoms and the aquatic medium is known to be a favourable environment for the transmission of this bacterial pathogen (Baudart et al., 2000). Furthermore, *Salmonella* has been found in Lousisiana turtle farms (Kaufmann et al., 1972; Gaertner et al., 2008) and also on turtles in Singapore (Toh et al., 1996), although not quantitatively studies. It is of national interest to investigate the incidence of *Salmonella* in red-eared sliders upon import, while in captivity as pets as well as in feral populations of this species. Such a study would provide insight to the possibility of zoonosis of *Salmonella* and possibly other diseases.

3. This dissertation documented the feeding of red-eared sliders in ponds and reservoirs. Non-quantitative data indicated that the sliders anticipated the feeding session and gathered in greater numbers around the same time daily. Such a study will be of interest to behavioural ecologists and well as urban management authorities. Further study on their behaviour, reproduction and diet (including potential geophagy) at other water bodies in Singapore would be of interest, as would an updated survey of native and non-native species of turtles in forest streams and other natural water bodies.

Recommendation 9: Cooperation of stakeholders is paramount for successful management of the red-eared slider populations in Singapore

The pathway leading to established populations of red-eared sliders in Singapore has been identified in this study and the previous eight recommendations provided ways in which populations of red-eared sliders can be managed in Singapore at various stages along that pathway. Different agencies and parties of interest have been identified and it is clear that management requires a coordinated effort from all of these agencies. The AVA is distinguishable from the other agencies as being involved in most of the major steps in the pathway, such as governing the import and sale of pets, making efforts to curb pet abandonment in Singapore, and animal welfare issues. Members of the public also regard AVA as the authority in pet-related issues. The AVA can play a major role in bringing together all stakeholders to tackle the issue in a systematic and synergistic manner. Table 8.1 provides a summary of recommendations and the stakeholders identified

Table 8.1 Summary of recommendations identifying target effects and stakeholders involved. (AVA: Agri-food and veterinary authority, MEWR: Ministry of Environment and Water Resources, MOE: Ministry of Education, NParks: National Parks Board, NLB: National Library Board, MDA: Media Development Authority, NUS: National University of Singapore, NTU: Nanyang Technological University).

Primary effect	Secondary effect	Stakeholders involved
1. Impose a minimum size restriction on imports and introduce a regulation that requires red-eared sliders to be microchipped. All costs should be borne by the customer by advising pet shops to increase the price of red-eared sliders.		
Source Reduce impulse buys	Introduction Microchips can be used to identify previous pet owners	AVA
2. Stricter enforcement of regulation that pet shops licensed to sell red-eared sliders are required to display and disseminate accurate information regarding this species.		
Source Reduce impulse buys	Introduction Greater commitment when an informed decision was made	AVA
3. Greater emphasis needs to placed on creating public awareness of the consequence of releasing animals and responsible pet ownership.		
Introduction Owners less likely to release pets		MEWR MOE AVA Science Centre NParks NLB MDA Interest groups and individuals
4. Increase in legislative awareness and enforcement.		
Introduction Owners less likely to release pets		AVA NParks
5. Create awareness of alternatives to releasing unwanted pets.		
Introduction Owners less likely to release pets		AVA NParks Interest groups and individuals
6. Suggest viable alternatives and guidelines for mercy releases.		
Introduction Other non-disruptive organisms released instead of red-eared sliders		AVA Religious groups and leaders
7. Control of established populations by culling.		
Established population Control and mitigation		NParks
8. Further research is required to be able to better identify key areas of concern.		
All		AVA NParks NUS / NTU MOE
9. Cooperation of stakeholders is paramount for successful management of the red-eared slider populations in Singapore.		
All		All

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Appendix I: Red-eared slider participation in four main activities

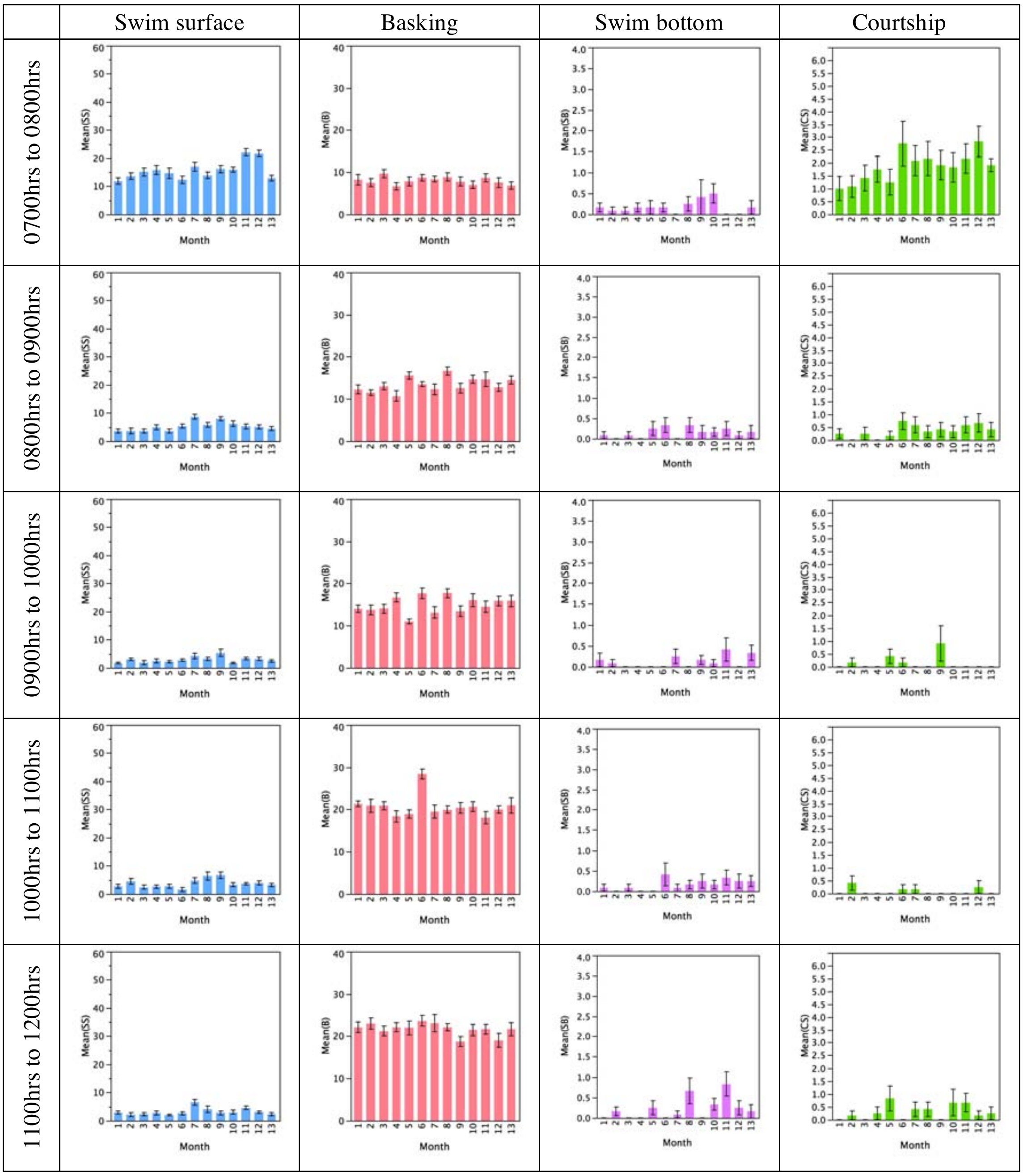

Figure 1. The mean number of red-eared sliders participating in the four main activities among months for each hour (0700hrs to 1200hrs).

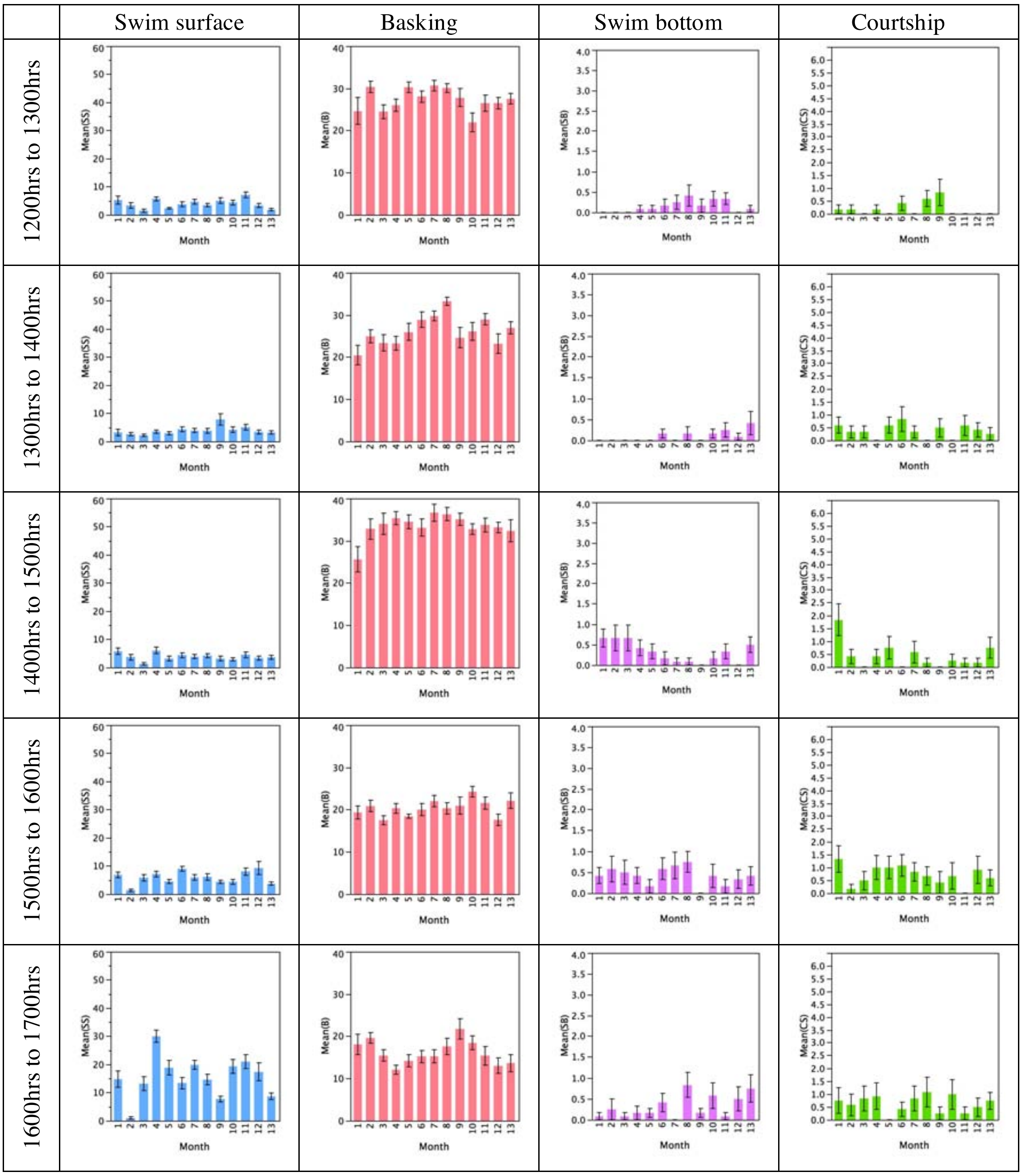

Figure 1 (continued). The mean number of red-eared sliders participating in the four main activities among months for each hour (1200hrs to 1700hrs).

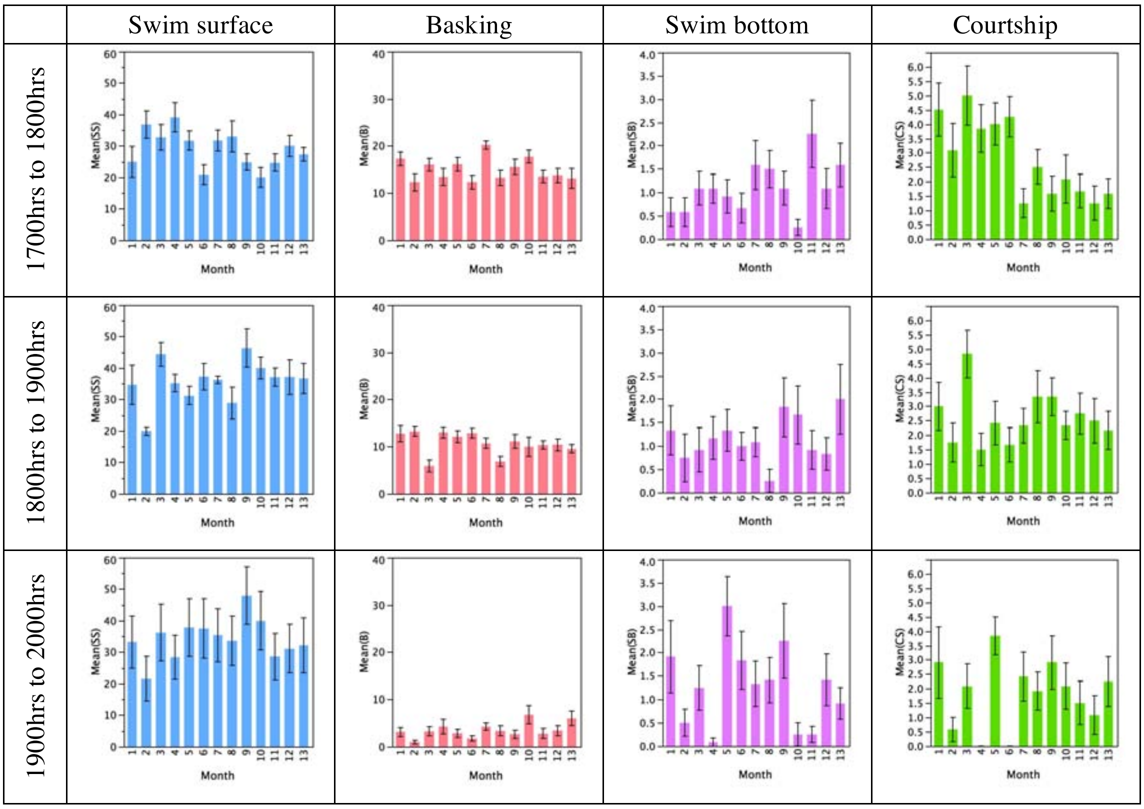

Figure 1 (continued). The mean number of red-eared sliders participating in the four main activities among months for each hour (1700hrs to 2000hrs).

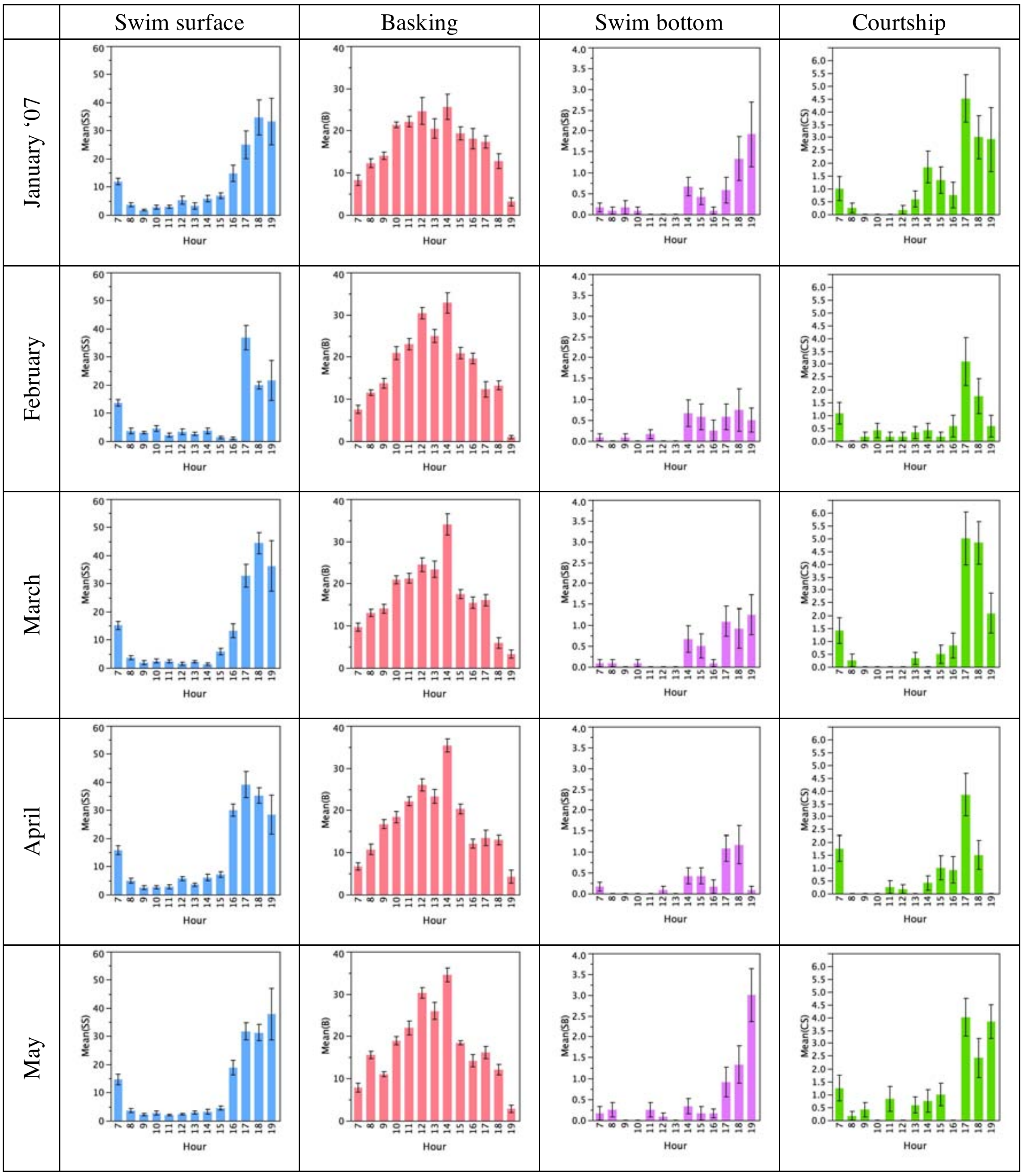

Figure 2. The mean number of red-eared sliders participating in the four main activities among hours for each month (January 2007 to May 2007).

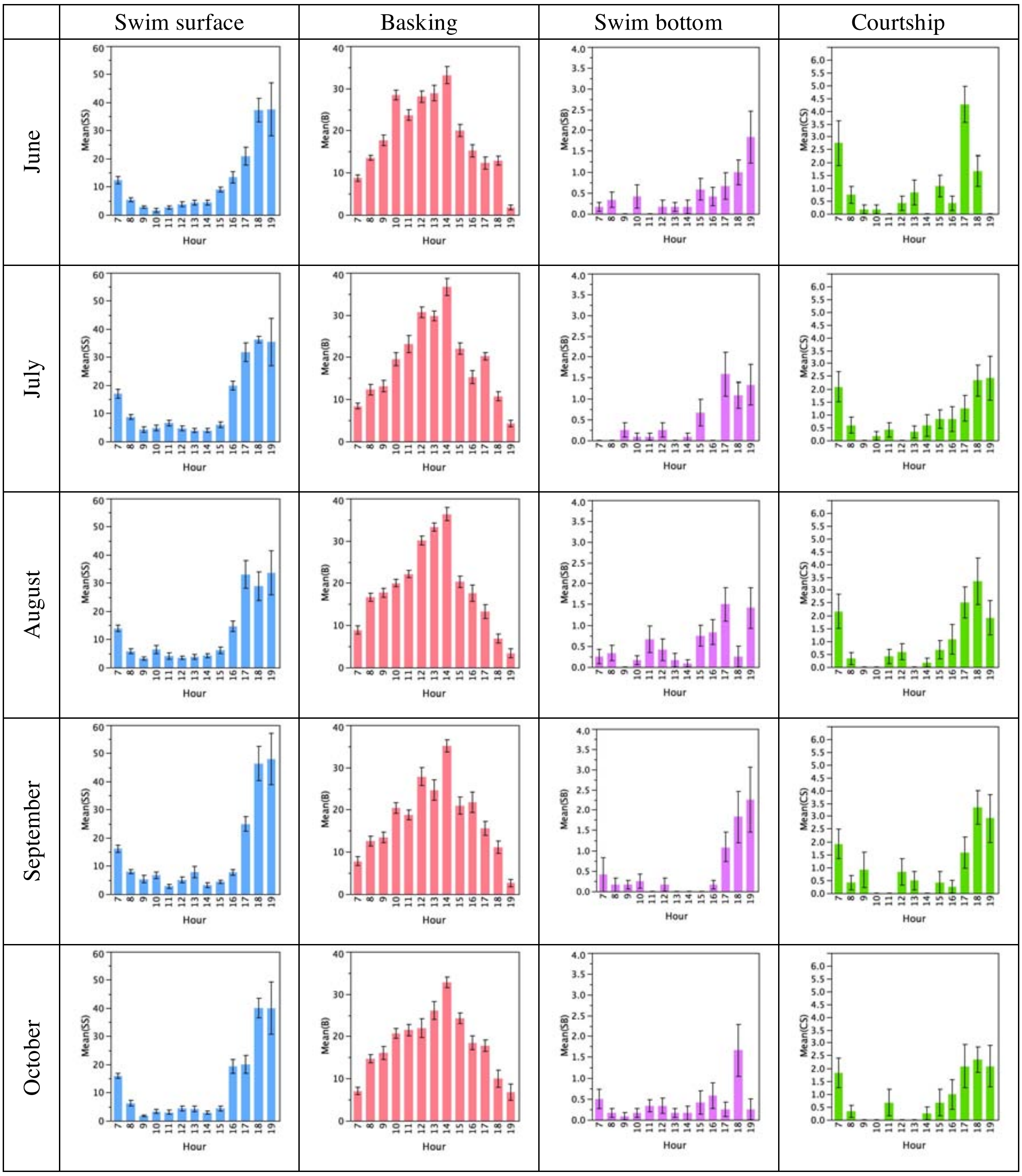

Figure 2 (continued). The mean number of red-eared sliders participating in the four main activities among hours for each month (June 2007 to October 2007).

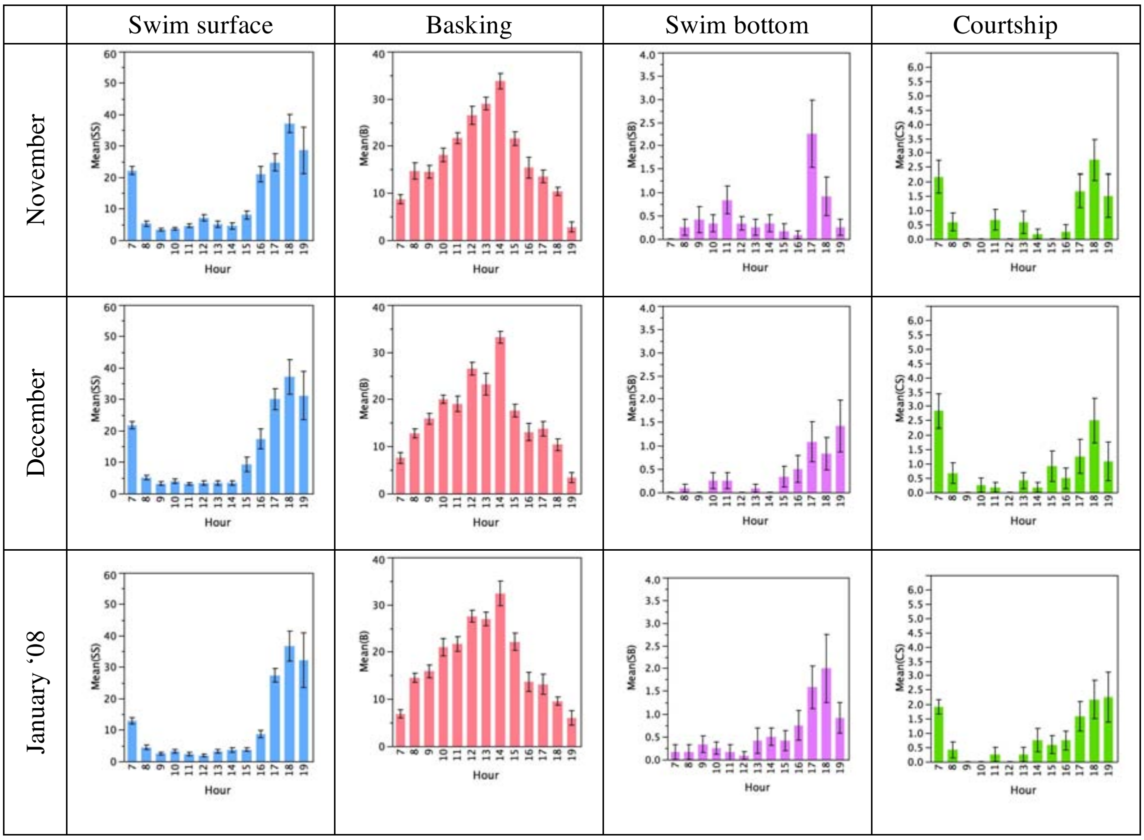

Figure 2 (continued). The mean number of red-eared sliders participating in the four main activities among hours for each month (November 2007 to January 2008).

Appendix II: Swimming slowly/stationary sequence

Swimming slowly / stationary sequence for a period of 6 minutes and 7 seconds. Subject was a 19cm male red-eared slider.

Time	Code	No. of seconds
15:10:41	SS	3
15:10:44	ST	3
15:10:47	SS	2
15:10:49	ST	6
15:10:55	SS	2
15:10:57	ST	3
15:11:00	SS	6
15:11:06	ST	3
15:11:09	SS	3
15:11:12	ST	3
15:11:15	SS	3
15:11:18	ST	2
15:11:20	SS	3
15:11:23	ST	3
15:11:26	SS	2
15:11:28	ST	5
15:11:33	SS	3
15:11:36	ST	3
15:11:39	SS	4
15:11:43	ST	3
15:11:46	SS	2
15:11:48	ST	3
15:11:51	SS	3
15:11:54	SS	3
15:11:57	ST	5
15:12:02	SS	11
15:12:13	ST	10
15:12:23	SS	28
15:12:51	ST	1
15:12:52	SS	236
15:16:48	OOS	-

Appendix III: Questionnaire used for surveying pet ownership and attitudes towards releasing and feeding

SURVEY OF FEEDING/OWNING ANIMALS

Dear resident,

I am a PhD student conducting a survey for my thesis at the National University of Singapore. My research is on the Red-eared terrapin/turtle (红耳龟) [shown in pictures on the right] and I would like to find out the extent of knowledge of Singaporeans on these common but relatively unknown species.

I would appreciate if you could spend some minutes to answer these questions. Your anonymity is guaranteed and all data collected will be used for research purposes only. I will collect the questionnaire __________________

If you want to know more about my project, please contact me at abigayle.ng@gmail.com

SECTION 1 – Pet ownership

a) Have you ever owned a pet?

☐ Yes: please answer the following questions.
☐ No: please skip to Section 3 (pg 3)

b) What kind of animal(s) and how many? [please choose all applicable]

e.g.

Yes	Animal	Number
√	Fish	6

Yes	Animal	Number
	Dog	
	Cat	
	Rabbit / hamster / guinea pig / chinchilla / mouse	
	Bird	
	Snake / lizard	
	Fish	
	Turtles / terrapin / tortoise	

c) If you no longer own these animals, please indicate why.

☐ Death (e.g. illness, accident, euthanasia, etc.)
☐ Sold / traded
☐ Adopted by others
☐ Lost
☐ Released
☐ Others (please specify: _______________)

1

SECTION 2 – Red-eared terrapins (红耳龟)

a) Have you ever owned a red-eared terrapin/turtle (see picture on page 1)?
- ☐ Yes: please answer the following questions
- ☐ No: please skip to Section 3 (pg 3)

b) How many red-eared terrapins/turtle have you owned? _______

c) Where did you get your red-eared terrapin/turtle?
- ☐ Bought from pet shop
- ☐ Gift
- ☐ Adopted from others
- ☐ Caught / found from the wild

d) How long did you keep each one of them for?

☐ < 3 months ☐ 3 months to 1 year ☐ 1 year to 5 years ☐ 5 years to 10 years ☐ > 10 years

e) If you no longer own these animals, please indicate why.
- ☐ Death (e.g. illness, accident, euthanasia, etc.)
- ☐ Sold / traded
- ☐ Adopted by others
- ☐ Lost
- ☐ Released
- ☐ Others (please specify: _____________)

If your red-eared terrapins/turtles were released, please answer the following question. If not, skip to Section 3.

f) Where were they released? [please indicate how many per site, e.g. MacRitchie (5)]

____

____

g) Why did you choose to release them? [choose all applicable]
- ☐ They have a better life
- ☐ They belong in the wild
- ☐ They will have friends
- ☐ They grew too big for my house
- ☐ They were fierce and bit me / my family
- ☐ They were not cute anymore
- ☐ They live too long
- ☐ I lost interest
- ☐ They are dirty and smelly
- ☐ I don't know what else to do
- ☐ Somebody recommended me to do so
- ☐ Others _______________

2

SECTION 3 – Terrapin release

a) Have you ever bought a red-eared terrapin (红耳龟) (see picture on page 1) for the purpose of releasing?

☐ Yes
☐ No

b) If yes, why did you want to release it / them?

____

SECTION 4 – Terrapin feeding

a) Have you ever fed terrapins/turtles in parks / reservoirs / ponds, etc.?

☐ Yes: please answer the following questions
☐ No: please skip to section 5 (pg 4).

b) How often do you feed the terrapins/turtles?

☐ Daily
☐ 1 to 2 times a week
☐ 1 to 2 times a month
☐ As and when / not regular

c) Where do you go to feed the terrapins/turtles?

____

d) What do you feed the terrapins/turtles with?

____

e) Why do you feed the terrapins/turtles?

____

____

____

____

SECTION 5 – Your perspective and opinions

a) Where do you think red-eared terrapins/turtles (红耳龟) (see picture on page 1) are from?

- ☐ Found native in Singapore
- ☐ Imported from overseas

b) To your understanding, is releasing animals in parks and reservoirs legal in Singapore?

- ☐ Yes
- ☐ No

c) How do you feel about the release of terrapins/turtles into parks and reservoirs?

- ☐ I like the idea.
- ☐ There is nothing wrong with it.
- ☐ It should not be done.
- ☐ No opinion / it doesn't affect me / never thought about it.
- ☐ Others (please specify: ________________)

d) How do you feel about the feeding of terrapins/turtles in parks and reservoirs?

- ☐ I like the idea.
- ☐ There is nothing wrong with it.
- ☐ It should not be done.
- ☐ No opinion / it doesn't affect me / never thought about it.
- ☐ Others (please specify: ________________)

e) Do you have any other comments about the issues mentioned in this survey?

____

____

SECTION 6 – General survey information

a) Number of members in household: ______________

b) Type of housing:

- ☐ Private apartment
- ☐ Semi-detached house
- ☐ Terrace house
- ☐ Bungalow
- ☐ Others (please specify: ____________________)

c) Ethnicity: Chinese / Malay / Indian / Others (please specify:________________)

- END -

Appendix IV: Additional comments from households surveyed

Comments supporting feeding	
1. Feeding is fun. 2. Feeding is interesting. 3. Feeding turtles is a good family activity. 4. If you have the money, it is good to spend some money buying food for the turtles and feeding them. 5. There is nothing wrong in feeding the turtles that are already there. 6. It's okay to feed the turtles because they are hungry. 7. It would be good to feed the turtles since it provides them food. 8. The turtles should be fed since they are already there. 9. if you don't feed the turtles they will starve to death.	10. It is kind to feed animals. 11. Feeding can attract more visitors to parks. 12. If you want to feed you must feed the right food. 13. Should feed the right food. 14. Feed only if you have the correct food. 15. Feeding is okay if done once in a while. 16. Feeding is okay if it is good for the animals.

Comments condemning feeding	
1. Feeding is illegal. 2. Feeding the turtles will dirty the water. 3. Feeding will dirty the parks. 4. Feeding will dirty the water. 5. Feeding will make the reservoir dirty. 6. Feeding will dirty the water. 7. Feeding turtles will make the place dirty 8. Feeding turtles in reservoirs will make our drinking water dirty. 9. Feeding turtles makes the water smelly. 10. Feeding may pollute the water. 11. Feeding might cause pollution. 12. Feeding will contaminate/pollute water. 13. Feeding will pollute the water. 14. Should not feed because it's unhygienic. 15. Feeding is unhygienic.	16. Feeding is very unhygienic, shouldn't feed because it will cause mosquitoes to breed. 17. Don't overfeed the turtles. 18. If there is excess food, water will get dirty. 19. Should not overfeed the turtles. 20. There is a fear of overfeeding the turtles. 21. Should not feed in case the animals get overfed. 22. The turtles should find their own food. 23. There is no need to feed the turtles because they can eat the grass. 24. No need to feed the turtles because they can fend for themselves. 25. Feeding is unnecessary 26. It is unnecessary to feed the turtles 27. Shouldn't feed because you might be feeding them the wrong things. 28. If you feed the animals they will start relying on humans feeding them.

Comments in support of releasing	
1. Releasing turtles adds variety to the reservoir. 2. The act of releasing an animal is good. 3. To release an animal is a good thing, but I am not sure if it is detrimental to the environment or whether the animal can survive. 4. It is good to release animals and cultivate life. 5. Releasing animals will increase biodiversity. 6. Releasing gives the animals freedom. 7. The released turtles will have more freedom in the wild. 8. Releasing is good because it gives the animals freedom (but bad because they are unable to survive on their own). 9. The turtles will have friends after they are released. 10. Releasing an animal gives them a new home. 11. I like the idea for religious reasons. 12. Releasing animals should be made legal in Singapore. 13. From personal experience, I found that they are difficult to maintain especially if the home is small. Releasing is the only solution.	14. I like to give freedom to the animals but am a bit worried that other people would harm them. 15. Releasing is acceptable if it involves harmless animals like turtles or tame dogs. 16. Releasing is okay if the turtles are young because they are able to adapt to the new environment. 17. Releasing is acceptable if it is not for selfish reasons (e.g. generating good karma for oneself). 18. Releasing is good as long as the environment is suitable for the animal. 19. It depends on whether the habitat is suitable. 20. It depends on whether the habitat is suitable. 21. Releasing is okay if the place is suitable. 22. Releasing is okay if the animal survives. 23. Releasing is okay if the environment is good for the animal. 24. Releasing is okay if the habitat is already populated with sliders.

Comments condemning releasing	
1. If you release your pet they won't know how to find food because they have been dependent on you. 2. The released turtles won't survive. 3. The turtles won't survive if you release them. 4. Turtles should not be released because they won't survive. 5. You should not release a turtle because you don't know if it will survive. 6. The pond/reservoir may not be their natural habitat and the turtles may not be able to feed themselves 7. Releasing turtles will lead to overcrowding. 8. It is irresponsible to release your pet. 9. It is irresponsible to leave pets unattended. 10. You should not buy pets if you are not going to be responsible towards them. 11. Releasing animals will upset the ecosystem.	12. Turtles should not be released but people don't really have a choice when they need to get rid of them. 13. Saw in news that it is illegal to release animals. 14. Should not get such pets since they are a responsibility. 15. If you don't want to keep your turtles you should give it to the zoo instead of releasing. 16. People should be more responsible for their pets. 17. People should stop releasing red-eared sliders in the sea. 18. The turtles dirty the water. 19. Releasing animals into the water will cause pollution. 20. The idea of releasing an animal is weird. 21. Turtles should not be released because they are unhygienic.

Call for management	
1. Sometimes people are left with no choice but to release their pets if they are unable to keep. 2. Releasing an animal is better than killing. 3. Sometimes people have no choice but to release the pet. 4. There should be provision for a place to release the turtles because they are aggressive in the wild. 5. Releasing should not be done but people have no choice if the turtles grow too big. 6. What else can I do if I cannot take care of my turtle anymore? 7. Releasing is the only option. 8. A place should be created to release turtles legally. 9. AVA should do something to regulate the release of turtles. 10. Releasing of animals should be managed by the government. 11. It is okay to release/feed the animals if properly managed. 12. Controlled release is okay 13. Releasing is okay if it is managed. 14. Ideally, a place for the release and feeding of these animals should be set up.	15. It would be wrong to release a turtle in the wild but it is acceptable if in a designated pond. 16. It is okay to release/feed the animals if allowed by the government. 17. Feeding should be regulated to only certain days/time. 18. Feeding should be managed. 19. Feeding should be managed by AVA or NParks 20. Feeding should be controlled otherwise it will cause pollution. 21. Turtle feeding should be managed. 22. Turtle feeding should be managed. 23. Feeding should be managed. 24. Feeding is okay if it is in a controlled manner. 25. Feeding is okay if it is allowed. 26. If it is allowed feeding is okay. 27. Feeding is okay if it is allowed. 28. Feeding is okay only if it is allowed. 29. It is okay to feed if it is within a proper sanctuary. 30. Releasing is okay if it is into a temple pond.

Call for Education	Discernment of Location
1. More should be done to educate people against releasing. 2. People know not to feed monkeys because there is a campaign for that. There is no public awareness campaign yet about terrapins. 3. Releasing is an impulsive action. Maybe it is because of certain cultures? More awareness can lead to less releases.	1. It is okay to release/feed animals in ponds but not in reservoirs because it is our drinking water. 2. It is okay to release/feed animals in ponds but not in reservoirs.

Need for responsibility	Other comments
1. People should find out more information about the pet before buying one. 2. The people who release their pets should be the ones responsible for feeding/taking care of them. 3. The pet is the responsibility of its owner. 4. As long as it is an animal with a life, it deserves love and concern. 5. Owning a pet requires a lifetime of perseverance and love. 6. People who feed the turtles sometimes litter the place with food wrappers.	1. We bring children to feed turtles because there is a lack of places with nature to go to in Singapore. 2. Feeding should not be done but sometimes it is fun. 3. Feeding the turtles once in a while for the sake of educating children is okay 4. Releasing is not common anymore. 5. Releases are the fault of those of Buddhist faith (I am a Christian). 6. Most people kick their pet turtles out when they grow big. 7. I don't really mind if a public place is made dirty by the animals, as long as the animal is not in my house. 8. I have observed some boys stomping on a turtle they had fished out of a pond. It is cruelty to animals. 9. These (pet ownership and releasing and feeding in public places) are not important issues. 10. Smuggling illegal animals is wrong. 11. I would prefer to release a red-eared slider in the sea.

Appendix V: The availability of euthanasia procedures at veterinary centres in Singapore

	Name of Veterinary Centre	Euthanasia	Price
1.	The Animal Doctors Pte Ltd	YES (NC)	$20 to $40
2.	The Animal Recovery Centre Pte Ltd	[3]NO	
3.	AAVC-Animal & Avian Veterinary Clinic	[1]YES (C)	$35
4.	Allpets & Aqualife Vets Pte Ltd	YES (C)	$30 - $40
5.	AMK Veterinary Surgery	YES (NC)	$25 - $35
6.	The Animal Clinic Pte Ltd	[1]YES (NC)	$10 - $30
7.	Animal Practice Pte Ltd	[3]NO	
8.	Animal Recovery Veterinary Centre	YES (C)	
9.	Asia Veterinary Pte. Ltd./ Defu Veterinary Surgery	-	-
10.	Clinic For Pets	[2]NO	
11.	Companion Animal Surgery Pte Ltd	NO	
12.	Edmond Tan Veterinary Surgery	NO	
13.	Heart2Heart Veterinary Hospital Pte Ltd	NO	
14.	Holland Village Veterinary Clinic	-	-
15.	James Tan Veterinary Centre Pte Ltd	YES (C)	$60 - $80
16.	Jireh Veterinary Clinic Pte Ltd	YES (NC)	< $10
17.	Mount Pleasant Animal Clinic (East) Pte Ltd	[2]NO	
18.	Mount Pleasant Animal Clinic (North Branch) Pte Ltd	YES (NC)	$35
19.	Mount Pleasant Animal Medical Centre (Bedok) Pte Ltd	YES (NC)	$20
20.	Mount Pleasant Animal Medical Centre Pte Ltd	YES (NC)	$20
21.	Mount Pleasant Referral Clinic	YES (NC)	$30
22.	Mount Pleasant Veterinary Centre	[2]NO	
23.	Namly Animal Clinic Pte. Ltd.	-	-
24.	P.A.W. (People Animal Wellness) Veterinary Centre Pte Ltd	YES (C)	$25
25.	Pet Care Centre & Clinic	[1]YES	$50 - $60
26.	Pet Clinic	2 to 5pm	
27.	Puppies Lodge Pte Ltd	NO	
28.	The Joyous Vet Pte Ltd	[3]NO	
29.	The Veterinary Clinic Pte Ltd	NO	
30.	Toa Payoh Veterinary Surgery	YES (NC)	$50
31.	Vet Practice Pte Ltd	YES (NC)	$25

[1] Suggested alternatives e.g. release in a temple, bring to SPCA, put up for adoption
[2] Recommended another vet / hospital
[3] Will perform euthanasia only if animal is in critical condition