CHAPTER 2 LITERATURE REVIEW

2.1 Amphibian biodiversity crisis

Amphibians are threatened globally by multiple anthropogenic factors. In Southeast Asia amphibians appear to be highly threatened (Rowley *et al*., 2010), but are highly understudied compared to the rest of the world (Rowley *et al*., 2010). These threats include habitat loss (Achard *et al*., 2002; Stuart *et al*., 2004) as Southeast Asia has the highest deforestation rate in the tropics (Rowley *et al*., 2010; Sodhi *et al*., 2004), and climate change as it is predicted that over the next century Southeast Asia is to get warmer and drier with greater variation in rainfall. Such a drier climate will lead to habitat loss as freshwater bodies dry up. The effect of climate change is substantial, particularly in tropical montane areas (Sala *et al*., 2000), where for example decreases in rainfall have already significantly altered amphibian communities in other tropical regions (Pounds *et al*., 1999), but the effects have been largely untested in the region (Bickford *et al*., 2010a), as well as the effects of the chytrid fungus, which has severely impacted hundreds of populations globally (Fisher *et al*., 2009; Skerratt *et al*., 2007) and is now widely documented in Southeast Asia (Bai *et al*., 2010; Gaertner *et al*., 2011; Goka, *et al*., 2009; Kusrini *et al*., 2008; Savage *et al*., 2011; Swei *et al*., 2011; Une *et al*., 2008; Vörös *et al*., 2012; Yang *et al*., 2009). Compounding these problems in the region is a general lack of knowledge of a large percentage of amphibians; therefore it is particularly difficult to prioritize habitats and species for conservation action (Rowley *et al*., 2010). This lack of baseline knowledge has also been noted in Thailand, for example, which probably has a greater knowledge base than its neighbors (Tantipisanuh and Gale, 2013). Recent recommendations have called for greater survey efforts to estimate baseline populations for Southeast Asia, for the purpose of understanding the basic ecology of amphibian communities (Rowley *et al*., 2010).

2.2 Influence of environmental factors on anuran richness and abundance

Although our specific knowledge of Southeast Asia is relatively weak, previous studies have indicated that a variety of physical and biotic factors are important in structuring tropical amphibian communities (Scott, 1976; 1982). One common method for looking at factors structuring communities is to examine species richness and abundance

patterns along elevational gradients (Colwell *et al*., 2004; Watkins *et al*., 2006). Studies have suggested that physical factors varying in parallel with elevational gradients, particularly water bodies (e.g., streams and ponds) suitable for amphibian breeding may be the dominant factor limiting the distribution of amphibians (Hofer *et al*., 1999). Changes seen along gradients may also be due to individual species responses to the physical factors that vary in parallel with the gradient because of their physiological tolerance limits (Hofer *et al*., 2000; Terborgh, 1971).

Amphibian species richness and abundance have been associated with a variety of environmental factors including: annual mean precipitation (Behangana *et al*., 2009; Fu *et al*., 2006), annual mean temperature (Fu *et al*., 2006), soil moisture (Khatiwada, 2011; Naniwadekar and Vasudevan, 2007), soil temperature (Naniwadekar and Vasudevan, 2007), percentage of canopy cover (Behangana *et al*., 2009), elevation (Khatiwada, 2011; Vasudevan *et al*., 2006), and/or stream characteristics related to breeding habitats, i.e., streams and pools (Malonza and Veith, 2012; Parris and McCarthy, 1999; Phochayavanich *et al*., 2010; Zimmerman and Bierregaard, 1986).

2.3 Emerging infectious disease (*Batrachochytrium dendrobatidis*, chytrid fungus)

Batrachochytrium dendrobatidis (chytrid fungus, *Bd*) is a significant threat to amphibian populations globally (Berger *et al*., 1998; IUCN, 2008). Several populations of amphibians have dramatically declined or gone extinct over the past 40 years, and *Bd* has been implicated as the causative agent of these population declines and extinctions. The fungus has been detected in amphibians in North, Central and South America, Europe, Africa and Australia (Berger *et al*., 1998; Lips, 1999; Lips *et al*., 2004; Weldon *et al*., 2004; Ouellet *et al*., 2005; Garner *et al*., 2005; Venegas *et al*., 2008). Over the past six years, *Bd* has also been reported from several amphibian populations in Asia with the first discovery in Japan (Une *et al*., 2008; Goka, *et al*., 2009), followed by reports of the occurrence of *Bd* from Indonesia (Kusrini *et al*., 2008), South Korea (Yang *et al*., 2009), China (Bai *et al*., 2010), Malaysia (Savage *et al*., 2011), Laos, Philippines and Vietnam (Swei *et al*., 2011), Cambodia (Gaertner *et al*., 2011; Mendoza *et al*., 2011), Singapore (Gilbert *et al*., 2012) and Thailand (Vörös *et al*., 2012).

To date, in Asia there appears to be a low infection rate at most sites where *Bd* is detected. In six of the Asian countries where infections were reported, the overall infection rate was only 2.4% (Swei *et al*., 2011) and there have been no reports of mass die-offs or enigmatic population declines associated with *Bd* in Southeast Asia (Rowley *et al*., 2010), which differs from many other regions.

Global climate change, the commercial wildlife trade, and pollution may all increase the movement or susceptibility to this fungus (Blaustein, 2006). Therefore, countries in Southeast Asia including Thailand may face increased risk from emerging infectious diseases such as from *Bd* due to the importation of amphibians for trade and consumption, including non-native species. The possibility of *Bd* transmission and infection may also increase because of the cultural belief of making merit through releasing live animals bought from markets or temples. As both amphibian adults and larvae can act as silent carriers of pathogens, i.e., infected but appearing asymptomatic, this probably further increases the risk of pathogen distribution (Mazzoni *et al*., 2003; Daszak *et al*., 2004; McLeod *et al*., 2008).

Swei *et al*. (2011) suggested that assessments of the susceptibility of Asian amphibians, especially wild montane species, to *Bd* infection should be carried out via laboratory and repeated field surveys as a first step in monitoring and preventing the spread of *Bd*, particularly in biogeographic areas and biodiversity hotspots where groups of species are at highest risk (Bickford *et al*., 2010a). In 2012, there was the first recorded instance of *Bd* in Thailand from a secondary forest of an abandoned rubber plantation in Songkla province of Peninsular Thailand (Vörös *et al*., 2012) (Figure 2.1). In light of this discovery and recent evidence that *Bd* may actually be endemic to the region (Goka *et al*., 2009), I investigated whether there was any evidence for the presence of *Bd* in a relatively undisturbed evergreen forest in western Thailand.

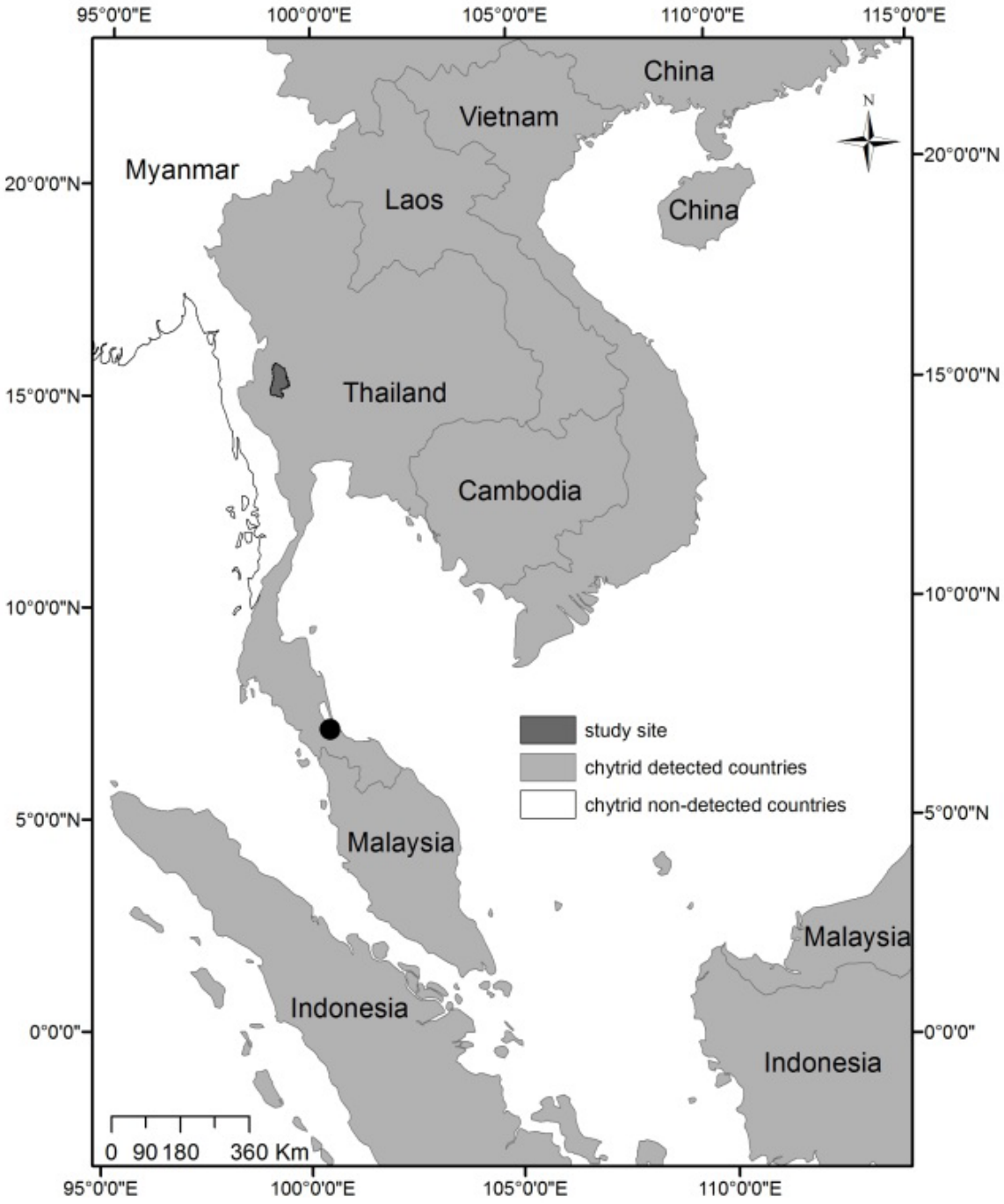

Figure 2.1 Map of Southeast Asia showing countries where *Bd* has been detected (light grey). The dark grey region marks the location of the study area in the Huai Kha Khaeng Wildlife Sanctuary, and the filled circle is where *Bd* was first detected in the wild in Thailand.