ผลของฝายชะลอความชุ่มชื้นต่อการชุมนุมและการกระจายตัวของสัตว์สะเทินน้ำสะเทินบก
และสัตว์เลื้อยคลานในบริเวณป่าผลัดใบในจังหวัดน่าน ประเทศไทย

นายรัชต โปชยะวณิช

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Effects of Check Dam on Species Assemblage and Distribution of Amphibian and Reptile in a Deciduous Forest in Nan Province, Thailand

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Field of Study	Biological Sciences
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รัชต โปชยะวณิช: ผลของฝายชะลอความชุ่มชื้นต่อการชุมนุมและการกระจายตัวของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานในบริเวณป่าผลัดใบในจังหวัดน่าน ประเทศไทย. (Effects of Check Dam on Species Assemblage and Distribution of Amphibian and Reptile in a Deciduous Forest in Nan Province, Thailand) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: อ. ดร. นพดล กิตนะ, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม: ผศ. ดร. วิเชฏฐ์ คนซื่อ, 167 หน้า.

ในประเทศไทยมีการสร้างฝายชะลอความชุ่มชื้นเป็นจำนวนมาก โดยที่ยังมีรายงานค่อนข้างน้อยเกี่ยวกับผลกระทบของฝายต่อสิ่งมีชีวิต การศึกษาครั้งนี้ได้ติดตามการชุมนุมและการกระจายตัวของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานในภาคสนามเพื่อใช้แสดงถึงผลกระทบของฝายต่อปัจจัยทางชีวภาพ โดยพิจารณาเปรียบเทียบผลกระทบใน 2 รูปแบบ คือ 1) เปรียบเทียบระหว่างพื้นที่ โดยพิจารณาข้อมูลที่สำรวจจากลำธารที่มีฝายและไม่มีฝายในช่วงระยะเวลาเดียวกัน และ 2) เปรียบเทียบระหว่างเวลา โดยพิจารณาข้อมูลที่สำรวจก่อนและหลังการสร้างฝายในพื้นที่เดียวกัน การสำรวจสัตว์ในภาคสนามใช้เทคนิคการสำรวจตามเส้นทางในลำธารและระบบนิเวศบก จำนวน 5 กลุ่มเส้นทาง กลุ่มละ 10 ซ้ำ โดยใช้ลำธารชั่วคราว 2 สาย ในพื้นที่ป่าอนุรักษ์และสถานีวิจัยของจุฬาลงกรณ์มหาวิทยาลัย ในจังหวัดน่าน และสำรวจทุกเส้นทางเดือนละ 2 ครั้ง ในเวลากลางวันและกลางคืน เป็นเวลา 2 ปี ตั้งแต่เดือน เมษายน พ.ศ.2552 ถึงเดือนเมษายน พ.ศ.2554 ผลการศึกษาพบว่าปัจจัยทางกายภาพที่เกี่ยวข้องกับน้ำในลำธาร ได้แก่ ช่วงเวลาที่มีน้ำ ความลึกของน้ำ และ จำนวนแอ่งน้ำ มีค่าสูงขึ้นอย่างมีนัยสำคัญเมื่อมีฝายทั้งในการเปรียบเทียบระหว่างพื้นที่และระหว่างเวลา แสดงให้เห็นว่าฝายสามารถยืดระยะเวลาการปรากฏของน้ำให้นานขึ้นได้ อย่างไรก็ดีการตรวจสอบความหลากชนิดด้วยกราฟ rarefaction พบว่าฝายไม่มีผลต่อความหลากชนิดของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานอย่างมีนัยสำคัญทั้งในการเปรียบเทียบระหว่างพื้นที่และระหว่างเวลา การวิเคราะห์องค์ประกอบชนิดของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานด้วยกราฟ NMDS และ การวิเคราะห์ความคล้าย (ANOSIM) แสดงให้เห็นว่าองค์ประกอบชนิดของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานโดยทั่วไปมีความคล้ายคลึงกันทั้งในกรณีที่มีฝายและไม่มีฝาย และเมื่อวิเคราะห์รูปแบบการกระจายของสัตว์ในถิ่นที่อยู่อาศัยต่าง ๆ ด้วยสถิติ Kruskal-Wallis และ การทดสอบ Tukey พบว่าการกระจายของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานบางชนิดมีการเปลี่ยนแปลงไปในกรณีที่มีฝาย แต่รูปแบบการกระจายของสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานส่วนใหญ่กลับไม่มีความแตกต่างที่สัมพันธ์กับการมีฝาย ผลการศึกษาโดยรวมแสดงให้เห็นว่าฝายชะลอความชุ่มชื้นเป็นมาตรการที่มีประสิทธิภาพสามารถยืดระยะเวลาการปรากฏของน้ำให้ยาวนานขึ้นได้โดยมีผลกระทบระยะสั้นเพียงเล็กน้อยต่อสังคมสัตว์สะเทินน้ำสะเทินบกและสัตว์เลื้อยคลานในพื้นที่ลำธารชั่วคราวในป่ารุ่น

สาขาวิชา วิทยาศาสตร์ชีวภาพ ลายมือชื่อนิสิต...

ปีการศึกษา 2554 ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก……………………………………..

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม………………………….……....

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RATCHATA PHOCHAYAVANICH: EFFECTS OF CHECK DAM ON SPECIES ASSEMBLAGE AND DISTRIBUTION OF AMPHIBIAN AND REPTILE IN A DECIDUOUS FOREST IN NAN PROVINCE, THAILAND. ADVISOR: NOPPADON KITANA, PH.D., CO-ADVISOR: ASSIST. PROF. WICHASE KHONSUE, DR.HUM.ENV., 167 PP.

Since numerous check dams have been constructed in Thailand and there were only a few reports on their effects on biotic components, a systematic field research on assemblage and distribution of amphibian and reptile was carried out to monitor the check dam effects in this study. Effects of the check dam were determined based on 1) spatial comparison between check dam and non-check dam areas during the same period and 2) temporal comparison between pre- and post-check dam periods of the same study site. Ten replicates of 5 transects at stream and terrestrial habitats were used for animal survey in two ephemeral streams at the Chulalongkorn University Forest and Research Station, Nan Province. The surveys in every transect were conducted in both daytime and nighttime on monthly basis for 2 years during April 2009 to April 2011. It was found that physical factors related to water pattern including hydroperiod, water depth and number of water body were significantly increased in check dam conditions in both spatial and temporal comparisons, indicating that the check dam could prolong the water availability of the stream. However, the rarefaction curves indicated that species diversity of amphibian and reptile was not significantly different between check dam and non-check dam conditions in both spatial and temporal comparisons. The non-metric multidimensional (NMDS) plots and analysis of similarity (ANOSIM) results also indicated that species composition of amphibian and reptile was generally similar between check dam and non-check dam conditions in both stream and terrestrial habitats. Although the distribution patterns, as revealed by Kruskal-Wallis test and non-parametric Tukey type multiple comparison, of some amphibians and reptiles were altered in a presence of the check dam, the distribution patterns of the majority of amphibian and reptile species were not different as a result of the check dam in both comparisons. Overall results suggested that the check dam can be regarded as an effective measure to prolong water period with minimal short-term impact on herptile community in the ephemeral stream habitat in the successive forest.

Field of Study : Biological Sciences | Student's Signature ....

Academic Year : 2011 | Advisor's Signature ....

Co-advisor's Signature ....

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CHAPTER I

INTRODUCTION

The drought problem has been reported in many parts of the world. The Intergovernmental Panel on Climate Change (IPCC) reported that some regions of the world can be susceptible to prolonged period of drought due to the problem of climate change (IPCC, 2007). There are numerous management methods used to solve this problem. Some methods, such as dam constructions, are well understood for their effects on environment. However, check dam, a small dam constructed across a gully or stream, is one of the drought management methods with less information on its effect on the environment. Check dams are constructed in many countries throughout the world (Taiwan: Liu, 1992; Iran: Kalantari et al., 2010; Ethiopia: Nyssen et al., 2004; Spain: Romero-Díaz, Alonso-Sarriá, and Martínez-Lloris, 2007; China: Xiang-zhou, Hong-wu, and Ouyang, 2004; Zeng et al., 2009). In Thailand, check dam has been initially and successfully implemented in rural areas according to the advices of His Majesty the King of Thailand since it is regarded as simple enough for local people to construct by themselves with minimal investment, yet effective enough for water and soil conservation (Huang et al., 2009; Xiang-zhou et al., 2004). As a result, many governmental offices and private sectors have participated in the check dam constructions throughout the country. Although numerous check dams have been builted, there are still few reports on the potential effect of the check dam on the environment especially on biotic component. The check dam can increase the absorption rate of underground water and the stream hydroperiod (Watershed Conservation and Management Office, 2008). Treepatanasuwan and Ploychareon (2006) reported that numbers of seedlings and saplings in the dry evergreen forest in the check dam construction area were higher than in the area with no check dam. At the river habitat, Shieh, Guh, and Wang (2007) concluded that check dam not only changes the physical characteristics of river but also have the negative impacts on the biodiversity of river habitat by 3 ways including 1) alter the migration of the organism to breeding site, 2) partitioning the population and community of animal in the river, and 3) reducing the habitat diversity. However, the information from river habitat was not universally applicable since most of the habitat types selected for check dam construction in Thailand were primary or secondary order streams which are usually non-permanent streams or ephemeral streams (Department of Local Administration, 2008). Therefore, the study on the effect of check dam on biotic factors is still needed to be conducted in this habitat type.

For the biotic component, the information on species assemblage and distribution pattern are important data for ecological study of any area. The biological diversity is frequently used as surrogate for ecosystem health and function. The persistence of any species in specific area indicates that there are available habitats for those species in the area (Ricklefs and Miller, 2000). So, the study on these 2 aspects can indicate the effects of check dam on the biotic factors in the area.

Since main objective of the check dam construction is to prolong the hydroperiod and increase moisture in the area, the organism used as an indicator to detect the effect of check dam on the biotic component in the ecosystem should be sensitive to the moisture change. In this study, amphibians are selected as monitoring species since, compared to other terrestrial vertebrates, they are the most sensitive taxon to moisture change due to their semi-permeable skin in adult, dependence on water in larva, and jelly-like with no hard shell protection in egg (Duellman and Trueb, 1994). In addition, reptile is also used as a sensitive indicator to environmental changes by the check dam because reptile is an ectothermic animal that relies on environmental sources for heat gain. Its daily activity is more restricted than an endothermic tetrapod (Vitt and Caldwell, 2009). In an ephemeral stream habitat, a less dense canopy cover and an availability of dry stream bed provide a perfect place for the reptile to gain heat from stream bed conduction and sun basking. In the presence of check dam, the prolonged water period in the ephemeral stream could reduce an occurrence of this dry stream bed and may affect the reptile assemblage in the check dam area. Therefore, the assemblage and distribution of amphibian and reptile were selected as the monitoring parameter to detect the effect of check dam on the biotic component in this study.

Recently, Chulalongkorn University planned to construct check dams in the University Forest and Research Station. This plan allowed us to set up a systematic field research in order to investigate the effect of check dam. In this study, presence and absence of the check dam were used as independent factor, while changes in physical factors, assemblage, and distribution pattern were used as dependent variables. Effects of check dam was determined base on 1) spatial comparison between check dam and non-check dam areas and 2) temporal comparison between pre- and post-check dam periods. In the spatial comparison, physical factors, assemblage, and distribution were compared between sites during the same study period. Therefore, similar pattern of weather conditions was expected in these 2 sites. In the temporal comparison, physical and biological factors were compared between 2 periods of the same study site. Therefore, similar condition of habitat was expected within these 2 periods.

Overall, there are 3 main objectives of this study as follows.

1. To compare the environmental conditions between check dam and non-check dam areas and between pre- and post-check dam periods.
2. To compare, spatially and temporally, the assemblage and distribution of amphibians between check dam and non-check dam conditions.
3. To compare, spatially and temporally, the assemblage and distribution of reptiles between check dam and non-check dam conditions.

CHAPTER II

LITERATURE REVIEWS

2.1 Check Dam and Its Effects on the Environment

Check dams are small dams constructed across a gully or stream in order to 1) reduce the velocity of water flows, 2) monitor and entrap sedimentation, 3) increase infiltration of water into the surrounded soil in order to, 4) increase the vegetation, and 5) reduce the flood peak discharge (Gray and Leiser, 1982 cited in Solaimani, Omidvar, and Kelarestaghi, 2008). Check dams are used for management of surface water, sediment and physical characteristics of the stream in many countries throughout the world (Taiwan: Liu, 1992; Iran: Kalantari et al., 2010; Ethiopia: Nyssen et al., 2004; Spain: Romero-Díaz et al., 2007; China: Xiang-zhou et al., 2004; Zeng et al., 2009).

Check dams can be made from very diverse materials such as low price local materials (bamboo, wood, log, clay, rock) or high cost concrete, resulting in varying range of life span of the check dams. The first and the most popular type is the local or temporary check dam with life span of approximately 3-5 years. This check dam is constructed with local materials, such as clay soil, rock and wood rod laid across the gully or the first order stream. The second type is a semi-permanent check dam which is constructed with permanent materials such as brick, ferroconcrete, and reinforced concrete. In general, it is usually constructed in the middle part of the second order stream with the width of less than 3 meters. The third type is the permanent check dam constructed with permanent materials similar to those of semi-permanent type with more solid structure. It is usually constructed in the far down stream of the second and the third order stream with the width of 5 meters or less (Department of Local Administration, 2008).

Since the main purposes of check dam construction are to improve physical components of environment, most of the researches on check dam effect are thus involved with water, sediment, and physical characteristics of the stream. The check dam can increase the absorption rate of underground water and the stream hydroperiod (Watershed Conservation and Management Office, 2008). Check dams (also known as silt trappers) were mentioned as the effective method for soil and water conservation (Huang et al., 2009; Xiang-zhou et al., 2004). The amount of sediments stored by the check dams was found to be higher than the amount of eroded materials in the downstream reaches of the check dam (Castillo et al., 2007). Zeng et al. (2009) demonstrated that check dam can reduce the soil erosion sediment by 1) restricting the channel depth and lateral erosions, 2) protecting the channel erosion base, 3) reducing the bed gradients of debris-flow channels, 4) fixing the channel bed, and 5) stabilizing the bank slopes. The results from Solaimani, Omidvar, and Kelarestaghi (2008) showed that check dams have influenced on width/depth ratios and maximum depth of channels. Check dams can also use for production of the upstream channel stability (Liu, 1992).

Although it can be concluded that check dam can change many physical factors, there are still few reports on the effect of check dam on biotic factors. Further, most of these reports are restricted only on change in plant community. Zeng et al. (2009) demonstrated that the check dam can facilitate growth of vegetations. DeBano and Heede (1987) concluded that the prolonged hydroperiod by the check dam allowed sedges and willows to become established and developed into a dense riparian community. Treepatanasuwan and Ploychareon (2006) also reported that numbers of seedlings and saplings in the dry evergreen forest in the check dam construction area were also higher than in the area with no check dam.

Although, most of these researches reported the positive effect of check dam in stream habitat, conflicting results were found in a riverine habitat. Shieh et al. (2007) concluded that the check dam not only changes the physical characteristics of the river but also have the negative impact on biodiversity of the river by 3 ways including 1) alter a migration of organisms to breeding site, 2) partition the population and community of animals in the river, and 3) reduce the habitat diversity.

2.2 Biology of Amphibian and Reptile in Relation to Environmental Factors Changed by the Check Dam

2.2.1 Amphibian

Basically, body of an amphibian compose of approximately 70–80% water, in which various ions necessary for proper physiological function are dissolved. Amphibian skin is unique among vertebrates because it is highly permeable. Moreover, their skin also functions as a major respiratory organ. Thus, the skin must be kept moist for an exchange of gases to occur. In the terrestrial habitat, amphibian often faces a problem of losing water rapidly and risking dehydration. Their activities in a given habitat are thus limited by this constraint (Vitt and Caldwell, 2009).

It has been reported that the check dam can extend water period in the stream to be longer than those in the natural stream (Watershed Conservation and Management Office, 2008). The check dam may also change the soil moisture content (Gray and Leiser, 1982 cited in Solaimani et al., 2008). These may change the limiting factors for some amphibian species, and could be the main effect of check dam on amphibian in the check dam area.

Another possible relationship between check dam effect and amphibian is about the vegetation cover. Several reports showed that the amphibian can be affected by vegetation cover (Heyer, 1967; Vonesh, 2001), while it was found that seeding have more chance to grow in the check dam area (DeBano and Heede, 1987; Treepatanasuwan and Ploychareon, 2006; Zeng et al., 2009). Heyer (1967) studied herpetofauna assemblage in 6 vegetation zones in neo-tropical region and demonstrated that assemblages of herpetofauna and vegetation zones were closely correlated. In addition, Vonesh (2001) demonstrated that the tropical African herpetofouna in the logged forest had species diversity lower than in the unlogged forest albeits their similar vegetation type.

2.2.2 Reptile

In global, regional, or small scale, spatial occurrence and temporal activity pattern of reptile is related one way or another to temperature. Since reptile is an ectothermic animal, reptile must rely on environmental sources for heat gain. So, their options for activity are more limited than other higher vertebrates, which maintain elevated body temperature by mean of metabolism. The control of body temperature in reptile is depended on behavioral adaptations. To maximize the heat gain or loss, the behavioral adjustment can be short-term movements, posturing, or both. Basking is one of the most effective heat-gain behavior in reptiles allowing them to gain heat from sunlight radiation as well as conduction from surfaces they come in contact with (Vitt and Caldwell, 2009).

An ephemeral stream is regarded as an ideal location for basking since it has less canopy cover than those on the terrestrial habitat. Moreover, water in the ephemeral stream is usually found only in some period of the year such as in rainy period. Thus, reptile can use this habitat for sun basking or heat absorption from the stream bed. Since water period may be longer in the check dam stream than those in the natural ephemeral stream, this may greatly affects the reptile assemblage in the check dam area.

Another importance factor which may be affected by the check dam is the density of plant along the stream. Some researches reported that the check dam stream can facilitate the growth of vegetations more than in the natural stream (DeBano and Heede, 1987; Treepatanasuwan and Ploychareon, 2006; Zeng et al., 2009). Other researches also reported that reptile can be affected by the covered plant (Friend and Cellier, 1990; Heyer, 1967; Vonesh, 2001). Friend and Cellier (1990) demonstrated that reptile species distribution in the wetland reflex a complex set of environment including the vegetation cover and height structure. Heyer (1967) also found that 4 different assemblages of herpetofauna influenced by difference forest types. Even in the same forest type, Vonesh (2001) showed that the herpetofouna in the logged forest was less diverse than in the unlogged forest.

2.3 Species Assemblage

Species assemblage is a term used to describe a biological diversity in a given time and place. Given that species diversity is a number of species in a community which may be weighted by their relative abundances, species diversity is broadly used as an umbrella concept for total biological diversity including genetic diversity within a species, group of organism in the specific time and place, or ecosystem diversity at the community or ecosystem level (Krebs, 2009). Species assemblage, therefore, is a more suitable term to describe the specific subset of the whole biological diversity. Its use is more specific to species diversity of a community which are phylogenetically related (Magurran, 2004).

Species diversity measurement is an important part of conservation biology (Krebs, 2009). Magurran and McGill (2011) also mentioned that quantifying the biological diversity over the space or time is useful to explain the natural patterns as well as to manage and plan a policy with the sustainable use of nature. The simplest form of biodiversity measurement is the number of species or species richness in a given area (Krebs, 2009).

The species richness of amphibian and reptile can be influenced by elevations (amphibian: Phochayavanich et al., 2010; reptile: Owen, 1989), seasons (amphibian: Allmon, 1991; Phochayavanich, 2007; reptile: Fitzgerald, Cruz, and Perotti, 1999), precipitations (herpetofauna: Owen, 1989; amphibian: Woinarski, Fisher, and Milne, 1999), soil textures (herpetofauna: Woinarski et al., 1999), burned areas (herpetofauna: Giaretta et al., 1999), litter volumes (amphibian: Allmon, 1991), litter moistures (amphibian: Allmon, 1991), and structures of cover plant (reptile: Fitzgerald et al., 1999). Moreover, herpetofauna composition can be influenced by the difference in land use (amphibian: Phochayavanich, Thirakhupt, and Voris, 2008; herpetofauna: Barrett and Guyer, 2008; Vonesh, 2001). Therefore, change in environmental factors due to construction or land modification may results in positive or negative impacts on the amphibian and reptile assemblages in varying degree.

2.4 Distribution Pattern

In natural condition, each species can survive within its range of ecological conditions. This depends on the tolerance of individual of that species. Ecologist can determine the distribution range of each species by drawing a boundary of an area in which the particular species was found in the natural condition (Smith and Smith, 2009). Distributions are primarily determined by a presence or an absence of the suitable habitat for that species (Ricklefs and Miller, 2000). Population distribution is also influenced by an occurrence of suitable environmental conditions (Smith and Smith, 2009).

Number of individual of each species does not disperse with the same level of abundance within the distribution range. The organism can inhabit only in a location that have all factors within the tolerance range (Smith and Smith, 2009). So, the density can vary widely from location to location depending on the environmental conditions. The distribution pattern is a term used to describe how individuals are distributed within a given area. As a result, effect of environmental change on the population level may be observed at the change in distribution pattern or different abundance within the distribution range in a given area.

The distribution pattern of amphibian and reptile can be influenced by specific microhabitats (herpetofauna: Heyer, 1967), suitable breeding sites (herpetofauna: Duellman, 1966), refuge abundance (reptile: Friend and Cellier, 1990), vegetation covers (herpetofauna: Heyer, 1967, Vonesh, 2001; reptile: Friend and Cellier, 1990), shade and mulch cover (herpetofauna: Duellman, 1966), number of fallen logs (herpetofauna: Vonesh, 2001), leaf litter covers (herpetofauna: Vonesh, 2001; reptile: Friend and Cellier, 1990), climatic factors (herpetofauna: Duellman, 1966; Heyer, 1967; Woinarski et al., 1999), soil textures (herpetofauna: Woinarski et al., 1999), soil moisture (amphibian: Friend and Cellier, 1990, herpetofauna: Vonesh, 2001), and flooding period and levels (herpetofauna: Friend and Cellier, 1990). Since most, if not all, of these factors can be affected by the construction or land modification, amphibian and reptile distribution pattern may be affected in the positive or negative ways and in varying degree by changes in these factors.

2.5 Preliminary Field Survey and Study Site Selection

2.5.1 Study Site

The study site, the Chulalongkorn University Forest and Research Station [CFRS], is a 300-ha area located at Lai Nan Sub-district, Wiang Sa District, Nan Province in northern part of Thailand (UTM zone 47Q: N2051960–2054260 and E0688400–0690360) (Figure 2-1). The average of total annual rainfall during 2000–2009 was 1159.6 mm. The average air temperature and relative humidity in that duration were 26.5 °c and 76.2 %, respectively. This area is covered by a deciduous forest composing of two plant communities: deciduous dipterocarp and mixed deciduous forest (Dumrongrojwatthana, 2004). According to Kutintara (1999), the wildlife compositions in the mixed deciduous and deciduous dipterocarp forest in Thailand are similar due to the similarity in plant community structure. Most of streams in this area are ephemeral streams that are filled only during the wet season. Even in the wet season, water in the stream is flowing only during a heavy rain, and become standing water and dries out only a few days later.

Dumrongrojwatthana (2004) reported that the CFRS was previously disturbed by human activities from low to high levels throughout the area in a past few decades. Although, when this study was conducted, both study streams were covered by the natural forest, it can be implied based on the previous research that forest covered at both streams are the successive forest, not primary forest. This also indicated that amphibian and reptile communities were potentially disturbed by human activities in the past.

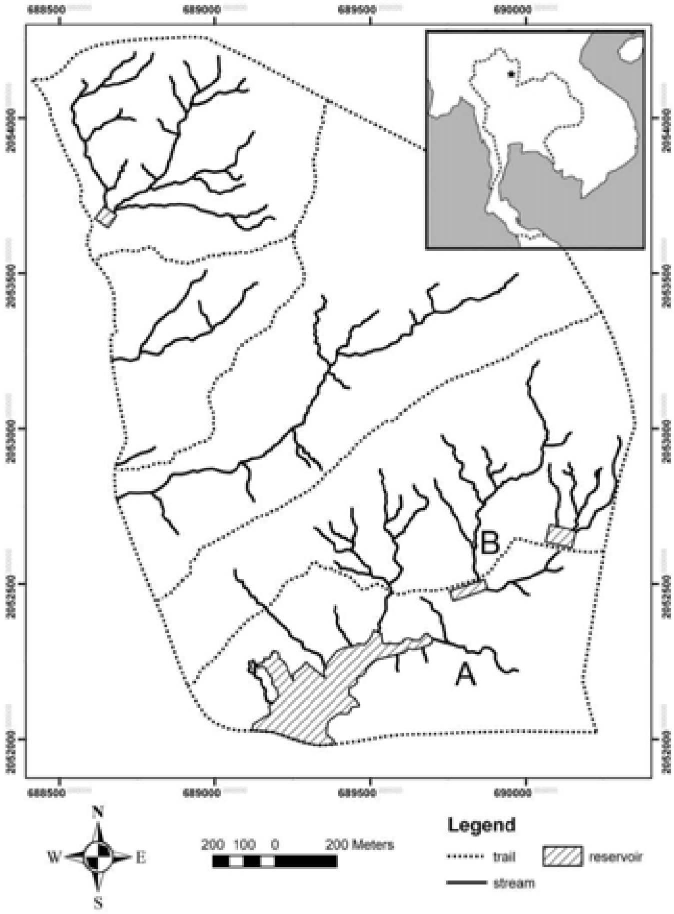

Figure 2-1 Map of the Chulalongkorn University Forest and Research Station, Nan Province, northern part of Thailand (Picture modified from Dumrongrojwatthana, 2004). “A” indicates the study stream with check dam construction completed in 2008, “B” indicates the study stream with check dam construction scheduled in the dry period of late 2009–early 2010.

2.5.2 Check Dam Construction Scheme

When this study was started (2009 A.D.), 27 check dams had been constructed at the CFRS (Figure 2-1). The largest number of the check dams are constructed in stream “A” (13 check dams). Ground survey also showed that slope of the stream and stream bank of stream “A” are not too steep indicating a more suitable habitat for amphibian and reptile. Therefore, stream “A” was selected as the study site. Among the remaining streams with no check dam construction, stream “B” was selected as another study site due to the similar stream characteristics (width, depth, and slope) with those of steam “A”. Both stream “A” and “B” are located in the deciduous forest with approximated distance of only 500 m, therefore the original compositions of amphibian and reptile are expected to be the same. In stream “A”, the check dam construction has been completed in 2008. In stream “B”, the check dam has been constructed during December 2009–February 2010 (dry period). The check dam height was designed to be similar to that of the stream depth or approximately 1 m, while the check dam length was designed to be longer than the stream width (2 m) so that its structure would securely embedded into the stream bank. The distance between check dams were determined by the maximum water level point of the downstream check dam (Figure 2-2). The check dams were constructed in orderly fashion until the end of that stream.

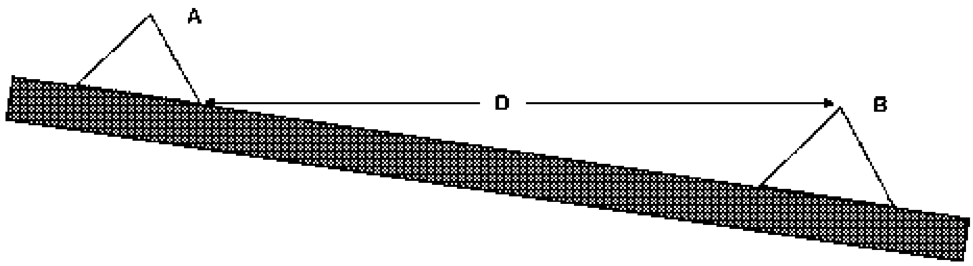

Figure 2-2 Diagram of check dam showing the distance between check dams.
A: upstream check dam, B: downstream check dam, D: distance between check dam

CHAPTER III

ENVIRONMENTAL CONDITIONS ALONG EPHEMERAL STREAMS AND TERRESTRIAL TRANSECTS IN A DECIDUOUS FOREST AT NAN PROVINCE: SPATIAL AND TEMPORAL COMPARISONS

3.1 Introduction

Numerous check dams have been constructed throughout the rural area in Thailand since it is regarded as simple enough for local people to construct by themselves with minimal investment, yet effective enough to prolong the surface water period. The check dam can increase the absorption rate of underground water and the stream hydroperiod (Watershed Conservation and Management Office, 2008). Check dams (also known as silt trappers) were mentioned as the effective method for soil and water conservation (Huang, et al. 2009; Xiang-zhou et al., 2004). The check dam can also reduce the soil erosion, influence on physical characteristics of the channels, and keep the upstream channel stability (Castillo et al., 2007; Liu, 1992; Solaimani et al., 2008; Zeng et al., 2009).

In Thailand, check dams are mainly constructed in ephemeral streams where water is present only during the wet season. Therefore, a duration when the check dam can perform its full function in this kind of stream greatly depends on the climatic conditions. Normally, the check dam will start its function at the onset of a rainy season when the stream is filled with rain and runoff water, and cease to function in a complete absence of precipitation during dry season.

Since the primary effect of check dam on environment is the change in water and moisture contents of soil and litter in the area, animals that are sensitive to the moisture change (i.e. amphibians) and the prolonged water period of the stream (i.e. reptiles) could be affected in varying degree. In order to evaluate effect of the check dam on these animals, it is thus crucial to initially examine climatic conditions as a contributing factor of weather in the area, as well as changes in environmental conditions as a result of the check dam, including hydroperiod, number of water body, water depth, soil moisture content and leaf litter moisture content. Therefore, objectives for this part of the study are as follows. First, it is aimed to describe the climate characteristics of the study area. Then, the second objective is to compare the environmental condition between check dam and non-check dam areas (spatial comparison). While, the third objective is to compare the environmental conditions between pre- and post-check dam periods (temporal comparison).

3.2 Methodology

3.2.1 Climate data and determination of season

Data on total rainfall and air temperature were collected from the nearest meteorological station every month from April 2009 to April 2011. Total rainfall and average air temperature of each month were plotted together in a climate diagram (Walter, Harnickell, and Mueller-Dombois, 1975). In this diagram, wet and dry seasons were determined based on the following criteria. The months that have the total amount of rainfall higher than twice of the average air temperature were indicated as in the wet season. On the other hand, months that have the total amount of rainfall lower than twice of the average air temperature were indicated as the dry season. This diagram was used to determine the start and the end of the study periods in this research. Each study period began at the onset of wet season or the start of check dam functioning period and ended at the end of dry season.

3.2.2 Transect sampling

There were 2 types of transects used to survey amphibian and reptile in this study. So, the physical factors and other fauna were sampled base on these transect types. The first one is a stream transect for the aquatic habitat and the second type is a terrestrial strip transect for the terrestrial habitat.

3.2.2.1 Stream transect

Ten stream transects were constructed in each stream (A and B) (Figure 3-1). Each stream transect was started from one check dam (in stream A) or the positions of the check dam construction (in stream B) to the next upstream check dam (or upstream check dam position) or the maximum water level point of that check dam. The width of stream transects was similar to the stream width or approximately 2 m, while the length of transect was the same as a distance between the two study check dams.

3.2.2.2 Terrestrial strip transect

There were 4 sets of terrestrial strip transects located parallel to the stream transect with a perpendicular distance from the stream of 5, 10, 25, and 50 m, respectively (Figure 3-1). As a result, there were 40 terrestrial transects in each stream. The length of each terrestrial transect was equal to the vector length of the corresponding stream transect.

All transects including 20 stream transects and 80 terrestrial transects were separated into 5 transect groups according to the distance from the stream. The data were analyzed according to these 5 transect groups including stream transect (0 m from the stream) and 5, 10, 25, and 50 m terrestrial transects.

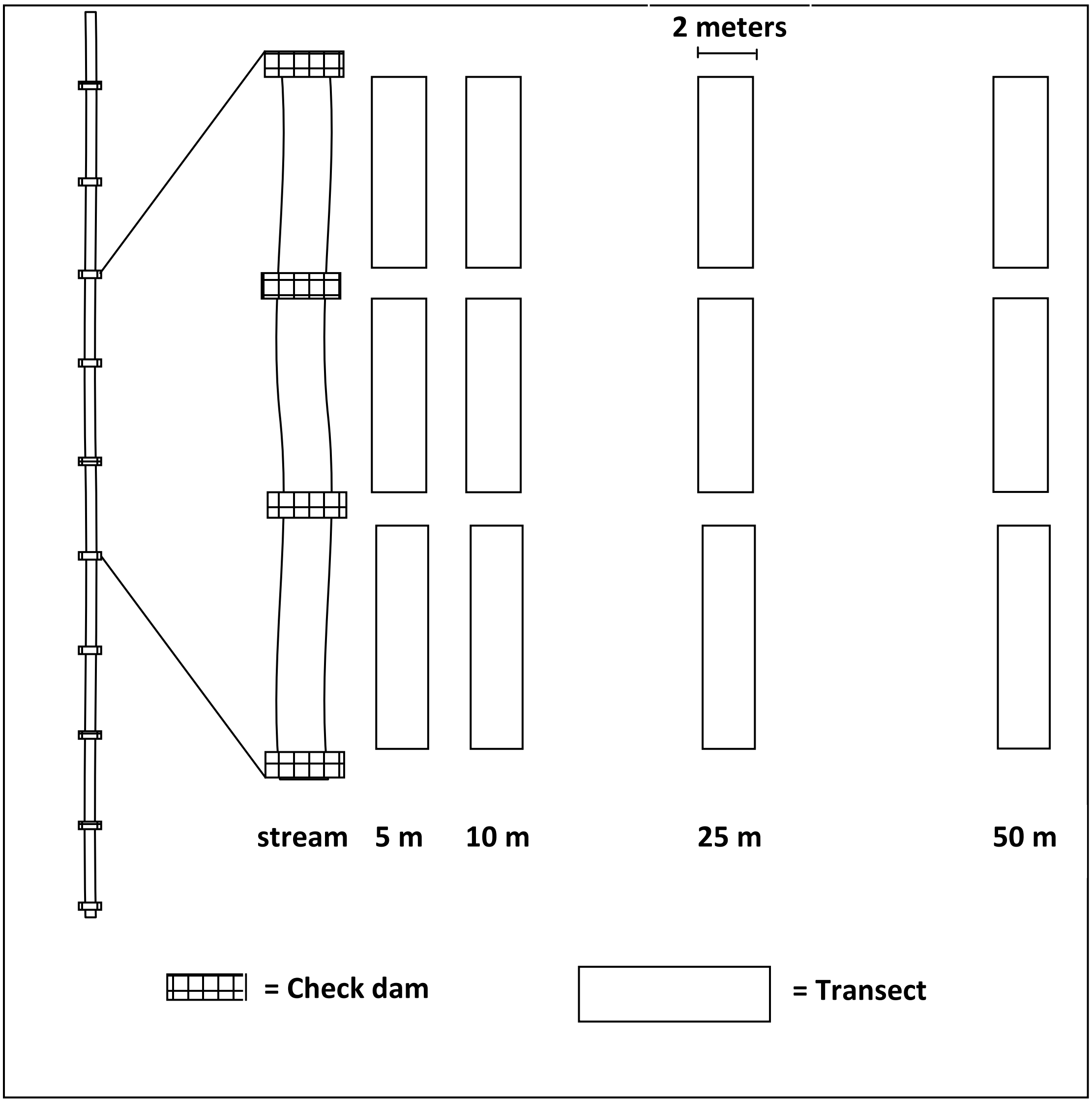

Figure 3-1 Diagram of a stream and 4 terrestrial strip transects (5, 10, 25, and 50 meters far from the stream) used for the study in each stream.

3.2.3 Physical factors

Number of days that water was present in the stream transect in each survey was recorded and used to determine a hydroperiod, and presented as percentage of the study period. Number of water body found in the stream transect in each survey was recorded. Water depth at the deepest point of the stream transect was recorded in each survey. Soil and leaf litter were collected from every transects in each survey. Their wet and dry weights were recorded to determine percentage of water content.

3.2.4 Survey of other fauna

Since several animals such as fish, crab, and aquatic insect can interact and play roles in the assemblage and distribution of amphibian (Duellman and Trueb, 1994), the presence and absence of other animals in the water body of the stream transects were recorded. Dip-net was used to collect other fauna from the water body in each survey in the stream transect. Taxon of fish and other macro-invertebrates found were identified to order level.

3.2.5 Data analysis

3.2.5.1 Spatial and temporal comparisons of physical factor in the presence and absence of check dam

For the spatial comparison between check dam and non-check dam areas, hydroperiod, number of water body, water depth, soil moisture content, and leaf litter moisture content were collected from both check dam (stream A) and non-check dam (stream B) areas every month during the 1st year of this study (April 2009 to March 2010). For the temporal comparison between pre- and post-check dam periods, hydroperiod, number of water body, water depth, soil moisture content, and leaf litter moisture content from stream B were collected every month from the 1st year (April 2009 to March 2010: pre-check dam period) and the 2nd year (May 2010 to February 2011: post-check dam period). The data were compared between the presence and absence of check dam by Mann-Whitney U-test.

3.2.5.2 Spatial and temporal comparisons of other fauna assemblage

The data from streams A and B in the 1st year of this study period were used for the spatial comparison and the data from stream B in the 1st and the 2nd year of study periods were used for the temporal comparison. The diversity of other fauna at the order level were compared between the presence and absence of check dam by rarefaction value and its 95% confidence interval calculated by EstimateS 8.2 program (Colwell, 2006). Afterward, the values were plotted as a function of sampling efforts. With this plot, significant difference in order diversity is indicated by an absence of overlap in the confidence interval of rarefaction curves at the maximum sampling effort (Colwell, Mao, and Chang, 2004).

3.3 Results

3.3.1 General climate description

During the 2 year study period from April 2009 to April 2011, the average air temperature and the average total rainfall of each month were 26.75°c and 80.54 mm, respectively. Since the study periods in this research were determined by the onset of wet season to an end of dry season based on the climate diagram (Figure 3-2), the study period of the 1st year started at April 2009 and ended at March 2010 (12 months) and the study period of the 2nd year started at May 2010 and ended at February 2011 (10 months). These study periods were used as the standard criteria for data manipulation and analysis in the entire research.

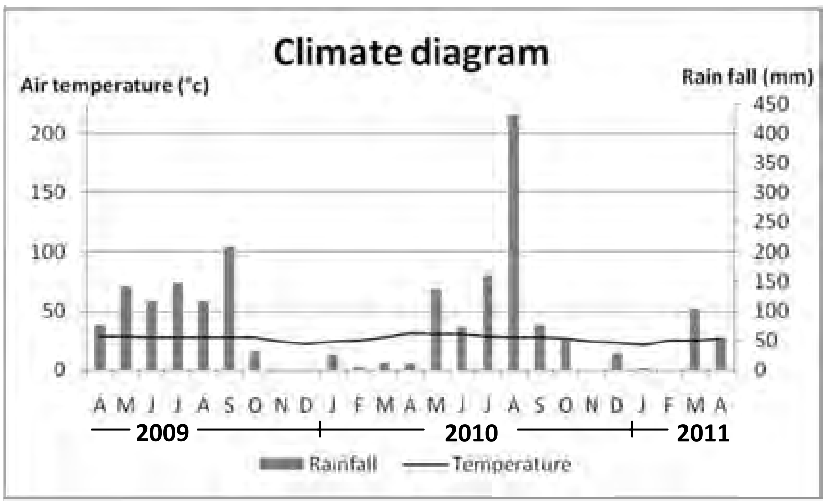

Figure 3-2 Climate diagram or climograph during the study period started from April 2009 to April 2011.

3.3.2 Spatial comparison of environmental conditions between check dam and non-check dam areas

Figure 3-3 showed photographs of stream A and B in the 1st year of this study where the data were obtained for the spatial comparison experiment.

Figure 3-3 Photographs of stream A and B during the 1st year of this study. Letter A1 and A2 respectively indicated the stream and terrestrial habitats in the check dam area. Letter B1 and B2 respectively indicated the stream and terrestrial habitats in the non-check dam area.

3.3.2.1 Water pattern in the stream

Several changes in physical factors were found in the check dam area. Total number of days that the available water was found in the stream during the study period in the check dam area (115 days) was higher than those in the non-check dam area (61 days). Table 3-1 shows that hydroperiod in the check dam area was significantly longer than those in the non-check dam area. The number of water body and water depth in check dam area were also significantly higher than those in the non-check dam area.

Table 3-1 Mean ± SD of hydroperiod, number of water body, and water depth in check dam and non-check dam areas.

Physical factors	Check dam	Non-check dam
Hydroperiod (%)	31.48±11.35*	16.82±12.64
Number of water body (Number per transect per month)	0.50±0.81*	0.22±0.48
Water depth (cm)	11.03±17.79*	2.12±5.17

Remark: An asterisk (*) indicates significant difference from the non-check dam area at $p \leq 0.05$.

3.3.2.2 Soil and leaf litter moisture content

The results indicated that soil moisture contents at stream transect and 5, 10, and 25 m terrestrial transects were significantly higher in the check dam area than those in the non-check dam area (Table 3-2). However, the soil moisture content at 50 m terrestrial transect was not significantly different between in these two areas.

Table 3-2 Mean ± SD of soil moisture content at each transect in check dam and non-check dam areas.

Transects	Check dam	Non-check dam
Stream	20.37±15.38*	10.98±8.73
5 m	11.93±9.15*	9.74±7.84
10 m	12.95±9.41*	9.14±6.98
25 m	9.73±7.74*	8.22±7.08
50 m	8.77±7.66	8.24±6.66

Remark: An asterisk (*) indicates significant difference from the non-check dam area at $p \leq 0.05$.

The results indicated that the leaf litter moisture content at 25 m terrestrial transect was significantly higher in the check dam area than those in the non-check dam area (Table 3-3). However, the leaf litter moisture contents at stream transect and 5, 10, and 50 m terrestrial transects were not significantly different between check dam and non-check dam areas.

Table 3-3 Mean ± SD of leaf litter moisture content at each transect in check dam and non-check dam areas.

Transects	Check dam	Non-check dam
Stream	40.56±40.79	38.99±32.70
5 m	46.24±43.86	50.69±46.73
10 m	58.88±53.47	47.87±38.89
25 m	58.36±50.20*	39.57±32.66
50 m	47.26±37.77	45.50±39.36

Remark: An asterisk (*) indicates significant difference from the non-check dam area at $p \leq 0.05$.

3.3.2.3 Other fauna in the stream

The combined data from check dam and non-check dam areas indicated that 7 orders of fish, insect, and other arthropods were found (Table 3-4). All 7 orders, including 1 order of fish, 4 orders of aquatic insects, and 2 orders of other arthropods, were found in the check dam area. However, only 3 orders of aquatic insects, and 1 order of other arthropods were found in the non-check dam area.

Table 3-4 Orders of fish, aquatic insects, and other arthropods in water body in check dam and non-check dam streams.

Group of animal	Check dam	Non-check dam
Fish	Cypriniformes	-
Aquatic insect	Odonata	Odonata
	Hemiptera	Hemiptera
	Coleoptera	Coleoptera
	Diptera	-
Other arthropods	Arachnida	Arachnida
	Decapoda	-

However, at the stream transects, the rarefaction curves of check dam and non-check dam areas (Figure 3-4) show an overlap between 95% confidence interval of these 2 curves, indicating that the order diversity of other fauna in the stream habitat was not significantly different between these 2 areas.

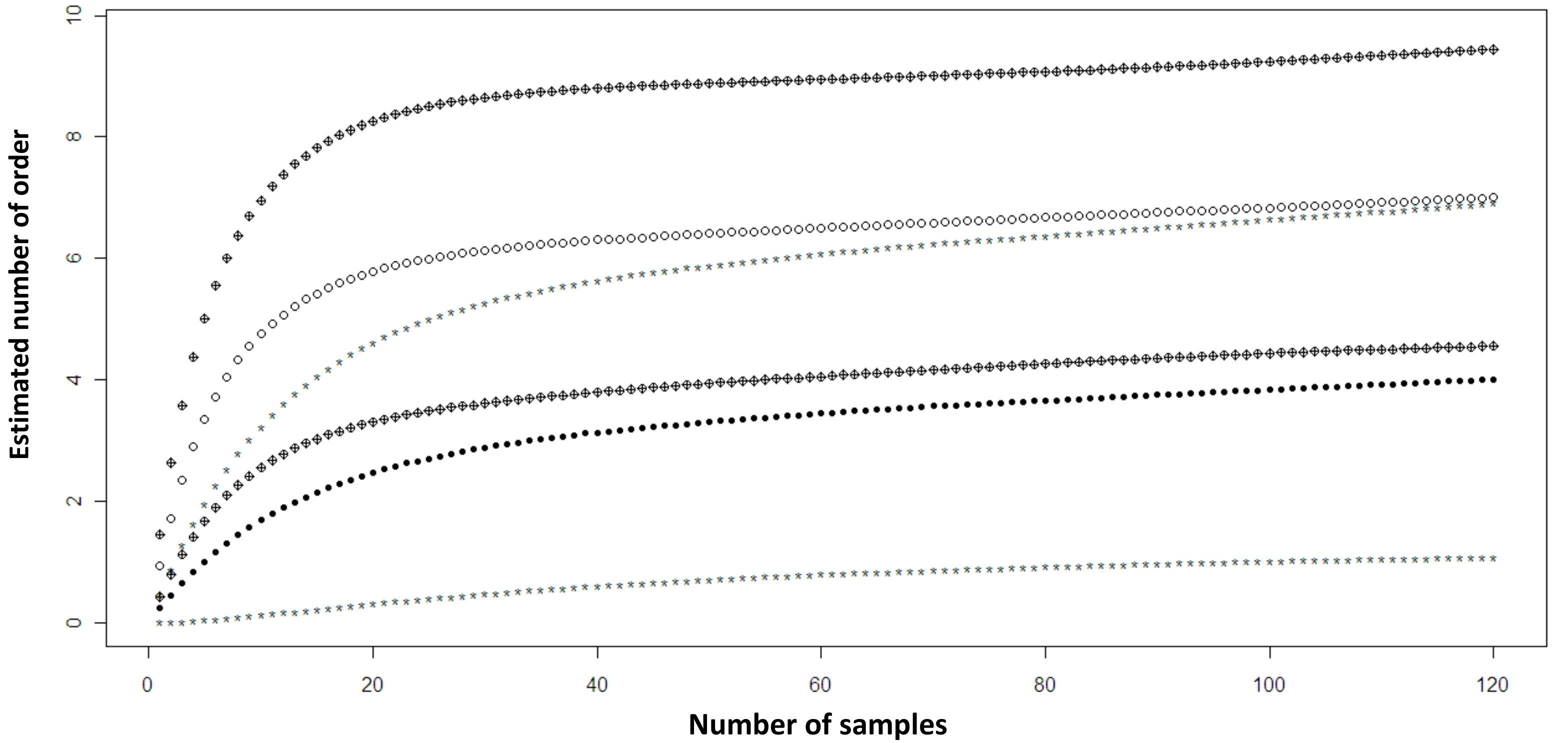

Figure 3-4 Comparison of order richness between check dam and non-check dam areas at stream habitat by rarefaction curve with 95% confidence interval. Open dots (°) represent check dam rarefaction curve. Close dots (•) represent non-check dam rarefaction curve. Plus cycle mark (⊕) and star mark (☆) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

3.3.3 Temporal comparison of environmental conditions between pre- and post-check dam periods

Figure 3-5 showed photographs of stream B during the 1^{st} and 2^{nd} year of this study when the data were obtained for temporal comparison.

Figure 3-5 Photographs of the stream B between pre- and post-check dam periods. The letter A and B indicated pre- and post-check dam periods, respectively.

3.3.3.1 Water pattern in the stream

Several changes in physical factors were found after check dam construction. Total number of days that the available water was found during the study period in the post-check dam period (148 days) was higher than those in the pre-check dam period (61 days). In stream B, the hydroperiod in post-check dam period was significantly longer than those in the pre-check dam period (Table 3-5). Number of water body and water depth in the post-check dam period was significantly higher than those in the pre-check dam period.

Table 3-5 Mean ± SD of hydroperiod, number of water body, and water depth in pre- and post-check dam periods.

Physical factors	Pre-check dam	Post-check dam
Hydroperiod (%)	16.82±12.64	48.68±12.82*
Number of water body (Number per transect per month)	0.22±0.48	0.75±0.89*
Water depth (cm)	2.12±5.17	20.85±26.87*

Remark: An asterisk (*) indicates significant difference from the pre-check dam period at p≤0.05.

3.3.3.2 Soil and leaf litter moisture content

Among 5 transect groups, only soil moisture content at the stream transect was significantly higher in the post-check dam period than those in the pre-check dam period (Table 3-6). The soil moisture contents at all 4 terrestrial transects were not significantly different between pre- and post-check dam periods.

Table 3-6 Mean ± SD of soil moisture content at each transect in pre- and post-check dam periods.

Transects	Pre-check dam	Post-check dam
Stream	10.98±8.73	20.70±15.09*
5 m	9.74±7.84	10.58±6.79
10 m	9.14±6.98	10.36±7.24
25 m	8.22±7.08	9.59±7.58
50 m	8.24±6.66	8.91±6.42

Remark: An asterisk (*) indicates significant difference from the pre-check dam period at p≤0.05.

Results of the leaf litter moisture content, however, were on the opposite direction with the results of soil moisture content. The leaf litter moisture contents at the stream transect were not significantly different between pre- and post-check dam periods, while the leaf litter moisture contents in all 4 terrestrial transect groups were significantly higher in the post-check dam period than those in pre-check dam period (Table 3-7).

Table 3-7 Mean ± SD of leaf litter moisture content at each transect in pre- and post-check dam periods.

Transects	Pre-check dam	Post-check dam
Stream	38.99±32.70	35.73±19.82
5 m	50.69±46.14	65.66±54.04*
10 m	47.87±38.89	62.52±52.34*
25 m	39.57±32.66	52.20±41.14*
50 m	45.50±39.36	57.65±43.47*

Remark: An asterisk (*) indicates significant difference from the pre-check dam period at $p \leq 0.05$.

3.3.3.3 Other fauna in the stream

The combined data from both pre- and post-check dam periods indicated that 7 orders of fish, insects and other arthropods were found (Table 3-8). Only 4 orders, including 3 orders of aquatic insects and 1 order of other arthropods, were found in the pre-check dam period, whereas all 7 orders including 5 orders of aquatic insects and 2 orders of other arthropods, were found in the post-check dam period.

Table 3-8 Orders of fish, aquatic insects, and other arthropods found in pre- and post-check dam periods.

Group of animal	Pre-check dam	Post-check dam
Aquatic insect	Odonata	Odonata
	Hemiptera	Hemiptera
	Coleoptera	Coleoptera
	-	Diptera
	-	Ephemeroptera
Other arthropods	Arachnida	Arachnida
	-	Decapoda

However, at the stream habitat, the rarefaction curves of pre- and post-check dam periods (Figure 3-6) show an overlap between 95% confidence interval of these 2 curves, indicating that the order diversity was not significantly different between these 2 periods in the stream habitat.

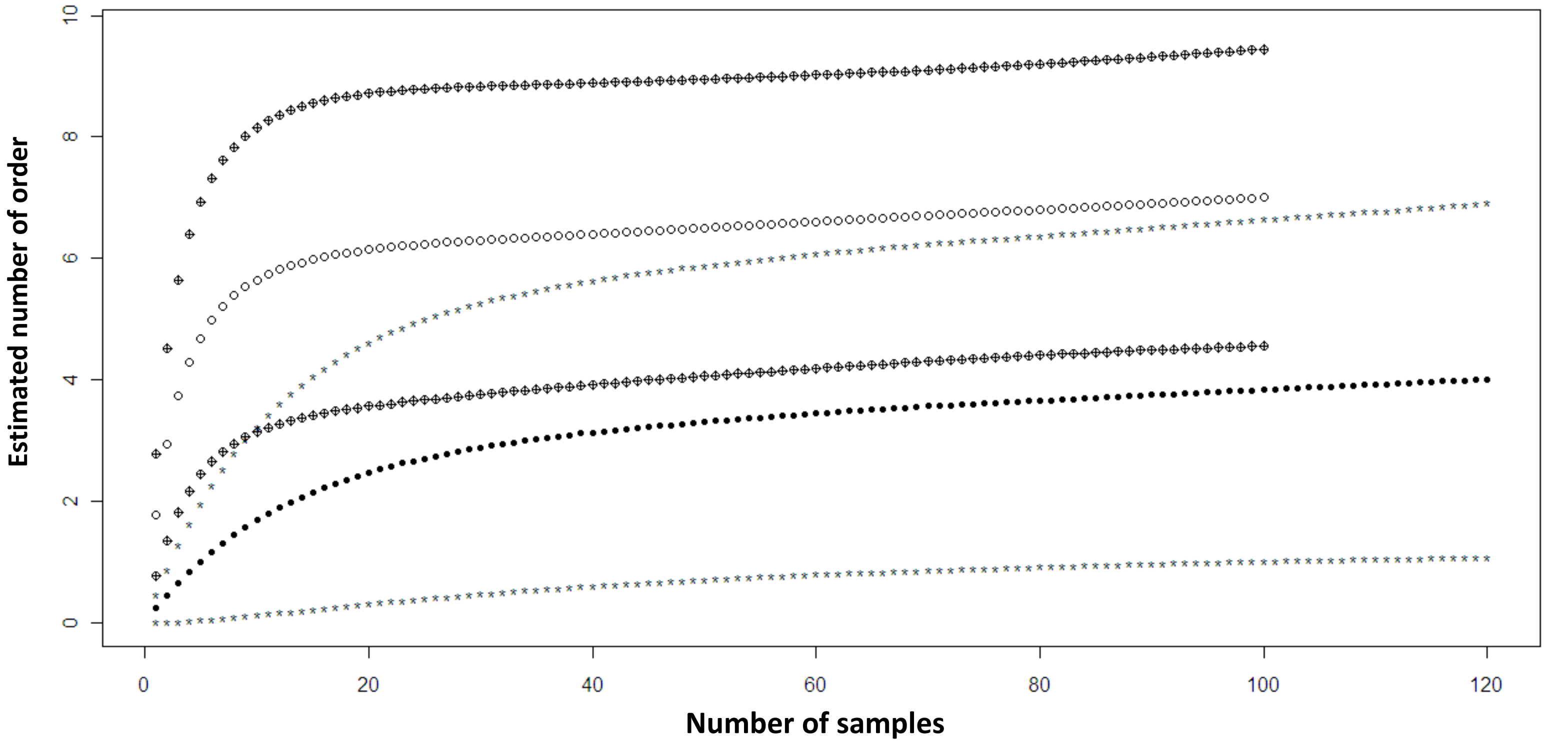

Figure 3-6 Comparison of order richness between pre- and post-check dam periods at stream habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent pre-check dam rarefaction curve. Open dots (°) represent post-check dam rarefaction curve. Star mark (✰) and plus cycle mark (⊕) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

3.4 Discussion

From the climate data during this 2-year period, the wet season of the study area started around April–May and ended around September–October, while the dry season started around October–November and ended around February–April. The periods of wet and dry seasons found in this study were similar to the general season description of Thailand by Royal Institute (2002).

According to the rainfall data, the raining season of the 2nd year came later than those of the 1st year (shift from April to May) and the end of dry season of the 2nd year came earlier than those of the 1st year (shift from April to March). Therefore, length of the 1st year study period was 12 months during April 2009 to March 2010 whereas length of the 2nd year study period was 10 months during May 2010 to February 2011.

The data of check dam and non-check dam areas indicated that hydroperiod, number of water body, and water depth were increased as a result of the check dam construction. Soil moisture contents in most transect groups including stream transect and 5, 10, and 25 m terrestrial transects, were also higher in the check dam area than those in the non-check dam area. These results show that the soil moisture content in the terrestrial transect groups can be potentially increased by the check dam. However, since the forest community in the check dam area is more toward a mixed deciduous forest whereas the forest community in the non-check dam area is more toward a deciduous dipterocarp forest (Dumrongrojwatthana, 2004), the difference in vegetation cover may be another possible factor that cause the difference in soil moisture contents between these area.

The leaf litter moisture content in most of the transect groups were similar between check dam and non-check dam areas. This could be concluded that the check dam has little or no effect on the leaf litter moisture content in this area. Alternatively, since both check dam and non-check dam areas were subjected to similar rainfall pattern and the canopy cover in these areas are relatively opened (Kutintara, 1999), the leaf litter moisture contents of these areas can be directly and similarly affected by the rainfall rather than the check dam.

Although, data on water pattern in the stream showed the significant difference between check dam and non-check dam areas, other fauna diversities in the water body did not show a significant difference between these 2 areas. This may be due to the fact that the water body presented in both check dam and non-check dam areas were standing water with similar holding capacity to these animals.

After the check dam construction, all physical factors indicated that the water was increased in the area. This confirms the earlier report that check dam can prolong the water in the stream. However, it is interesting to note that the soil moisture content in this part (pre- vs. post-check dam comparison) did not showed the same results as in the previous part (check dam vs. non-check dam comparison). Only soil moisture content in the stream transect was significantly higher in the post-check dam period than those in the pre-check dam period. In every terrestrial transect, the soil moisture content were similar between pre- and post-check dam periods. This indicated that check dam can affect the soil moisture content only in the stream transect but not in the terrestrial transects.

The leaf litter moisture content data showed that leaf litter moisture value were significantly different between pre- and post-check dam periods at all terrestrial transects whereas the values in the stream transect was not significantly different. These indicate that check dam may not be the cause of change in leaf litter moisture content in the terrestrial habitat. The possible reason for this discrepancy is about the different in weather pattern between years. Since the canopy cover in the study area (deciduous dipterocarp forest) are more opened that other evergreen forest types (Kutintara, 1999), the rainfall can be directly affected to the leaf litter moisture content. Therefore, the difference in leaf litter moisture contents between in pre- and post-check dam periods may be due to the difference in rainfall patterns between years rather than the check dam.

Although all physical factors indicated that the water pattern in the stream were different between pre- and post-check dam periods, other fauna diversities (at the order level) were not significantly different between pre- and post-check dam periods. This could be due to the similar pattern of standing water in both pre- and post-check dam periods where the aquatic insect and other arthropod communities could be established in the same way in these periods.

However, it is of importance to note that, based on the results from spatial and temporal comparisons, four groups of animal including Cypriniformes (fish), Diptera (larva of fly), Ephemeroptera (larva of mayfly), and Decapoda (shrimp) were found only in the check dam condition. These indicated that the prolonged hydroperiod caused by the check dam could support and sustain some groups of animal that the natural condition of the ephemeral stream cannot.

CHAPTER IV

EFFECTS OF CHECK DAM ON AMPHIBIAN ASSEMBLAGE AND DISTRIBUTION ALONG EPHEMERAL STREAMS IN A DECIDUOUS FOREST AT NAN PROVINCE: A SPATIAL COMPARISON BETWEEN CHECK DAM AND NON-CHECK DAM ARES

4.1 Introduction

Check dams have been widely implemented in rural areas of Thailand since it is regarded as simple enough for local people to construct by themselves with minimal investment, yet effective enough to prolong the surface water period. Since the check dam can increase the absorption rate of underground water and the stream hydroperiod (Watershed Conservation and Management Office, 2008), it was considered as an effective method for soil and water conservation (Huang et al., 2009; Xiang-zhou et al., 2004). Check dam can also reduce the sediment erosion, influence on physical characteristic of the channels, and keep the upstream channel stability (Castillo et al., 2007; Liu, 1992; Solaimani et al., 2008; Zeng et al., 2009). Although, there are several researches on the effect of check dam on physical factors, there is still a lack of information about its effect on biotic factors especially on the animal in the vicinity area.

One importance aspect of biotic factors is the species assemblage and distribution pattern in the particular area because the biological diversity is frequently used as surrogate for ecosystem health and function, and the persistence of any species in specific area indicates that there are available habitats for those species (Ricklefs and Miller, 2000). Since water and moisture patterns are the primary change as a result of the check dam construction, and amphibian is the most sensitive terrestrial vertebrate to water and moisture change (Vitt and Caldwell, 2009), amphibian assemblage and distribution pattern were selected as monitoring parameters in this study. In this part of the study, the effects of check dam were determined based on a spatial comparison between check dam and non-check dam areas in the same survey period in order to minimize effect of weather conditions. The objectives of this study include 1) to determine and compare the amphibian assemblage, and 2) to determine and compare the distribution pattern of amphibian along the ephemeral streams between check dam and non-check dam areas.

4.2 Methodology

4.2.1 Study site and survey period

At the Chulalongkorn University Forest and Research Station, Nan Province (UTM zone 47Q: N2051960-2054260 and E0688400-0690360), an ephemeral stream with existing check dams (stream A) and another similar stream without any check dam (stream B; Figure 2-1) were used in this study as a check dam area and a non-check dam area, respectively. The surveys were conducted at both areas in the same period during April 2009 to March 2010.

4.2.2 Amphibian survey method

There were 2 types of transects used to survey amphibian in this study. The first one is a stream transect for an aquatic habitat. The second type is a terrestrial strip transect for the terrestrial habitat.

4.2.2.1 Stream transect

Ten stream transects were constructed in each check dam and non-check dam streams. Each stream transect was started from one check dam (in check dam stream) or the positions of the check dam construction (in non-check dam stream) to the next upstream check dam (or upstream check dam position) or the maximum water level point of that check dam (Figure 3-1). The width of stream transects was similar to the stream width or approximately 2 m yet the length of transect was depended on the distance between two corresponded check dams. Therefore, the total number of stream transects in both check dam and non-check dam were 20 stream transects.

4.2.2.2 Terrestrial strip transect

There were 4 terrestrial strip transects located parallel with each stream transect with the perpendicular distance from the stream of 5, 10, 25, and 50 m, respectively (Figure 3-1). The total number of terrestrial transects in both check dam and non-check dam areas was 80 transects. The length of each transect was equal to the vector length of the corresponding stream transect.

The active survey based on transect sampling (Heyer et al., 1994) was used to survey amphibian along each stream and terrestrial transects. Amphibians in the water, on the bare ground, under the leaf litter, and on the tree with height less than 1.5 m were recorded from these transects. Each survey was begun at the starting point to the end of the transect. Amphibians were identified to species and numbers of individuals of each species were recorded. In each month, the surveys were conducted for 16 consecutive days until every transect was studied. For each day, the total of 6 transects, including 3 transects from check dam area and 3 transects from non-check dam area, were surveyed during day time (9:00-12:00) and other 6 transects were surveyed during night time (19:00-22:00). The selection of these transects were on random basis. During each survey, special care was given to avoid habitat disturbance in the remaining transects.

From all 100 transects (20 stream transects and 80 terrestrial transects), the data were separated into 5 transect groups according to the distance from the stream composing of stream transect (0 m from the stream) and 5, 10, 25, and 50 m transects far from the stream.

4.2.3 Data analysis

The data were analyzed according to the transect groups and compared between check dam and non-check dam areas.

4.2.3.1 Amphibian assemblage

Proportional abundance of each amphibian species in each area was used for the general comparison of amphibian species so that the high abundance species could be identified. This was calculated by dividing amphibian density of each species by the total amphibian density found in a particular area.

Amphibian assemblage was divided into species diversity and composition. For amphibian diversity, rarefaction model was used to compare the amphibian species richness to avoid the effect of unequal transect length between check dam and non-check dam areas (Magurran, 2004). Rarefaction value and its 95% confidence interval were calculated by EstimateS 8.2 program (Colwell, 2006). Afterward, the values of check dam and non-check dam were plotted as a function of sampling efforts. With this plot, significant difference in species diversity is indicated by an absence of overlap in the confidence interval of rarefaction curves between check dam and non-check dam areas at the maximum sampling effort (Colwell et al., 2004). For amphibian composition analysis, dissimilarity matrix between check dam and non-check dam areas was constructed based on the Bray-Curtis distance measurement. Then, two dimensional ordination was plotted by using non-metric multidimensional scaling (NMDS). The data were also analyzed by analysis of similarity (ANOSIM) with 1,000 permutations to test for the significant difference in amphibian composition between check dam and non-check dam areas. The R-statistics from ANOSIM indicates the dissimilarity in species compositions between two sites, and normally ranges from 0 (highly similar between groups) to 1 (highly different between groups). The following criteria (Clarke and Gorley, 2001) was used to interpret the data:

$R \geq 0.75$ indicates well separation between these two compositions.

$R = 0.74$ to 0.5 indicates separation with some overlap.

$R = 0.49$ to 0.25 indicates separation with strong overlap.

$R < 0.25$ indicates no difference between these two compositions.

The construction of the dissimilarity matrix, the ordination plot, and the analysis of similarity were run by using "vegan" package in R program (R Development Core Team, 2011).

4.2.3.2 Amphibian distribution pattern

In order to conform with the nonparametric requirements, the abundance showed in this part were in the form of mean rank of abundance and can be calculated as follows. First, number of species found in each transect were combined to get the total sample number (N). Second, abundance of every species in every transect was sorted from the lowest to the highest. In this case, the rank of abundance would range from 1 (the lowest abundance) to N (the highest abundance). Finally, mean rank of abundance of each transects is calculated based on an average of rank number of every samples found in the particular transect.

For each check dam and non-check dam areas, the abundance of each amphibian species was compared among 5 transect groups by Kruskal-Wallis Test with nonparametic Tukey-type multiple comparisons at $p \leq 0.05$ (Zar, 1999). There are three possible scenarios of the difference in distribution pattern between check dam and non-check dam areas as follows. First, an abundance of a particular species showed a significantly higher value in one transect group in the check dam area and showed a significantly higher value in another transect group in the non-check dam area. Second, an abundance of a particular species did not show any significant difference among transects in the non-check dam area, but showed a significantly higher value in one or some transect groups in the check dam area. Third, an abundance of a particular species showed a significantly higher in one or some transect groups in the non-check dam area, but showed no significant difference among transects in the check dam area.

4.3 Results

4.3.1 Amphibian assemblage

4.3.1.1 Amphibian diversity

The overall amphibian species richness found in both check dam and non-check dam areas during the 1st year study period was 16 species (Table 4-1). The species richness in check dam and non-check dam areas were equally at 15 species. The highly abundant species found in these two areas are *Occidozyga martensii, Microhyla fissipes, M. butleri,* and *Micryletta inornata*.

The rarefaction curves of check dam and non-check dam areas at every transects (Figure 4-1 to 4-5) show varying degree of overlap between 95% confidence interval of these two curves, indicating that the amphibian diversity was not significantly different between these two areas at any of the stream and terrestrial habitats.

Table 4-1 Proportional abundance of amphibian in check dam and non-check dam areas.

Family/Species	Proportional abundance		
	Check dam	Non-check dam	Both areas
Bufonidae			
Bufo macrotis	0.125	0.042	0.084
Ranidae			
Fejervarya limnocharis	0.037	0.037	0.037
Hoplobatrachus rugulosus	0.001	-	0.001
Limnonectes pileatus	0.001	0.008	0.005
Occidozyga lima	0.016	0.003	0.009
Occidozyga martensii	0.269	0.175	0.222
Rhacophoridae			
Chirixalus doriae	-	0.003	0.001
Polypedates leucomystax	0.028	0.014	0.021
Microhylidae			
Calluella guttulata	0.001	0.011	0.006
Kaloula pulchra	0.009	0.017	0.013
Microhyla berdmorei	0.004	0.014	0.009
Microhyla butleri	0.052	0.177	0.115
Microhyla heymonsi	0.078	0.099	0.088
Microhyla fissipes	0.220	0.223	0.221
Microhyla pulchra	0.065	0.045	0.055
Micryletta inornata	0.095	0.132	0.114
Total species richness	15	15	16

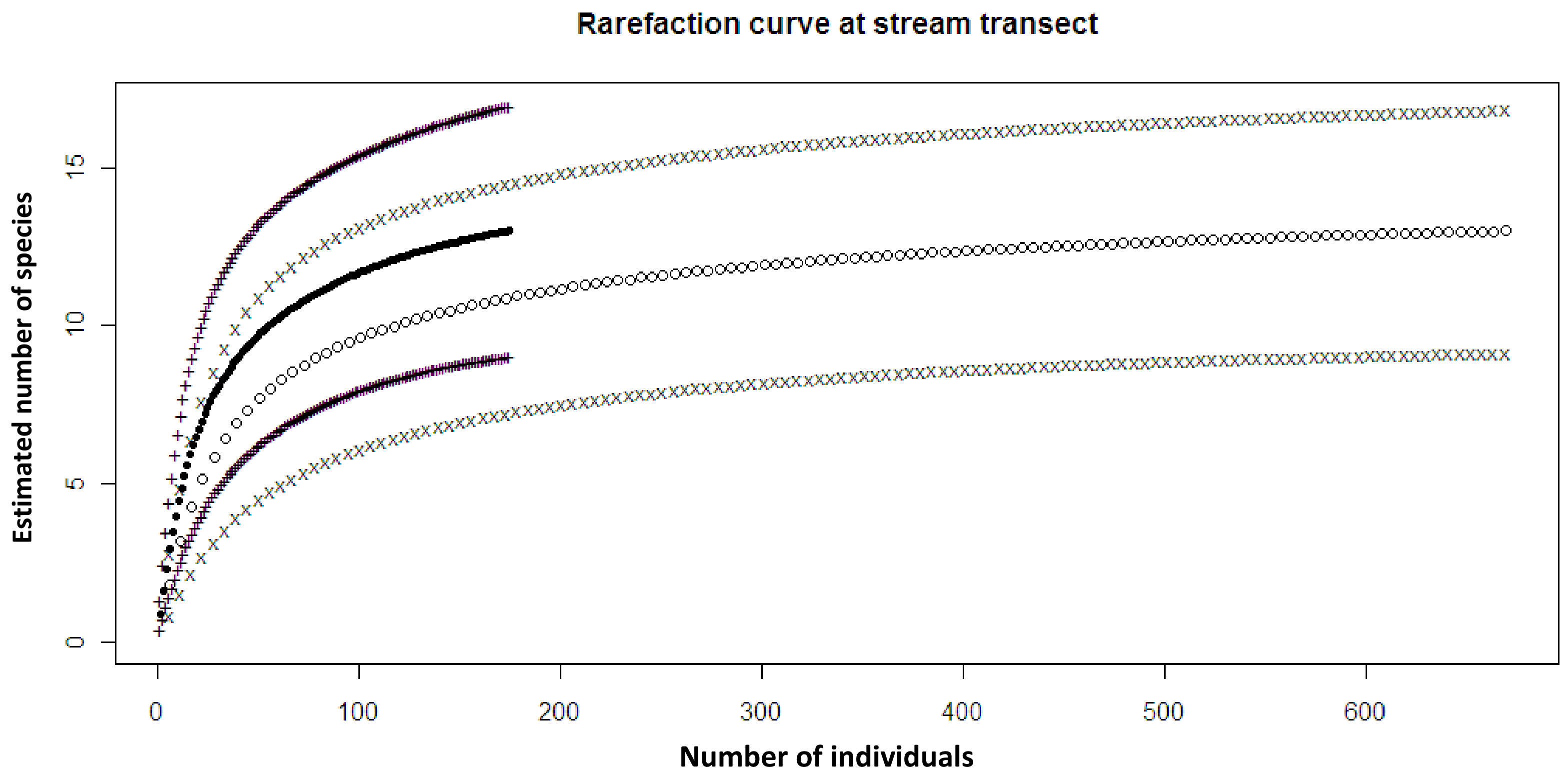

Figure 4-1 Comparison of species richness between check dam and non-check dam areas at the stream habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (•) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

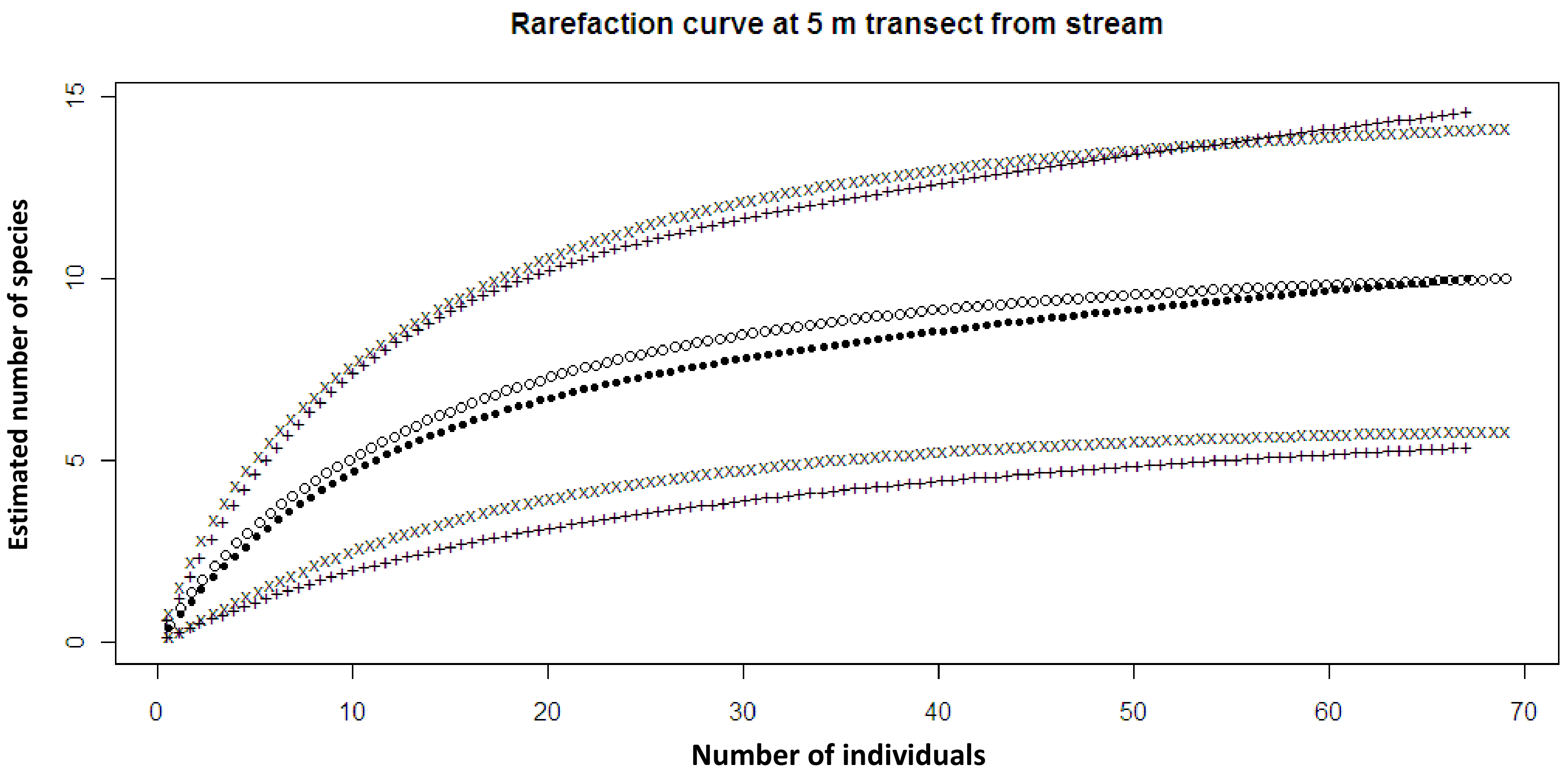

Figure 4-2 Comparison of species richness between check dam and non-check dam areas at the 5 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (•) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

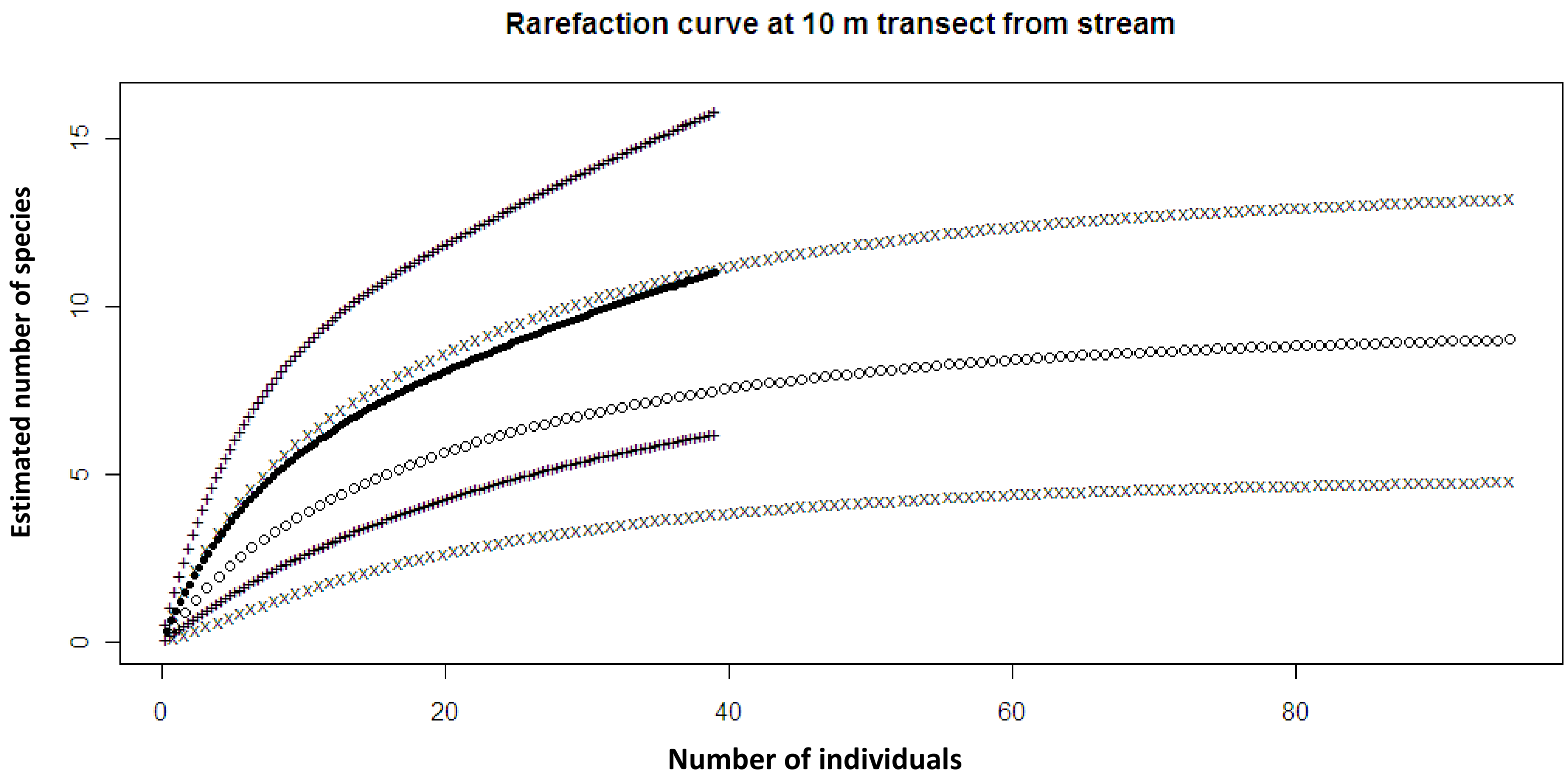

Figure 4-3 Comparison of species richness between check dam and non-check dam areas at the 10 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (•) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

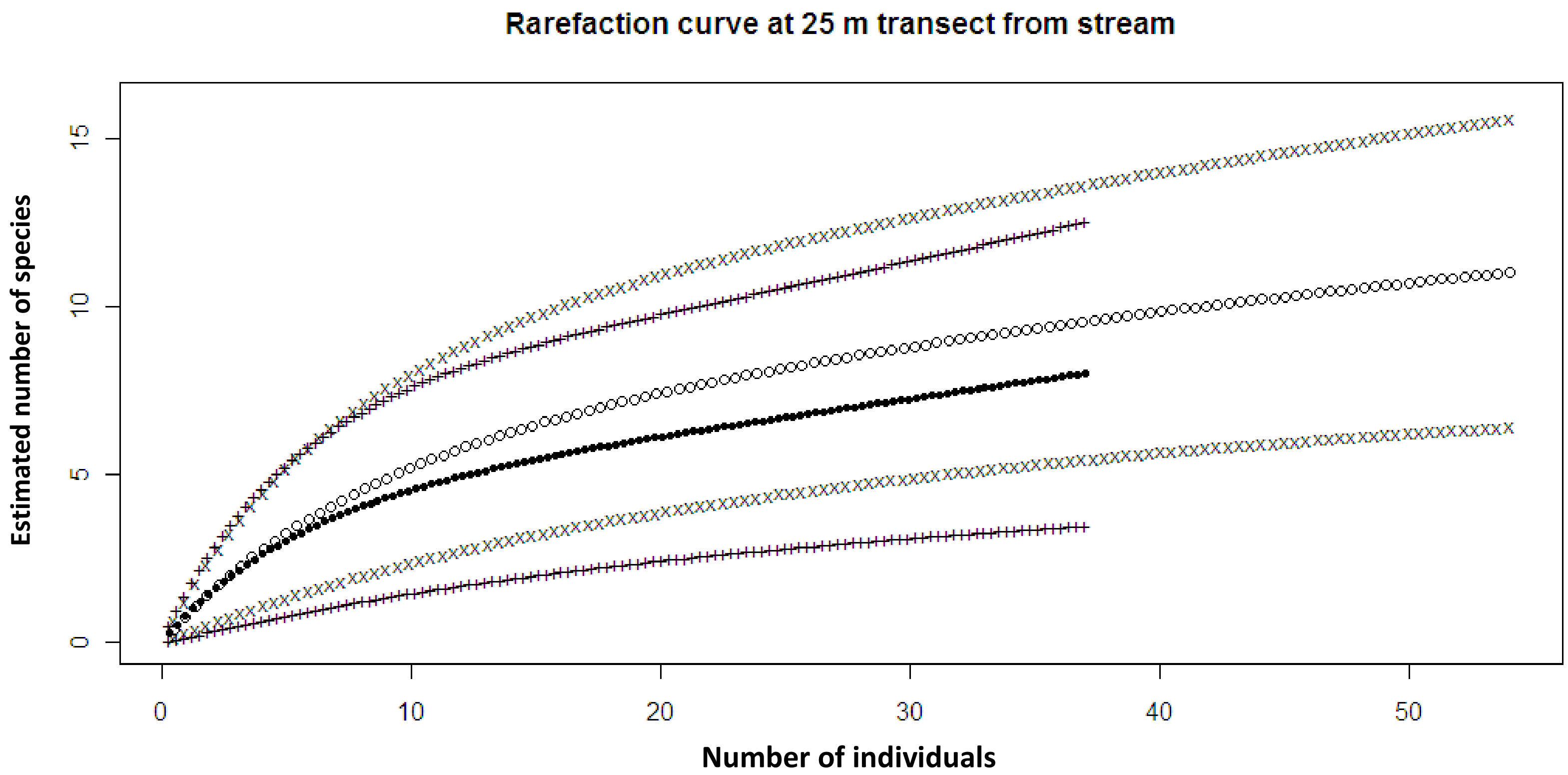

Figure 4-4 Comparison of species richness between check dam and non-check dam areas at the 25 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (●) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

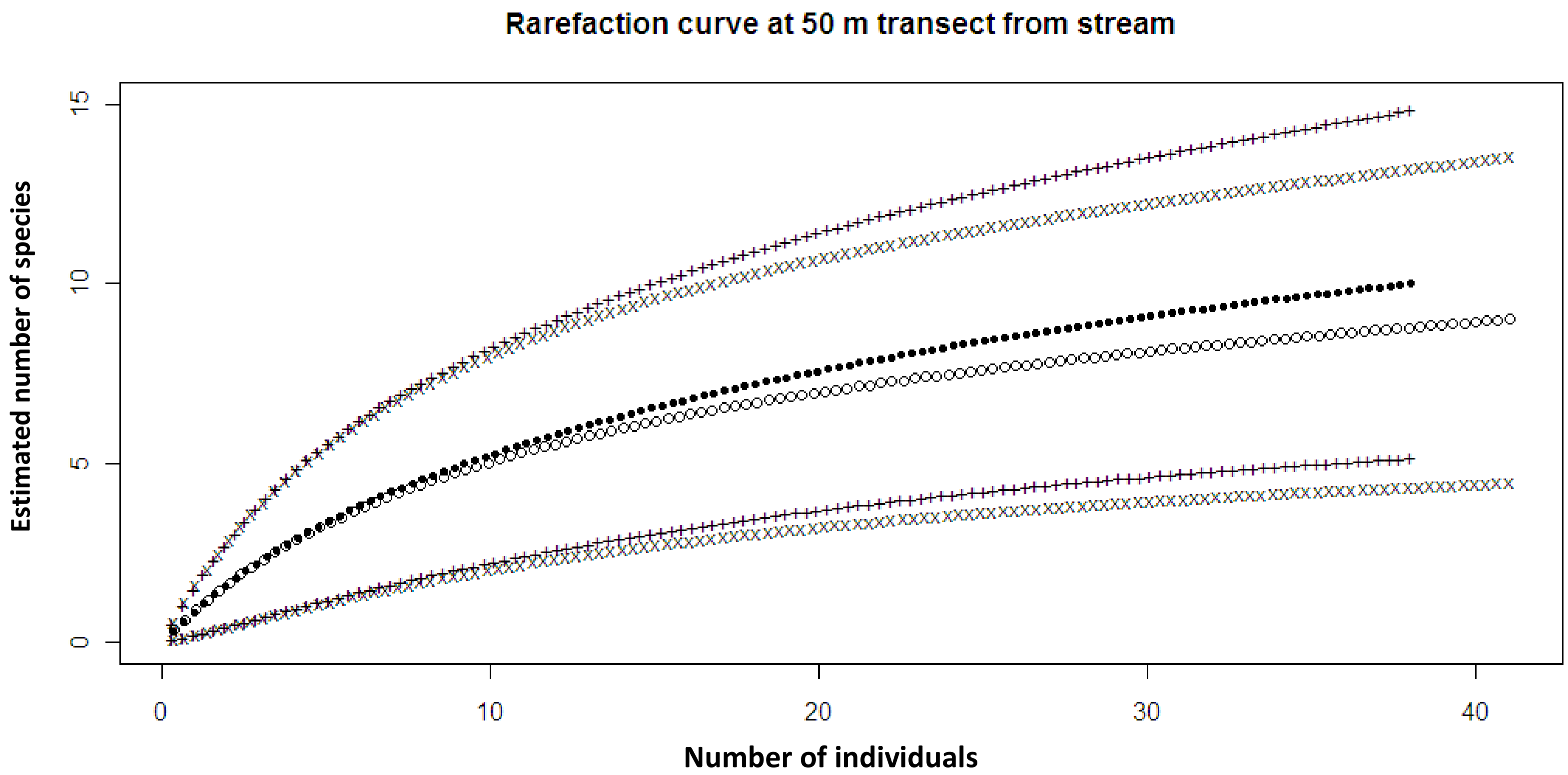

Figure 4-5 Comparison of species richness between check dam and non-check dam areas at the 50 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (•) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

4.3.1.2 Amphibian composition

Among the 16 species found in these areas during the 1st year study period, 14 species were similarly found in both areas. There was one species (*Hoplobatrachus rugulosus*) that solely found in the check dam area, and another one species (*Chirixalus doriae*) that solely found in the non-check dam area.

The NMDS plots showed that the amphibian compositions were similar between check dam and non-check dam areas at all habitats (Figure 4-6 to 4-10). ANOSIM results also supported the similarity in amphibian compositions between these two areas (Table 4-2). According to the R statistics, the amphibian compositions were not different between check dam and non-check dam areas at stream, 5 m, 10 m, and 25 m habitats (R=-0.01 to 0.18), and were separated with strong overlap at 50 m habitat (R=0.37, $p \leq 0.05$).

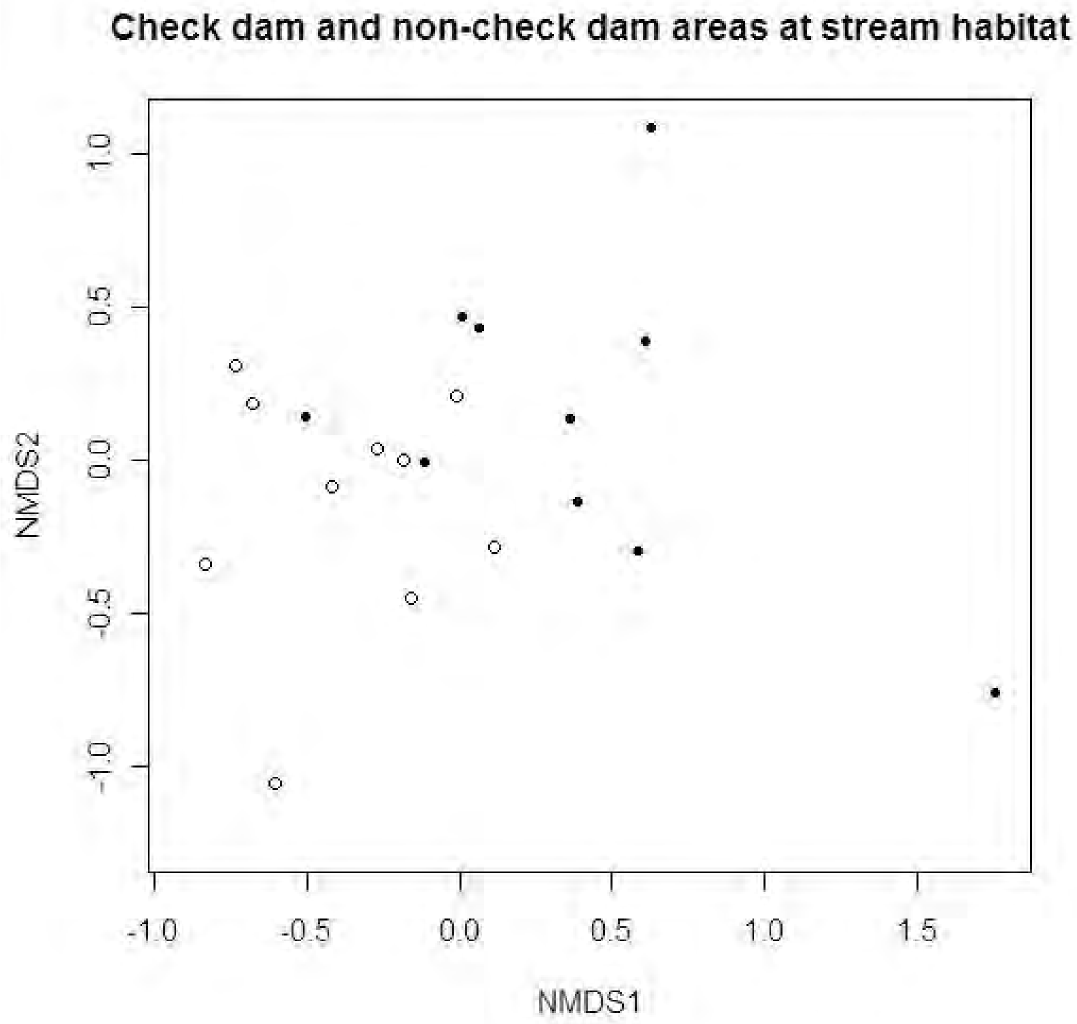

Figure 4-6 Two dimension NMDS plots of amphibian composition at the stream habitat in check dam and non-check dam areas (stress=0.14). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

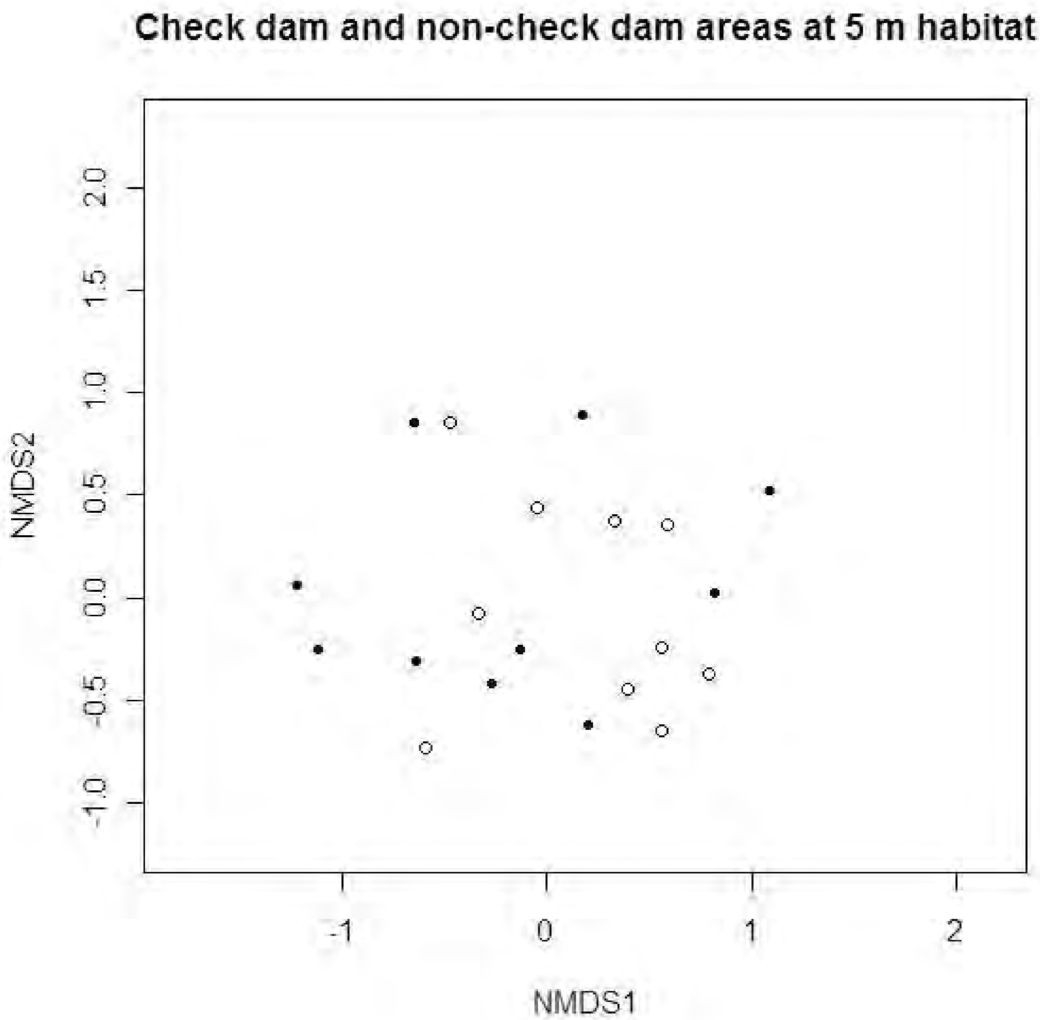

Figure 4-7 Two dimension NMDS plots of amphibian composition at the 5 m terrestrial habitat between check dam and non-check dam areas (stress=0.17). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

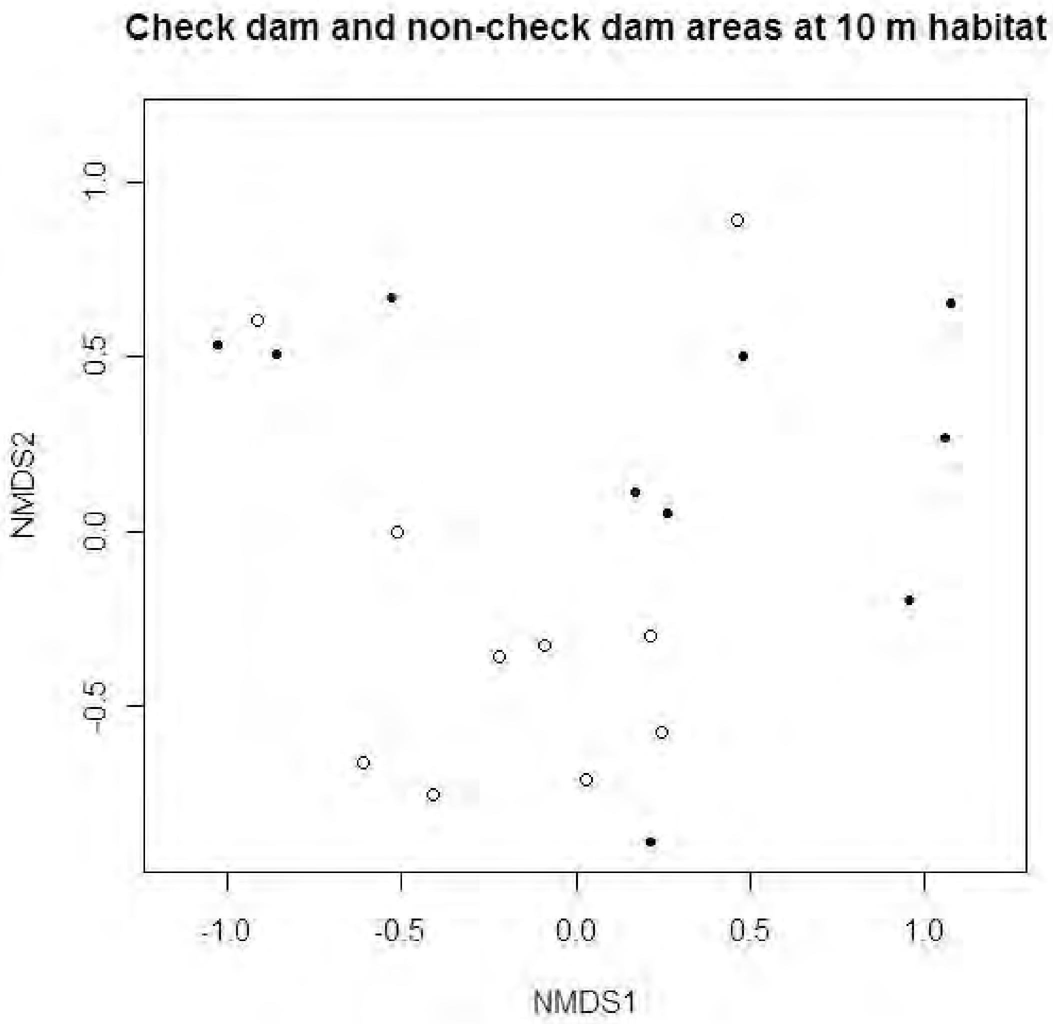

Figure 4-8 Two dimension NMDS plots of amphibian composition at the 10 m habitat terrestrial between check dam and non-check dam areas (stress=0.15). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

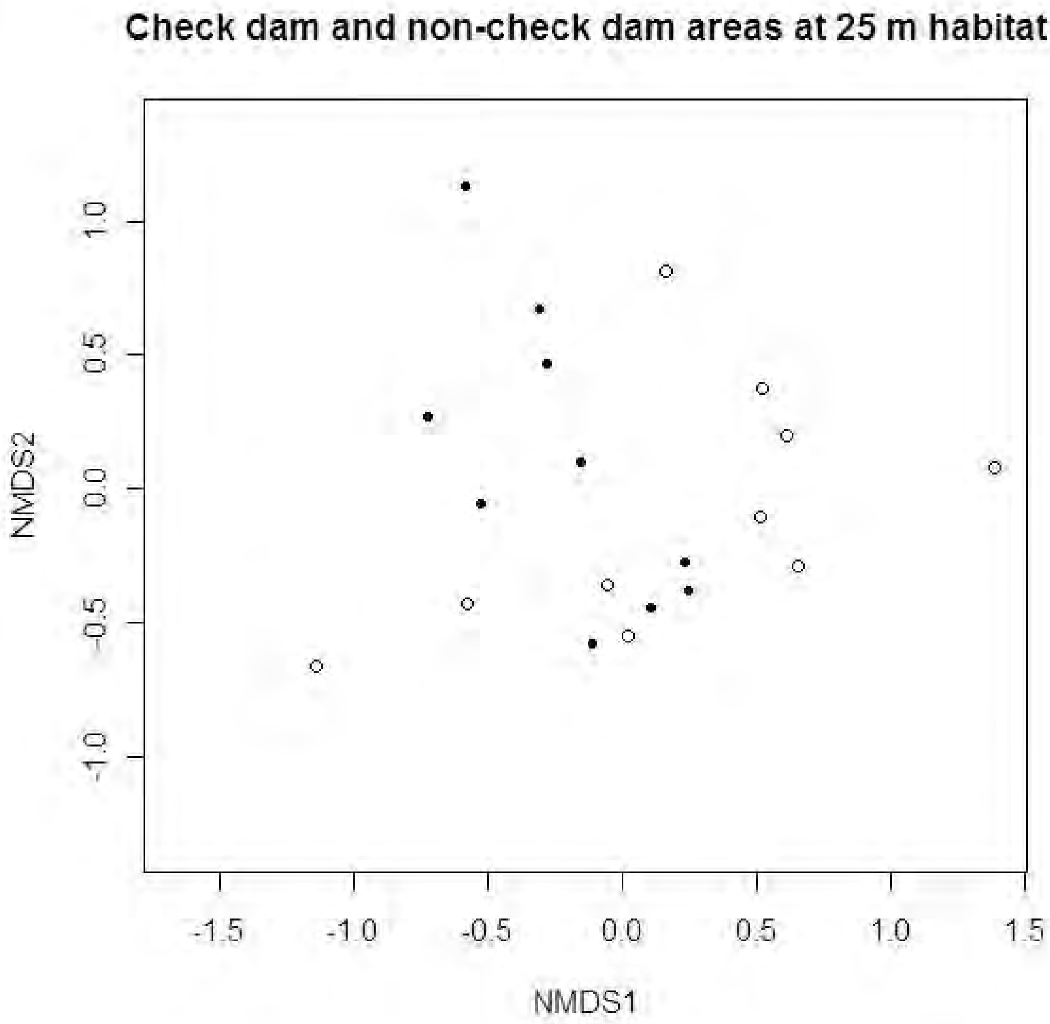

Figure 4-9 Two dimension NMDS plots of amphibian composition at the 25 m habitat terrestrial between check dam and non-check dam areas (stress=0.16). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

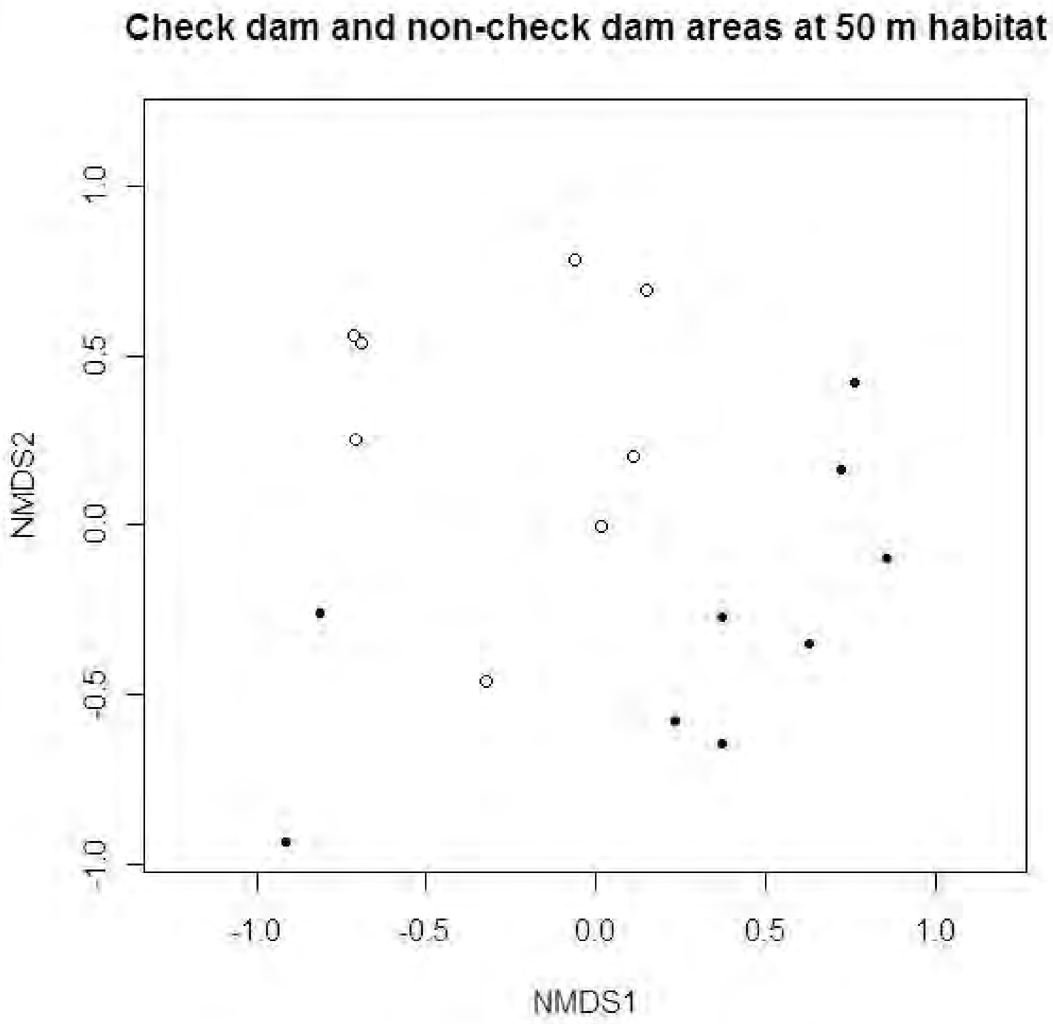

Figure 4-10 Two dimension NMDS plots of amphibian composition at the 50 m terrestrial habitat between check dam and non-check dam areas (stress=0.16). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

Table 4-2 Comparison of amphibian composition between check dam and non-check dam areas at stream and terrestrial habitats based on ANOSIM.

Statistics value	Habitats				
	stream	5 m terrain	10 m terrain	25 m terrain	50 m terrain
R	0.18	-0.01	0.16	0.18	0.37
p	0.006	0.473	0.037	0.024	0.005

Remark: R $\geq$ 0.75 indicates well separation between these two compositions.
R = 0.74 to 0.5 indicates separation with some overlap.
R = 0.49 to 0.25 indicates separation with strong overlap.
R < 0.25 indicates no difference between these two compositions.

4.3.2 Amphibian distribution pattern

From the overall data, 16 species were found in both check dam and non-check dam areas. Among these species, 14 species were overlapped between these areas. Therefore, only these 14 amphibian species were subjected to further analysis for the distribution patterns in both check dam and non-check dam areas. After analyzing the data, it was found that the distribution patterns of 12 species were not affected by the check dam. However, the distribution patterns of two species (*Occidozyga martensii* and *Microhyla fissipes*) were found to be significantly affected by the check dam.

The abundance of *O. martensii* did not show a significant difference among 5 transects in the non-check dam area, but showed a significantly higher abundance at the stream transect group in the check dam area (Figure 4-11).

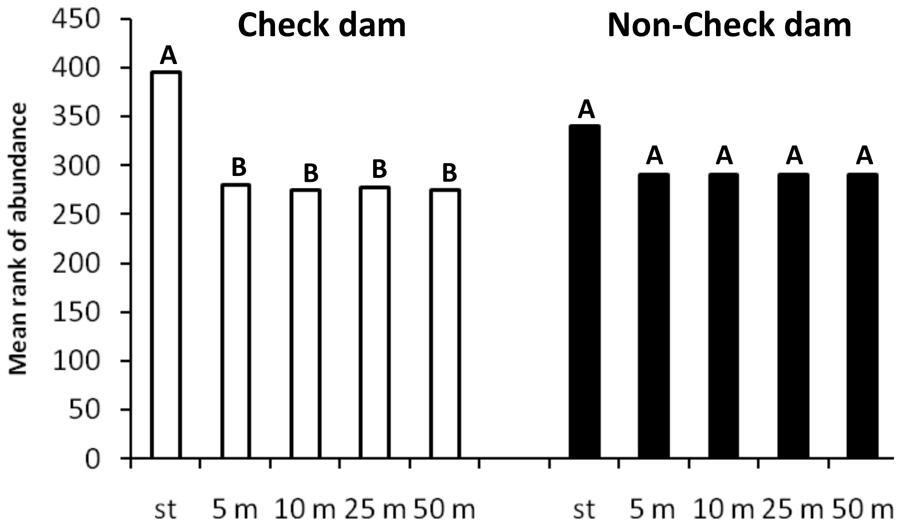

Figure 4-11 Distribution patterns of *O. martensii* among 5 transects at both check dam and non-check dam areas. White bar indicates the distribution pattern in the check dam area, and black bar indicates the distribution pattern in the non-check dam area. Difference in letter (A and B) indicate a significant difference at $p \leq 0.05$ among transects in each area.

For *M. fissipes*, the abundance did not show a significant difference among transects in the non-check dam area, but the abundance can be divided into 3 significant groups in the check dam area (Figure 4-12). The highest abundance was found in the stream transect. Then, the abundance gradually reduced in the middle group (5 and 10 m terrestrial transects) and the last group (25 and 50 m terrestrial transects), respectively.

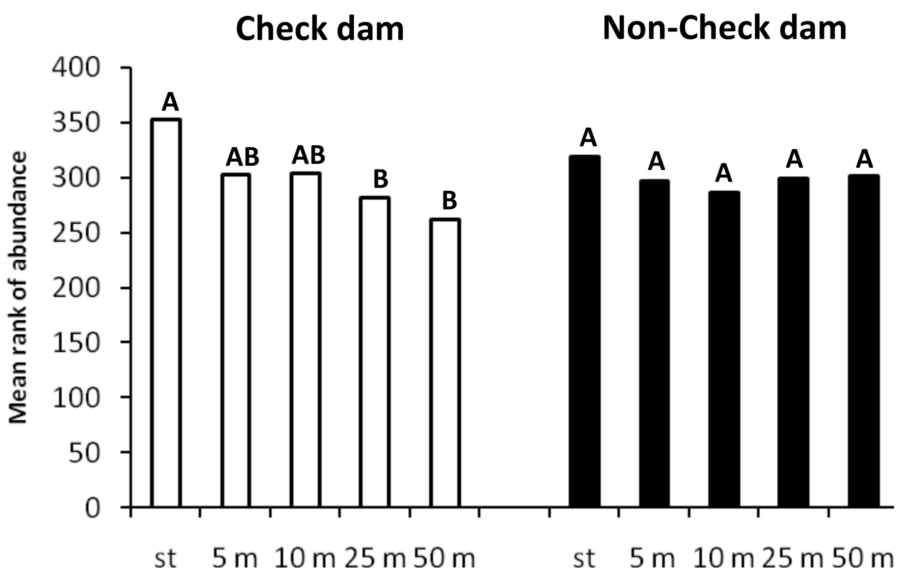

Figure 4-12 Distribution patterns of *M. fissipes* among 5 transects in both check dam and non-check dam areas. White bar indicates the distribution pattern in the check dam area, and black bar indicates the distribution pattern in the non-check dam area. Difference in letter (A and B) indicates a significant difference at $p \leq 0.05$ among transects in each area.

4.4 Discussion

Although previous researches reported that amphibian diversity was positive correlated with the hydroperiod (Pechmann et al., 1989 and Snodgrass et al., 2000), there was no different in amphibian assemblage between check dam and non-check dam areas in this study albeit the significant differences in hydroperiod, water depth, and number of water body between check dam and non-check dam areas. The lack of significant difference in this study could be due to a relatively short hydroperiod that may be not enough to change the amphibian assemblage in this area. In this study, most of amphibian species found in the stream were the ephemeral pond breeders. Although the check dam can prolong the hydroperiod in the stream, it was still not enough for the tadpoles of other amphibian with different breeding mode, such as the stream breeder, to complete the development until metamorphosis and survive in this relatively low oxygen stream. Therefore, the diversity and composition of amphibian found these streams tend to be similar with or without the check dam.

Another possible explanation for the discrepancy could be the fact that those previous researches (Pechmann et al., 1989 and Snodgrass et al., 2000) conducted an amphibian survey in wetland habitats with relatively different hydroperiods from this current habitat. Therefore, the effects of prolonged hydroperiod found in those researches were the long-term effect, whereas the effect found in this study was a short-term effect based on only 1 year after the check dam construction. As a results, the long-term study is still needed to be conducted in order to address the long-term effect of check dam on amphibian assemblage in this area.

Earlier research on the effect of check dam on biodiversity at riverine habitat concluded that the check dam has negative effect on biodiversity in the river by 3 ways (Shieh et al., 2007) including 1) alter the migration of the organism to breeding site, 2) separate the population and community of animal in the river, and 3) reduce the habitat diversity. However, the results of this current study did not show the strong impact of check dam on amphibian assemblage in the ephemeral stream, suggesting a different check dam effects in a different habitat type.

In this study, the distribution patterns of majority of amphibian species were not affected by the check dam. However, the distribution patterns of two amphibian species including *O. martensii* and *M. fissipes* were significantly different between check dam and non-check dam areas. The highest abundance of these amphibians in the check dam area was found at the stream transect. This could be due to the fact that the reproductive mode of these two species was both ephemeral pond breeders. In the natural stream conditions, the water bodies in the ephemeral stream could dry out quickly after raining. However, the prolonged hydroperiod in the check dam area could provide sufficient water bodies as a suitable habitats for egg laying and tadpole development. Therefore, these two frog species have chance to lay more eggs in a longer period in the check dam stream than those in the non-check dam stream. As a results, significantly high abundances of these amphibian species were evident in the stream transect in the check dam area.

Moreover, since amphibian has the semi-permeable skin, the water balance in their body depended on the moisture in the surrounding habitat (Duellman and Trueb, 1994). In the check dam area, check dam can prolong both water and moisture in the stream, so the stream in check dam area may have more capacity to support amphibian than those in the natural stream.

The results from this 1-year study indicated that although check dam can change physical factors (i.e. prolonged hydroperiod) (Chapter III) in the stream, the check dam did not show strong impacts on assemblage of amphibian, the highly sensitive terrestrial vertebrate to the moisture change. Given the fact that this study area was disturbed by human activities in the past (see Chapter II), it is of importance to note that this conclusion is based on the amphibian community that withstand prior human disturbance, not a pristine community.

However, the results indicated that the distribution patterns of the two most common amphibian species were affected by the check dams. The results showed that the check dam may support the reproduction of these two species by prolonging the suitable habitat for their reproduction. Based on these results, the distribution pattern of these two species can be further used as a sensitive indicator to detect the effect of check dam on the biotic component at the population level in the future.

CHAPTER V

EFFECTS OF CHECK DAM ON AMPHIBIAN ASSEMBLAGE AND DISTRIBUTION ALONG EPHEMERAL STREAMS IN A DECIDUOUS FOREST AT NAN PROVINCE: A TEMPORAL COMPARISON BETWEEN PRE- AND POST-CHECK DAM PERIODS

5.1 Introduction

Numerous check dams have been constructed in rural areas of Thailand, since it is regarded as simple enough for local people to construct by themselves with minimal investment, yet effective enough to prolong the surface water period. Check dam can increase the absorption rate of water (Watershed Conservation and Management Office, 2008), prolong the hydroperiod (Watershed Conservation and Management Office, 2008), entrap the soil erosion particle (Huang et al., 2009; Xiang-zhou et al., 2004) and change the physical characteristic of the stream (Castillo et al., 2007; Liu, 1992; Solaimani, et al., 2008; Zeng et al., 2009). Although there are many researches on the effect of check dam on physical factors in the area, there is still a lack of information on the check dam effect on biotic factors, especially on the animal in the surrounding area.

Since a persistence or a distribution pattern of a species in the area can be used to determine the suitability of habitat for a particular animal (Ricklefs and Miller, 2000), parameter frequently used to determine ecosystem health and function is the assemblage or biodiversity of animals. In case of check dam effects, the water and moisture pattern seem to be one of the primary change as a result of the check dam. Therefore, amphibian assemblage and distribution pattern were selected as monitoring parameters for this study because amphibian shows a relatively greater sensitivity to water and moisture change than other terrestrial vertebrates (Vitt and Caldwell, 2009). In this part of the study, the effects of check dam were determined based on the temporal comparison between pre- and post-check dam periods in the same study area in order to minimize effect of habitat characteristics. The objectives of this study include 1) to determine and compare the amphibian assemblage, and 2) to determine and compare the distribution pattern of amphibian along the ephemeral stream between pre- and post-check dam periods.

5.2 Methodology

5.2.1 Study site and survey period

This study was conducted at stream B (Figure 2-1) for 2 years during April 2009 to February 2011. In this stream, there was originally no check dam presented. Later on, check dams were constructed in the dry period of the stream during December 2009 to February 2010. This allowed a systematic comparison of biotic components between pre-check dam and post-check dam periods. In this study, the survey period began at the onset of wet season or the start of check dam functioning period and ended at the end of dry season. According to the climate diagram (Figure 3-2 in Chapter III), the pre-check dam period in this study was during April 2009–March 2010 and the post-check dam period was during May 2010–February 2011.

5.2.2 Amphibian survey methods

There were 2 transect types used for amphibian surveys. Stream transect was used for amphibian survey at aquatic habitat and terrestrial strip transect was used for amphibian surveys at terrestrial habitats.

5.2.2.1 Stream transect

During the pre-check dam period, the stream transect started from one planned check dam construction site to the next upstream check dam construction site (Figure 3-1). In the post-check dam period, the stream transect started from one check dam to the next upstream check dam or the maximum water level of that check dam. The width of transect was similar to the stream width or approximately 2 m, while the length of transect was the same as a distance between the two check dams. According to this plan, there were 10 stream transects at stream B available for amphibian surveys in the stream habitat.

5.2.2.2 Terrestrial strip transect

Four terrestrial strip transects were located parallel with each stream transect including 5, 10, 25, and 50 m transects far from the stream (Figure 3-1). The length of transect was equal to the vector distance of the corresponding stream transect, and the width of transect was 2 m. Total of 40 terrestrial strip transects was used for amphibian surveys in each periods.

All both stream and terrestrial strip transects, amphibian was monitored by the active surveys base on transect sampling method (Heyer et al., 1994). The surveys were conducted on the following micro-habitats: in the water, on the bare ground, under the leaf litter and on the tree with height of less than 1.5 m. Amphibians found were identified to species, and numbers of individual were recorded. In each month, the surveys were conducted for 16 consecutive days until every transect was studied. For each day, the total of 3 transects were surveyed during day time (9:00-12:00) and other 3 transects were surveyed during night time (19:00-22:00). The selection of these transects were on random basis. During each survey, special care was given to avoid habitat disturbance in the remaining transects.

The data of 50 transects were divided into 5 transect groups according to the distance from the stream, including stream transect (0 m from the stream) and 5, 10, 25, and 50 m transects from the stream.

5.2.3 Data analysis

The data were analyzed separately according to the transect groups and compared between pre- and post-check dam periods.

5.2.3.1 Amphibian assemblage

Proportional abundance of each amphibian species in each area was used for comparison of amphibian species so that the high abundance species could be identified. This value was calculated by dividing amphibian density of each species by the total amphibian density found in a particular area.

Amphibian assemblage was divided into species diversity and composition analysis. For amphibian diversity, rarefaction model was used to compare the amphibian species richness in order to preclude the effect of unequal length in the survey period between pre- and post-check dam periods (Magurran, 2004). Rarefaction value and its 95% confidence interval were calculated by EstimateS 8.2 program (Colwell, 2006). Afterward, the values of pre- and post-check dam were plotted as a function of sampling efforts. With this plot, significant difference in species diversity is indicated by an absence of overlap in the confidence interval of rarefaction curves between pre- and post-check dam periods at the maximum sampling effort (Colwell et al., 2004). For the amphibian composition analysis, dissimilarity matrix between pre- and post-check dam periods was constructed base on the Bray-Curtis distance measurement. Then, two dimensional ordination was plotted by using non-metric multidimensional scaling (NMDS). The data were also analyzed by analysis of similarity (ANOSIM) with 1,000 permutations to test for the significant difference in amphibian composition between pre- and post-check dam periods. The R-statistics from ANOSIM indicates the dissimilarity in species compositions between these two periods and normally ranges from 0 (highly similar between groups) to 1 (highly different between groups). The following criteria (Clarke and Gorley, 2001) was use to interpret the data:

$R \geq 0.75$ indicates well separation between these two compositions.

$R = 0.74$ to 0.5 indicates separation with some overlap.

$R = 0.49$ to 0.25 indicates separation with strong overlap.

$R < 0.25$ indicates no difference between these two compositions.

The construction of the dissimilarity matrix, the ordination plot, and the analysis of similarity were run by using "vegan" package in R program (R Development Core Team, 2011).

5.2.3.2 Amphibian distribution pattern

In order to conform with further analysis, abundance showed in this part were in the form of mean rank of abundance that can be calculated as follows. First, number of species found in each transect were combined to get the total sample number (N). Second, abundance of every species in every transect was sorted from the lowest to the highest. In this case, the rank of abundance would range from 1 (the lowest abundance) to N (the highest abundance). Finally, mean rank of abundance of each transects is calculated based on an average of rank number of every samples found in the particular transect.

The abundance of each amphibian species in both pre- and post-check dam periods was compared among transect groups by Kruskal-Wallis Test with nonparametic Tukey-type multiple comparisons at $p \leq 0.05$ (Zar, 1999). Three possible scenarios of the difference in distribution patterns between pre- and post-check dam periods are as follows. First, the high abundance of a particular species shift from one transect group in the pre-check dam period to another transect group in the post-check dam period. Second, the abundance of a particular species did not show a significant difference among transects in the pre-check dam period but showed a significantly higher abundance in one or more transects in the post-check dam period. Third, the significantly higher abundance of a particular species was showed in one or more transects of the pre-check dam period but did not show any significant difference among transects in the post-check dam period.

5.3 Results

5.3.1 Amphibian assemblage

5.3.1.1 Amphibian diversity

The overall species richness found in stream B during pre- and post-check dam periods was 17 species (Table 5-1). Species richness in pre- and post-check dam periods was 15 and 14 species, respectively. The highly abundant species found in these two periods are *Occidozyga martensii, Microhyla fissipes,* and *M. butleri*.

The rarefaction curves showed the similar results among every transect groups in these pre- and post-check dam periods. Since there were overlaps in the 95% confidence interval between pre- and post-check dam period at every transect (Figure 5-1 to 5-5), it can be concluded that the amphibian species richness was not significantly different between pre- and post-check dam periods at any of the stream and terrestrial habitats.

Table 5-1 Proportional abundance of amphibian in pre- and post-check dam periods.

Family/Species	Proportional abundance		
	Pre-check dam	Post-check dam	Both periods
Bufonidae			
Bufo macrotis	0.042	0.001	0.022
Ranidae			
Fejervarya limnocharis	0.037	0.105	0.071
Hoplobatrachus rugulosus	-	0.003	0.002
Limnonectes pileatus	0.008	0.001	0.005
Occidozyga lima	0.003	-	0.001
Occidozyga martensii	0.175	0.256	0.215
Rana lateralis	-	0.003	0.002
Rhacophoridae			
Chirixalus doriae	0.003	-	0.001
Polypedates leucomystax	0.014	0.023	0.019
Microhylidae			
Calluella guttulata	0.011	0.001	0.006
Kaloula pulchra	0.017	0.026	0.021
Microhyla berdmorei	0.014	-	0.007
Microhyla butleri	0.177	0.215	0.196
Microhyla heymonsi	0.099	0.096	0.097
Microhyla fissipes	0.223	0.180	0.202
Microhyla pulchra	0.045	0.068	0.056
Micryletta inornata	0.132	0.022	0.077
Total species richness	15	14	17

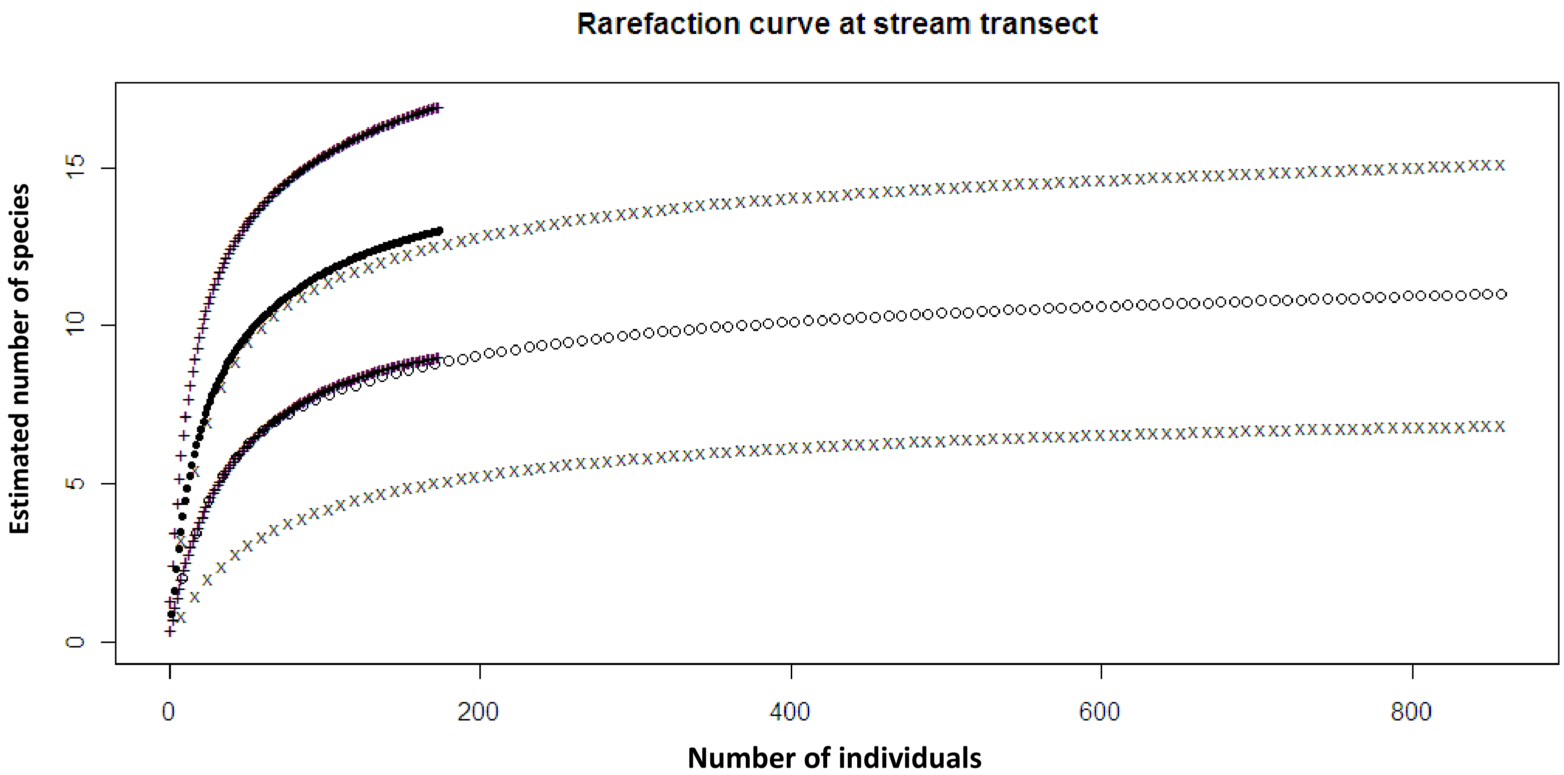

Figure 5-1 Comparison of species richness between pre- and post-check dam periods at the stream habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

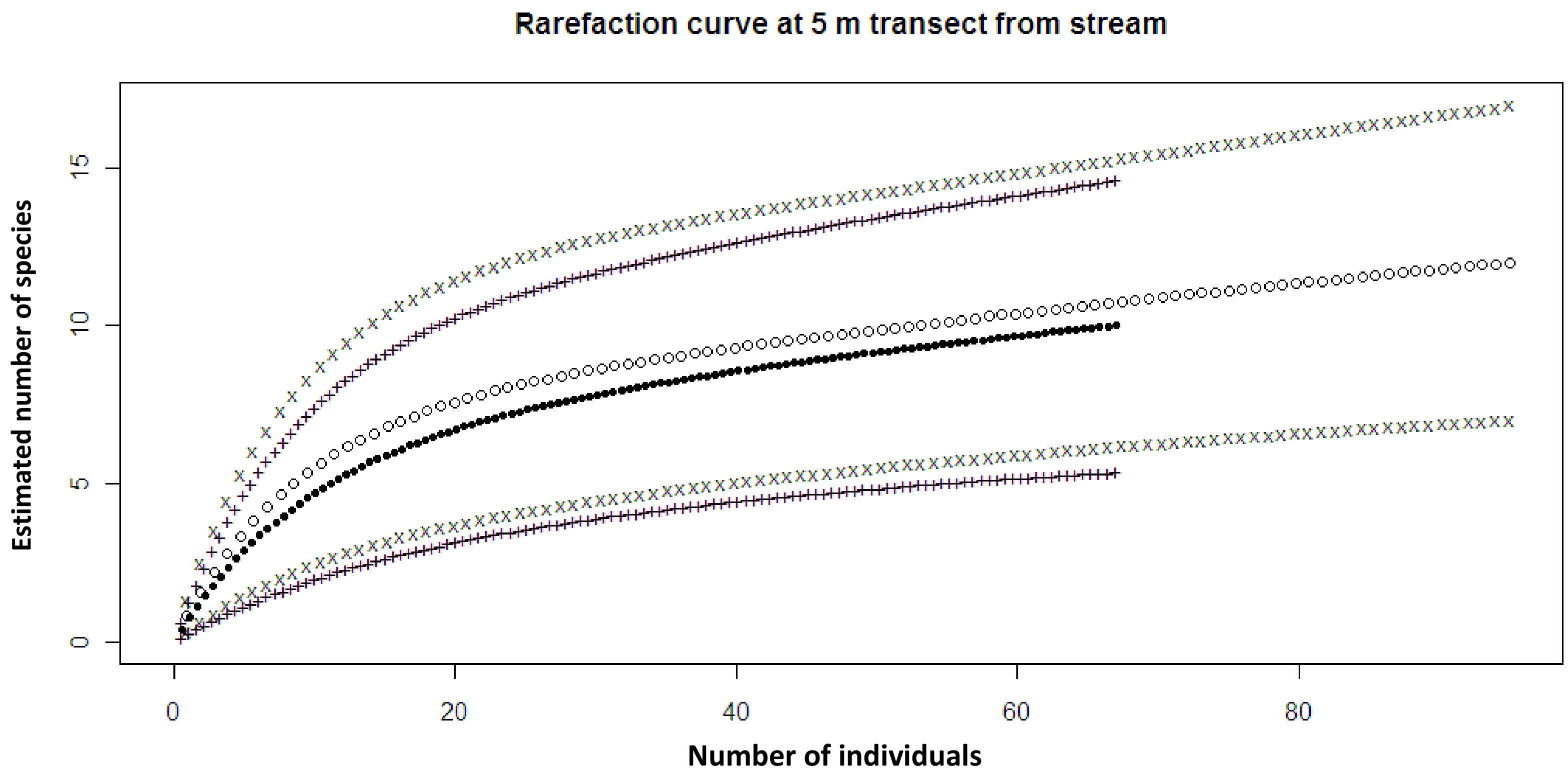

Figure 5-2 Comparison of species richness between pre- and post-check dam periods at the 5 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

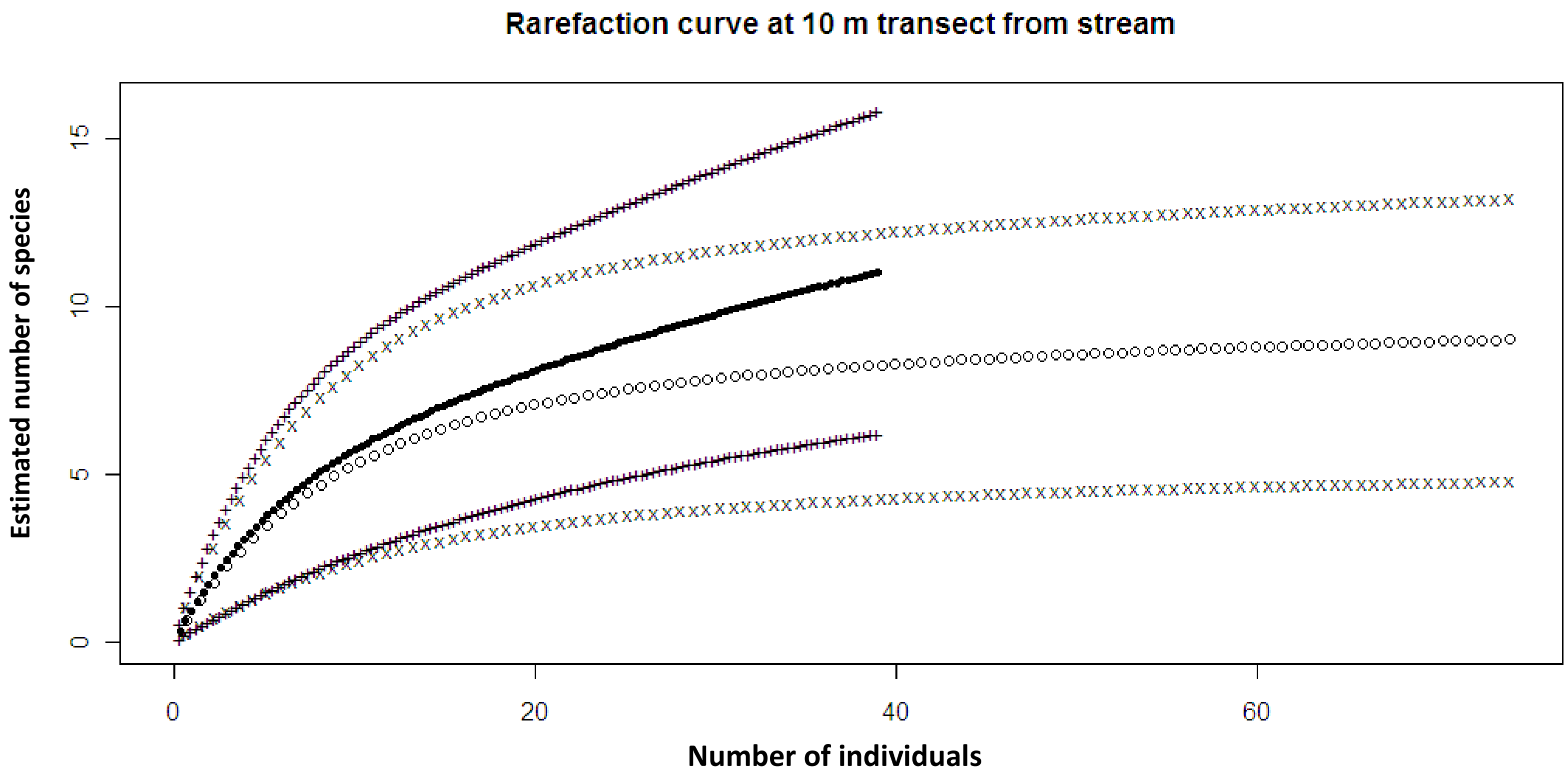

Figure 5-3 Comparison of species richness between pre- and post-check dam periods at the 10 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

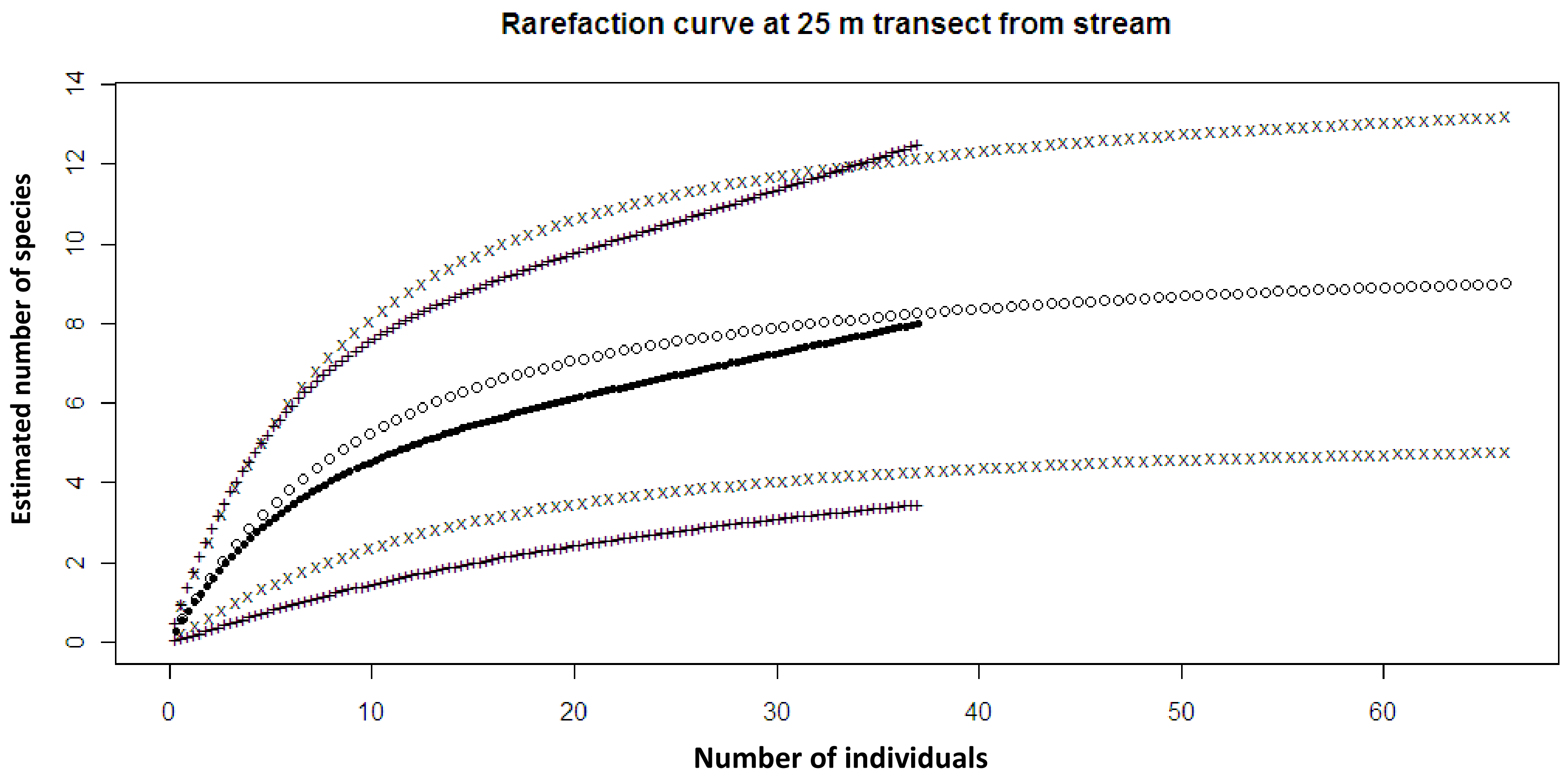

Figure 5-4 Comparison of species richness between pre- and post-check dam periods at the 25 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

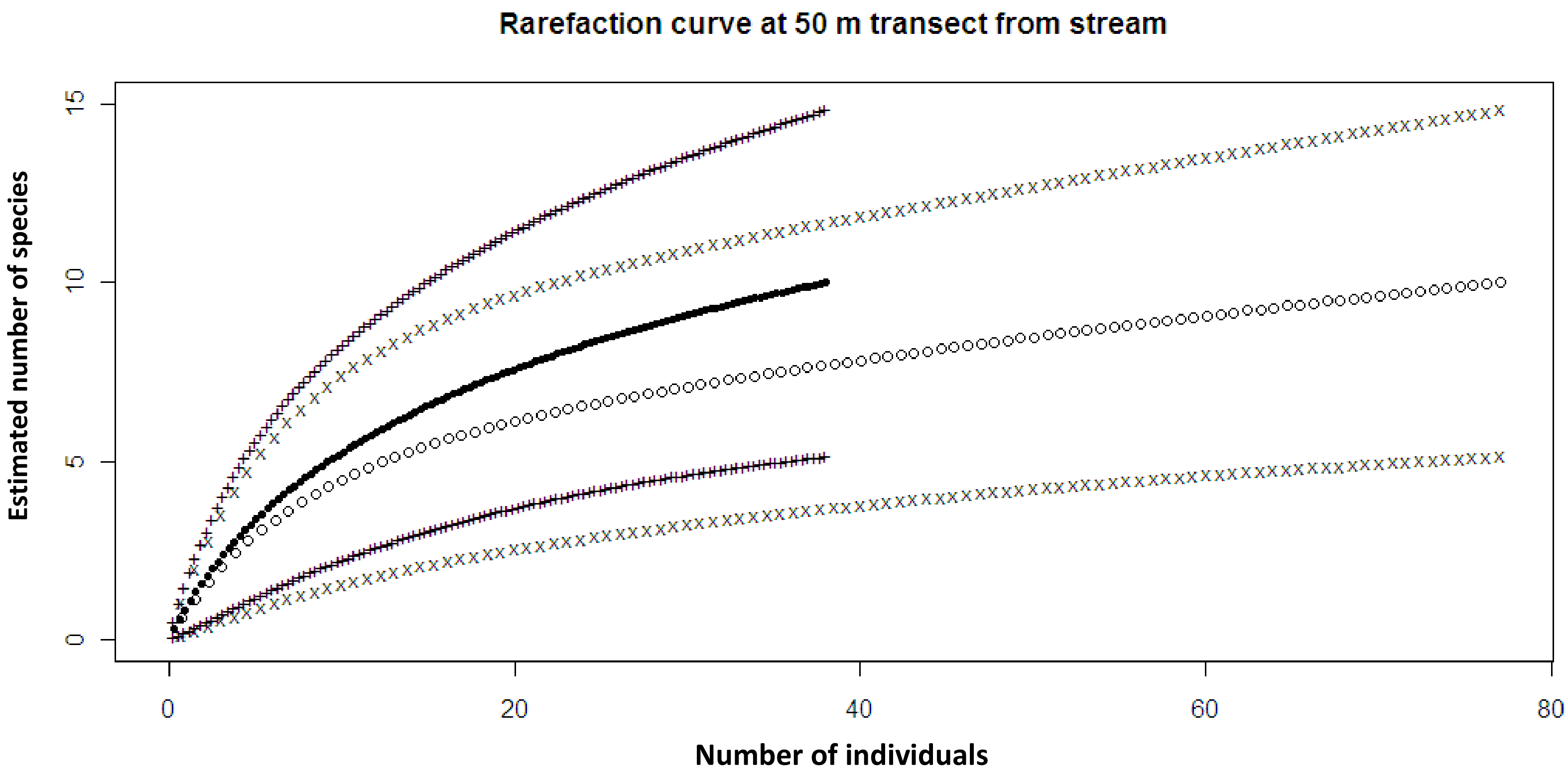

Figure 5-5 Comparison of species richness between pre- and post-check dam periods at the 50 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

5.3.1.2 Amphibian composition

Among 17 amphibian species found in stream B during these periods, 12 species were similar found in both pre- and post-check dam periods. There were three species (*Occidozyga lima*, *Chirixalus doriae,* and *Microhyla berdmorei*) that solely found in the pre-check dam period, and other two species (*Hoplobatrachus rugulosus* and *Rana lateralis*) that solely found in the post-check dam period.

The results of two dimension NMDS indicated that amphibian compositions at the stream habitat seems to be fairly partitioned between pre- and post-check dam periods (Figure 5-6). Results of analysis of similarity (ANOSIM) also confirmed that the amphibian compositions in the stream habitats can be separated with some overlapped between these 2 periods (Table 5-2; R=0.65, $p \leq 0.05$). However, the amphibian compositions at the terrestrial habitat in NMDS plots were inseparable between pre-and post-check dam periods. ANOSIM results also indicated that the amphibian compositions at terrestrial habitat seemed to be not different between pre- and post-check dam periods (R=0.18 to 0.28, $p \leq 0.05$).

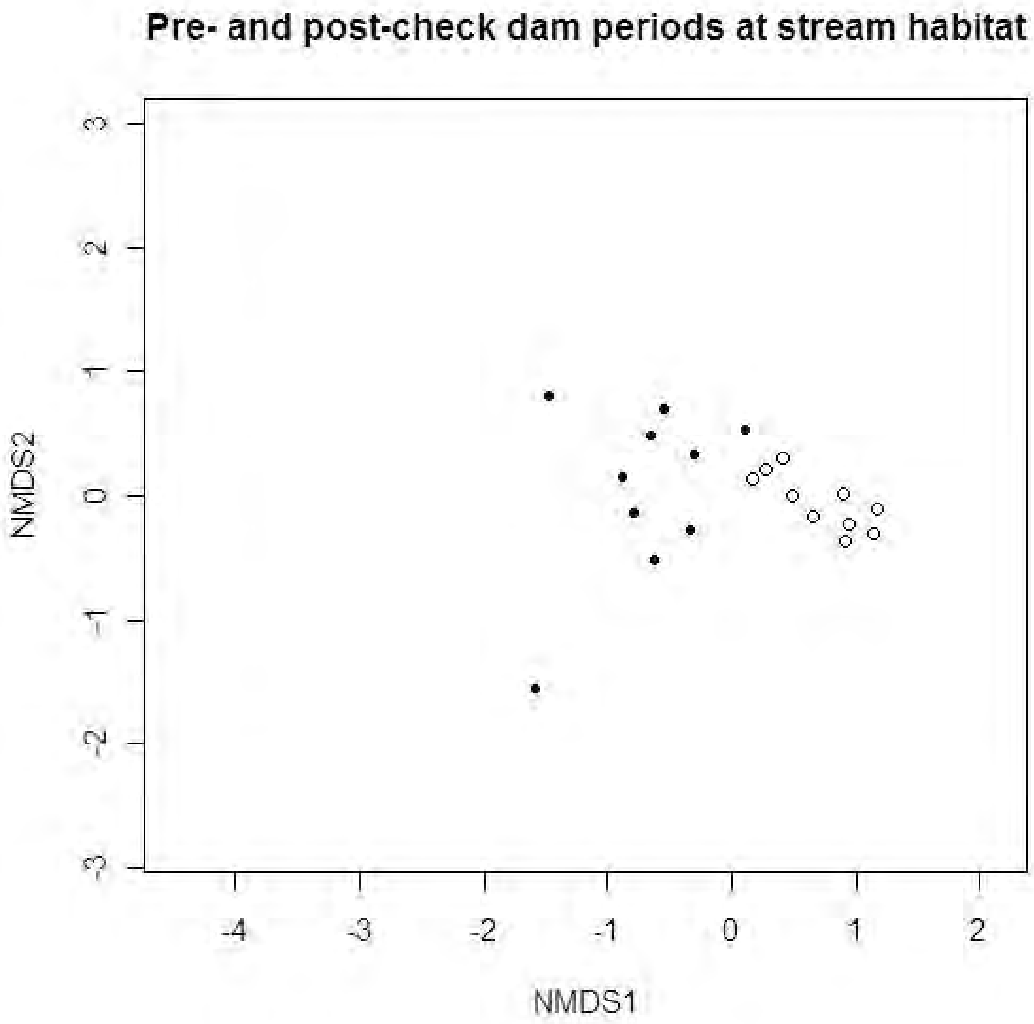

Figure 5-6 Two dimension NMDS plots of amphibian composition at the stream habitat in pre- and post-check dam periods (stress=0.10). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

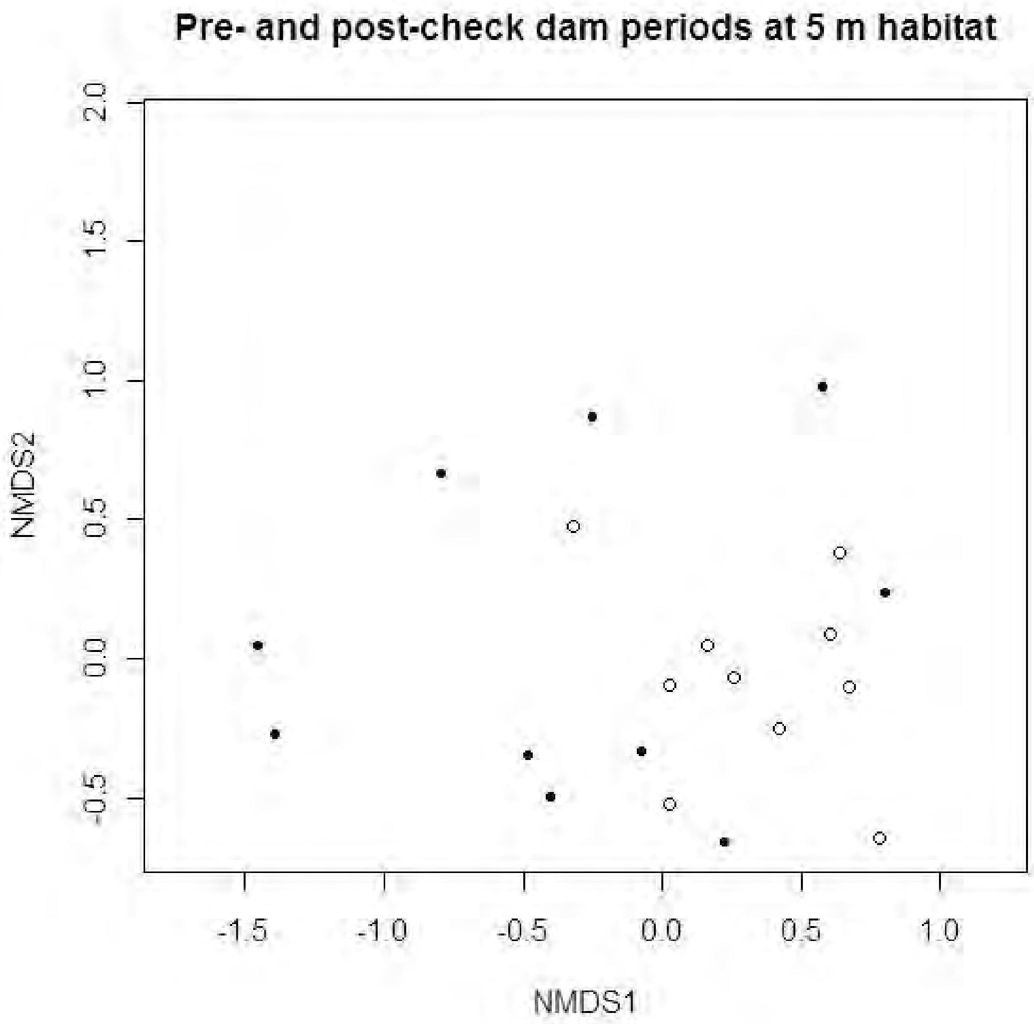

Figure 5-7 Two dimension NMDS plots of amphibian composition at the 5 m terrestrial habitat in pre- and post-check dam periods (stress=0.17). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

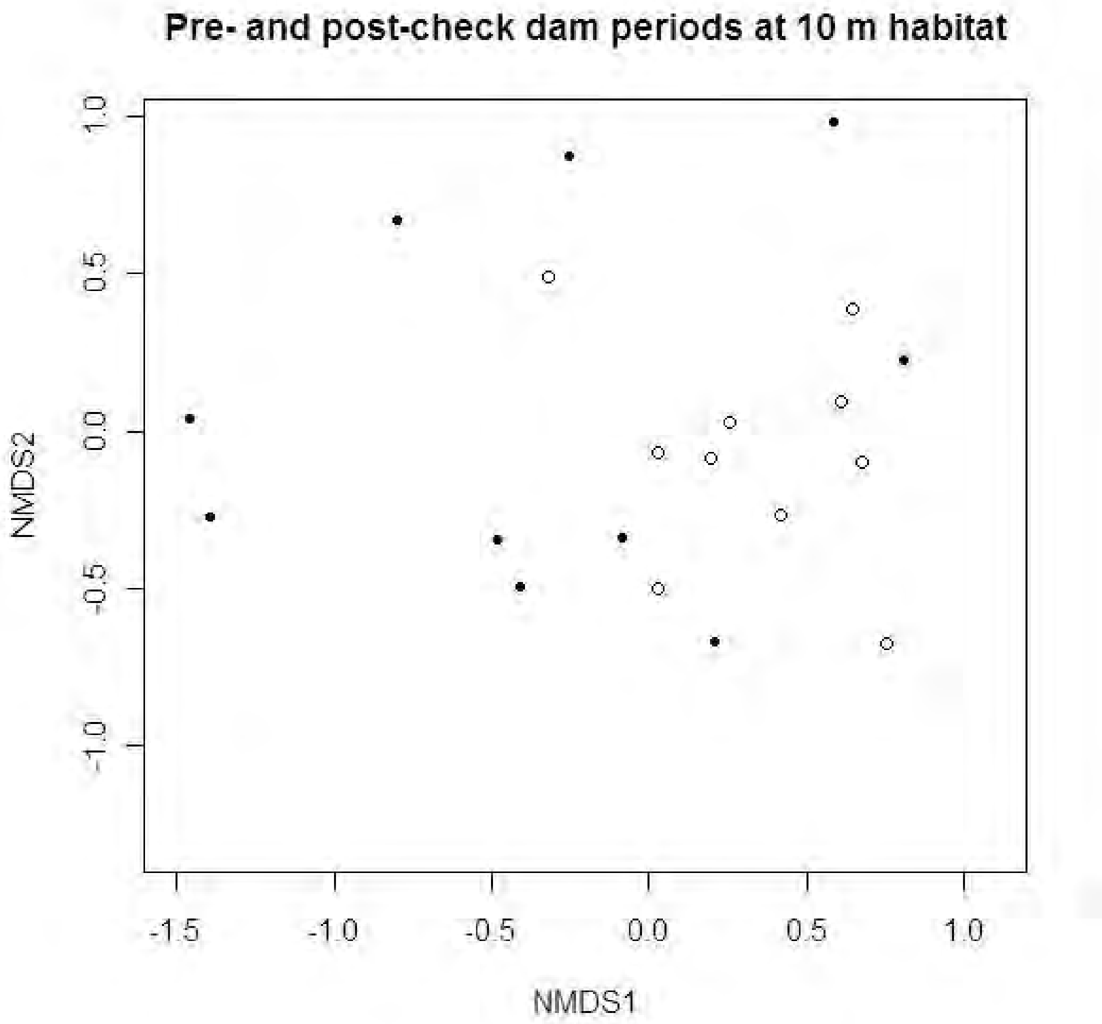

Figure 5-8 Two dimension NMDS plots of amphibian composition at the 10 m terrestrial habitat in pre- and post-check dam periods (stress=0.13). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

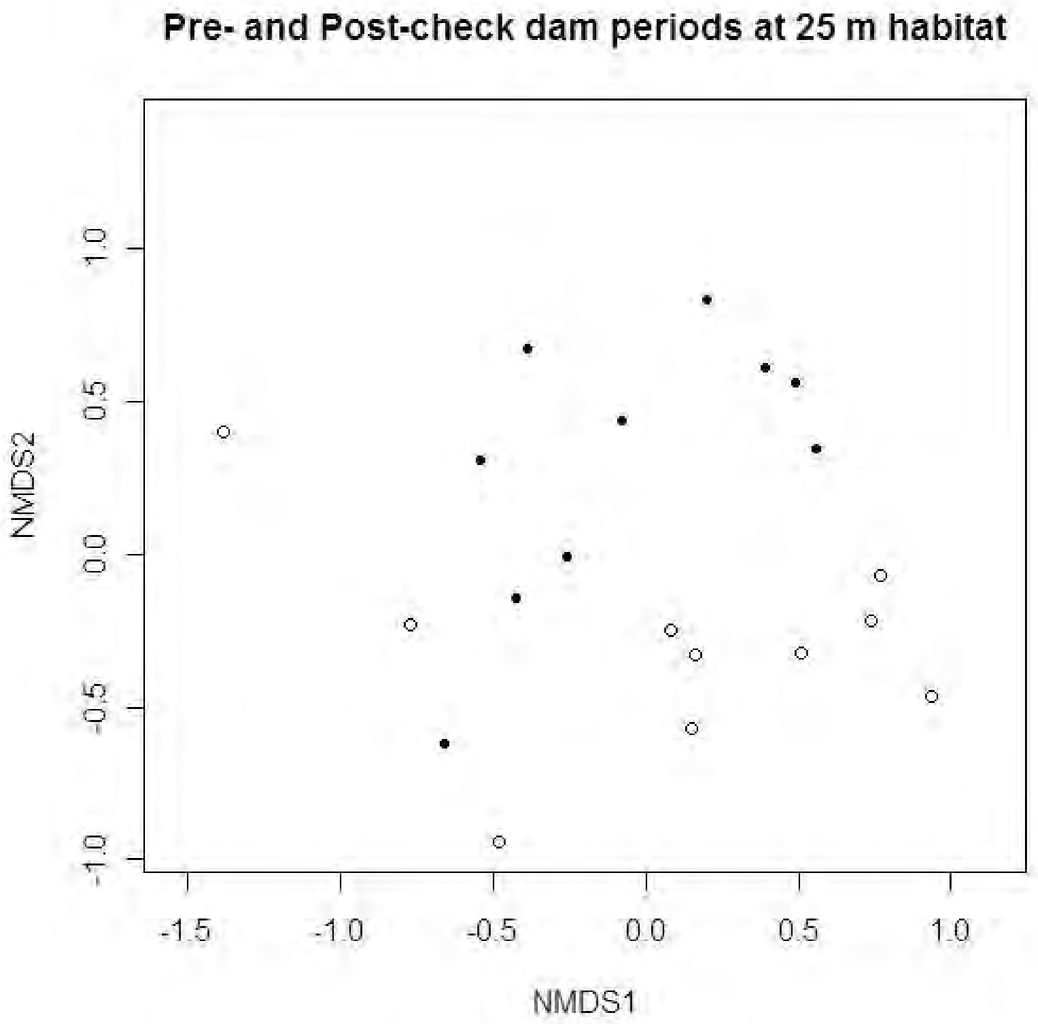

Figure 5-9 Two dimension NMDS plots of amphibian composition at the 25 m terrestrial habitat in pre- and post-check dam periods (stress=0.17). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

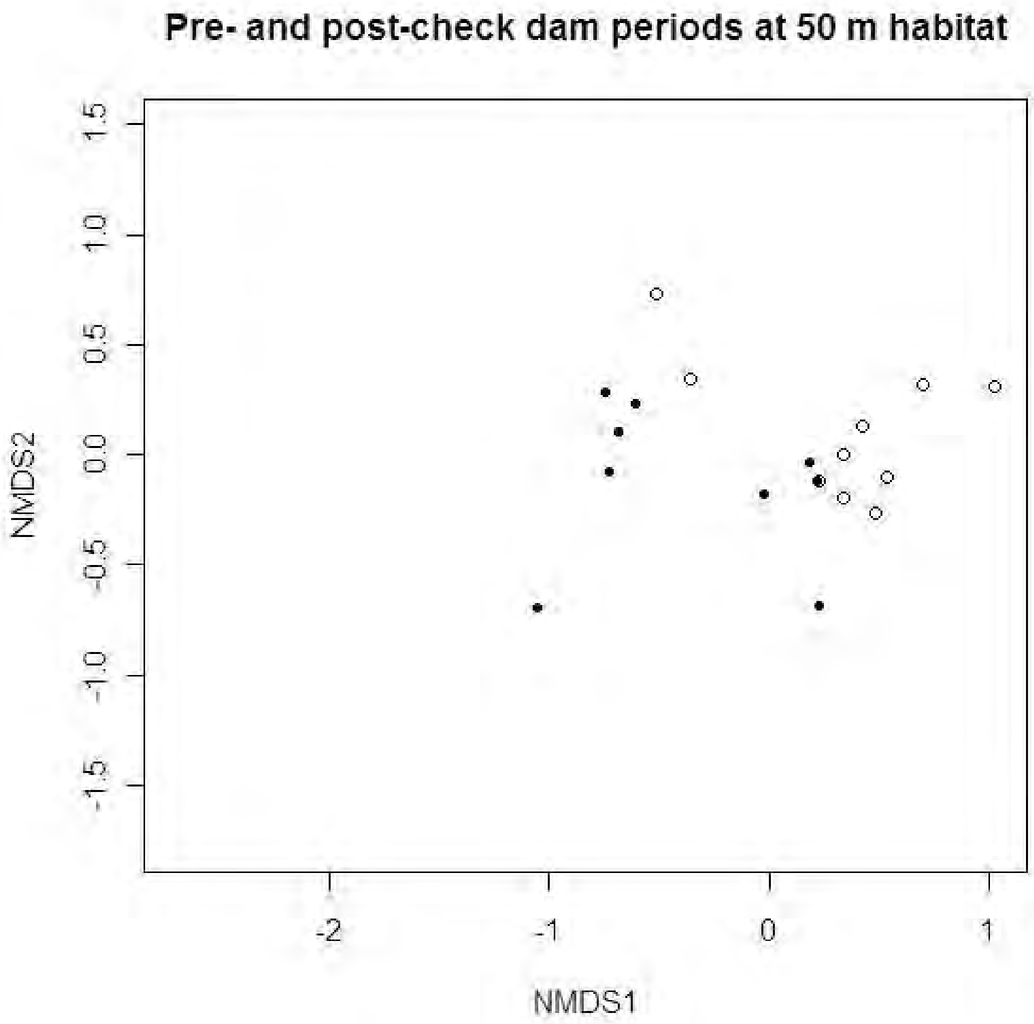

Figure 5-10 Two dimension NMDS plots of amphibian composition at the 50 m terrestrial habitat in pre- and post-check dam periods (stress=0.11). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

Table 5-2 Comparison of amphibian composition between pre- and post-check dam periods at stream and terrestrial habitats based on ANOSIM.

Statistics value	Habitats				
	stream	5 m terrain	10 m terrain	25 m terrain	50 m terrain
R	0.65	0.18	0.28	0.25	0.25
p	0.002	0.011	0.001	0.006	0.012

Remark: R $\geq$ 0.75 indicates well separation between these two compositions.
R = 0.74 to 0.5 indicates separation with some overlap.
R = 0.49 to 0.25 indicates separation with strong overlap.
R < 0.25 indicates no difference between these two compositions.

5.3.2 Amphibian distribution pattern

Among 17 species found in both pre- and post-check dam periods, 12 amphibian species were commonly found in these two periods. Therefore, the distribution patterns of these species were subjected to further comparison between pre- and post-check dam periods. It was found that the distribution patterns of most species were not affected by the check dam. However, the distribution patterns of four species including *Occidozyga martensii, Fejervarya limnocharis, Microhyla fissipes,* and *M. heymonsi* were found to be significantly affected by the check dam.

The abundance of *O. martensii* was not significantly different among 5 transect groups in the pre-check dam period but the abundance at the stream transect was significantly higher than other transects in the post-check dam period (Figure 5-11).

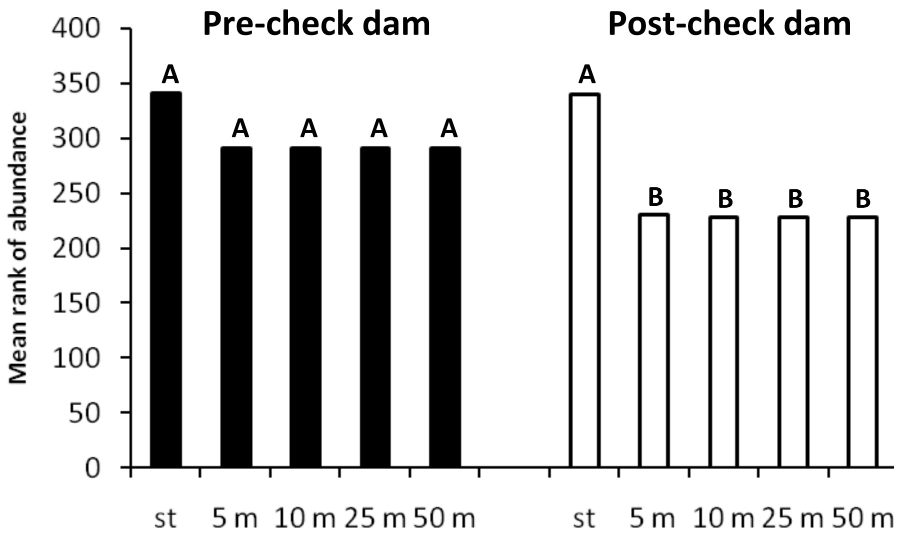

Figure 5-11 Distribution patterns of *O. martensii* among 5 transects in both pre- and post-check dam periods. Black bar indicates the distribution pattern in the pre-check dam period, and white bar indicates the distribution pattern in the post-check dam period. Difference in letter (A and B) indicates the significant difference at $p \leq 0.05$ among transects in each period.

The abundances of *F. limnocharis* did not show a significant difference among transects in the pre-check dam period, but the abundance can be divided into 3 significant groups in the post-check dam period (Figure 5-12). The highest abundance was found in the stream transect. Then, the abundance gradually reduced in the middle group (5, 10, and 25 m terrestrial transects) to the last group (50 m terrestrial transect), respectively.

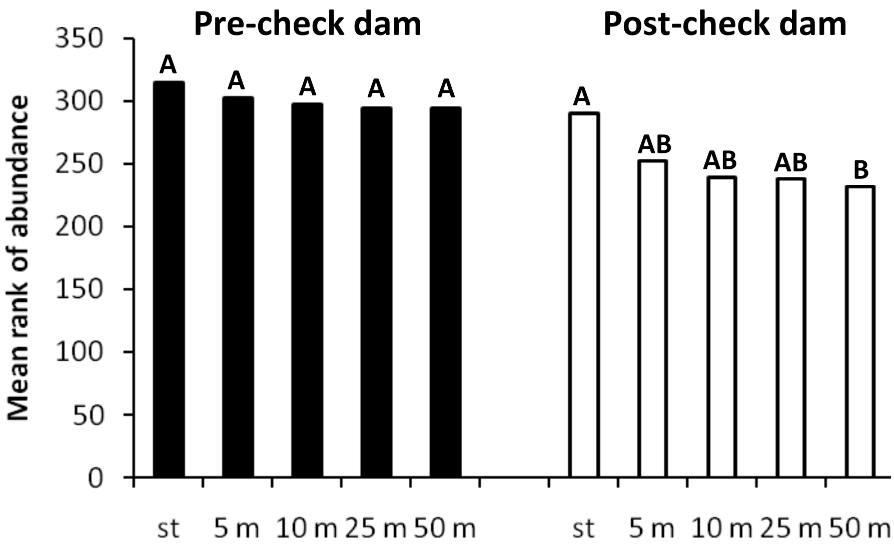

Figure 5-12 Distribution patterns of *F. limnocharis* among 5 transects in both pre- and post-check dam periods. Black bar indicates the distribution pattern in the pre-check dam period, and white bar indicates the distribution pattern in the post-check dam period. Difference in letter (A and B) indicates a significant difference at $p \leq 0.05$ among transect in each period.

For *M. fissipes* in the pre-check dam period, its abundance did not show a significant difference among transect, but the abundance can be divided into 3 significant groups in the post-check dam period (Figure 5-13). The highest abundance was found in the stream transect. And, the abundance gradually reduced in the middle group (5, 10, and 50 m terrestrial transects) and the last group (25 m terrestrial transect), respectively.

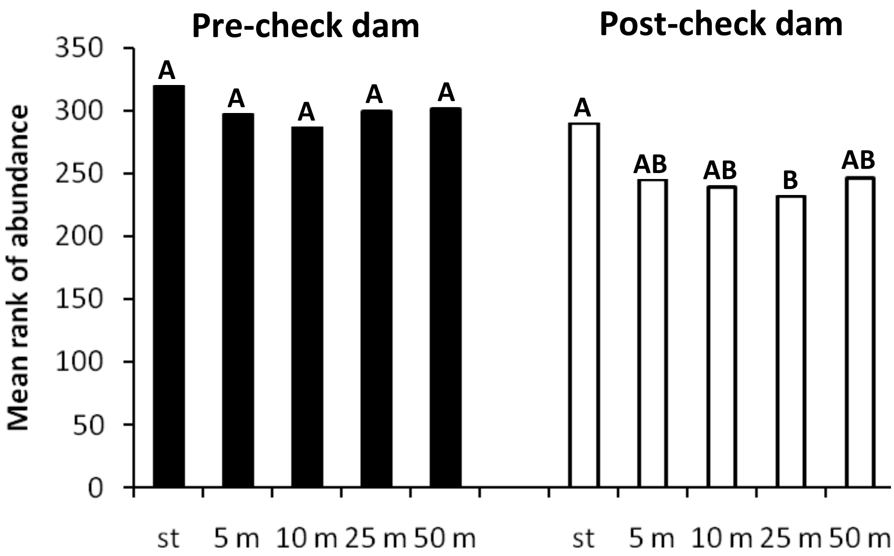

Figure 5-13 Distribution patterns of *M. fissipes* among 5 transects in both pre- and post-check dam periods. Black bar indicates the distribution pattern in the pre-check dam period, and white bar indicates the distribution pattern in the post-check dam. Difference in letter (A and B) indicates a significant difference at $p \leq 0.05$ among transect groups in each period.

For *M. heymonsi*, the abundance was not significantly different among transects in the pre-check dam period, but can be divided into 3 significant groups in the post-check dam period (Figure 5-14). The highest abundance was found in the stream transect. Then, the abundance gradually reduced in the middle group (5 m terrestrial transect) to the last group (10, 25, and 50 m terrestrial transects), respectively.

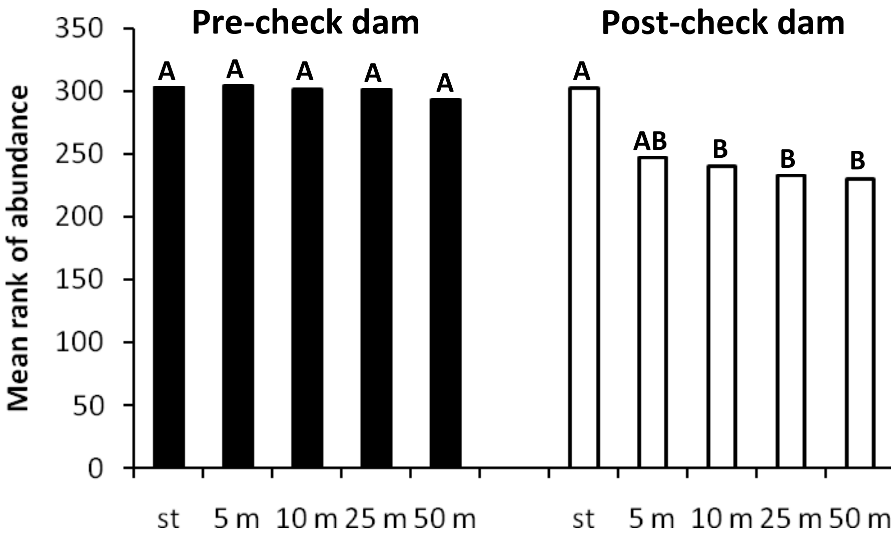

Figure 5-14 Distribution patterns of *M. heymonsi* among 5 transect in both pre- and post-check dam periods. Black bar indicates the distribution pattern in the pre-check dam period, and white bar indicates the distribution pattern in the post-check dam. Difference letter (A and B) indicates a significant difference at $p \leq 0.05$ among transect groups in each period.

5.4 Discussion

Unlike prior researches reported on positive correlation between amphibian species richness and the hydroperiod (Pechmann et al., 1989; Snodgrass et al., 2000), the results from the current study showed no difference in amphibian assemblage between pre- and post-check dam periods despite the significant differences in hydroperiod, water depth, and number of water body between these two periods. The possible explanation for the discrepancy could be the fact that those previous studies conducted an amphibian survey in wetland habitats with relatively different hydroperiods from this current habitat (Pechmann et al., 1989 and Snodgrass et al., 2000). Therefore, the effects of prolonged hydroperiod found in those researches were the long-term effect, whereas the effect found in this study was a short-term effect based on the survey after only one year of check dam installation. As a results, the long-term study is still needed in order to address the long-term effect of check dam on amphibian species richness in this area.

Although the result from NMDS and ANOSIM indicated that amphibian compositions were similar between pre- and post-check dam periods at all terrestrial habitats, NMDS and ANOSIM of the amphibian composition at the stream habitat indicated that there were changes in the composition after check dam construction. This may be due to difference in microhabitat requirements of each amphibian species. In a previous research on micro-habitat of amphibians in Thailand by Khonsue (1996), *Microhyla* spp. can be normally found on bare ground, rocks, and particularly in leaf litter, but rarely found in water bodies. On the other hand, *Occidozyga martensii* can be commonly found in many habitats including in water bodies. Moreover, some previous report in nearby country also mentioned that frogs in the genus *Occidozyga* were usually found in or near the water body (Inger, 1966; Inger and Stuebing, 2005). After the check dam construction, the water period is prolonged in the ephemeral stream habitat so that habitat preferred by some amphibians such as *Occidozyga martensii* is readily available. Therefore, longer hydroperiod in the post-check dam period may positively affect the abundances of some amphibian species and may negatively affect the abundances of some other species in the same time.

The findings that amphibian compositions at the stream habitats can be affected by the check dam were evident only with a temporal comparison, but not in the spatial comparison (Chapter IV). This may be due to the difference in intensity of the water related parameter in the stream habitat. Degrees of difference in hydroperiod, number of water body, and water depth between pre- and post-check dam periods (temporal comparison, Table 3-5) were much higher than the difference between non-check dam and check dam areas (spatial comparison, Table 3–1). At present, there is no evident to determine whether the check dam effect on amphibian composition in the stream habitat is positive or negative to the whole community since amphibian compositions in the terrestrial habitats were still the same. Therefore, long-term monitoring is still need in order to conclude this effect.

Although the distribution patterns of majority of amphibian species were not different between pre- and post-check dam periods, four amphibian species showed different distribution patterns between these two periods. In the pre-check dam period, these species showed similar distribution pattern in which the abundances were similar among 5 transects. However, in the post-check dam period, the abundance of these species showed the significantly higher value at the stream than the terrestrial habitat. This could be due to the fact that all of these 4 species, including *O. martensii, F. limnocharis, M. fissipes,* and *M. heymonsi*, were the ephemeral pond breeders. In the ephemeral stream, the water was normally dry out quickly after raining. Therefore, these 4 amphibian species only have a short period to perform their breeding activities in the natural condition without the check dam. In the prolonged hydroperiod of the post-check dam period, these amphibian species could have more time to carry out their breeding activities. As a result, significantly higher abundances of these amphibians were evident in the stream transect duing the post-check dam period.

Since amphibians have a semi-permeable skin, the water in their body could easily leak to the environment (Duellman and Trueb, 1994) and their life is much dependent on moisture in the environments. In the post-check dam period, check dam can prolong both water and moisture content in the stream. Therefore, the moisture and water content of the stream could provide higher support to amphibian in the post-check dam period than those in the pre-check dam period.

While the species richness of amphibian were still the same after the check dam constructions in both steam and terrestrial habitats, the amphibian composition in the stream habitat was found to be significantly affected by the check dam similar to the results of environmental conditions monitoring (Chapter III) that some physical factors (i.e. prolonged hydroperiod) of the stream were changed as a result of the check dams. For the distribution pattern, 4 out of 17 amphibian species showed significantly higher abundance at the stream habitat after check dam construction. The distribution pattern indicated that check dam could prolong the reproductive period or provide the high moisture habitat for these 4 species.

Therefore, it can be concluded based on this 2-year data that the check dam is one of the appropriated tool that can prolong the water availability in the area with minimal negative short-term effect on amphibian species richness and distribution pattern in the ephemeral stream habitat. However, given the fact that this study area was disturbed by human activities in the past (see Chapter II), it is of importance to note that this conclusion is based on the amphibian community that withstand prior human disturbance, not a pristine community.

Moreover, long-term monitoring is still needed to be conducted in order to confirm this finding. The long-term study should focus on the check dam effect on the amphibian composition at the stream habitat. In addition, the distribution patterns of these 4 amphibian species (*O. martensii, F. limnocharis, M. fissipes,* and *M. heymonsi*) can be further applied as the sensitive indicator to detect the effect of check dam on the biotic component at the population level in the future.

CHAPTER VI

EFFECTS OF CHECK DAM ON REPTILE ASSEMBLAGE AND DISTRIBUTION ALONG EPHEMERAL STREAMS IN A DECIDUOUS FOREST AT NAN PROVINCE: A SPATIAL COMPARISON BETWEEN CHECK DAM AND NON-CHECK DAM ARES

6.1 Introduction

Since check dam is regarded as a simple measure to prolong surface water of a stream with minimal financial and technical investment, numerous check dams have been builted in rural area of Thailand. The check dam can increase the absorption rate of underground water and the stream hydroperiod (Watershed Conservation and Management Office, 2008). In Thailand, natural habitats selected for check dam construction is usually the primary or secondary order stream that is normally non-permanent (ephemeral stream; Department of Local Administration, 2008). In this stream type, the water in the stream could dry out only just after the rain. Afterward, the stream bed with less canopy cover than surrounding habitats could be used for other biological activities involving a direct exposure to sunlight such as sun basking. In a presence of the check dam, the prolonged hydroperiod caused by the check dam could reduce an occurrence of this dry stream bed and may affect the habitat selection of organisms in the area.

Although effects of the check dam on physical factors are well documented (Castillo et al., 2007; Liu, 1992; Solaimani et al., 2008; Zeng et al., 2009), its effect on biotic factors is still limited. In this part of the study, reptile is used as a monitoring species for the check dam effects based on its ectothermic life strategy. Reptiles cannot generate heat for maintaining their body temperature by themselves and need to rely on heat gain from environmental sources through behavioral adjustment (Vitt and Caldwell, 2009). Therefore, reptiles living in vicinity of the ephemeral stream could utilize this habitat for sun basking or heat absorption from the stream bed.

Since biological diversity is frequently used as a surrogate for ecosystem health, and a persistence of any species in a specific area is an indicative of habitat availability for the species (Ricklefs and Miller, 2000), assemblage and distribution pattern can thus be used to determine whether the alteration of stream habitat would make the area unfit for a particular organism. In this part of the study, the effects of check dam on reptile assemblage and distribution pattern were determined based on a spatial comparison between check dam and non-check dam areas in the same survey period in order to reduce effect of weather conditions. The objectives of this study include 1) to determine and compare the reptile assemblage and 2) to determine and compare the distribution pattern of reptile along the ephemeral streams between check dam and non-check dam areas.

6.2 Methodology

6.2.1 Study site and survey period

This study was carried out at the Chulalongkorn University Forest and Research Station, Nan Province (UTM zone 47Q: N2051960-2054260 and E0688400-0690360) where one ephemeral stream with existing check dams (stream A) and another similar stream without any check dam (stream B; Figure 2-1) were selected as study sites. The reptile surveys were conducted at both check dam and non-check dam areas in the same period during April 2009 to March 2010.

6.2.2 Reptile survey methods

Two transect types were used for reptile survey. Stream transect was used for the survey at aquatic habitats, and terrestrial strip transect was used for the survey at terrestrial habitats.

6.2.2.1 Stream transect

Stream transect started from one check dam (in the check dam stream) or the position of the check dam construction (in the non-check dam stream) to the next upstream check dam (or upstream check dam position) or the maximum water level point of that check dam (Figure 3-1). The stream transect width was similar to the width of the stream or approximately 2 m, while the length of transect was similar to a distance between the two check dams. In this study, there are 10 stream transects in each check dam and non-check dam areas.

6.2.2.2 Terrestrial strip transect

In each stream transect, there are 4 terrestrial strip transects located parallel with the perpendicular distance from the stream of 5, 10, 25, and 50 m, respectively (Figure 3-1). Therefore, total of 40 strip transects was used for reptile survey in each check dam and non-check dam areas. The width of terrestrial transect was 2 m and the length of the transect was similar to the length of the corresponding stream transect.

The active survey base on transect sampling (Heyer et al., 1994) was used to survey the reptile along each stream and terrestrial transects. Reptiles in the water, on bare ground, under the leaf litter and on the tree with height of less than 1.5 m were recorded from these transects. Reptiles were identified to species and numbers of individuals of each species were recorded. In each month, the surveys were conducted for 16 consecutive days until every transect was studied for both daytime and nighttime. For each day, the total of 6 transects, including 3 transects from check dam area and 3 transects from non-check dam area, were surveyed during the day time (9:00-12:00) and other 6 transects were surveyed during the night time (19:00-22:00). The selection of these transects were on random basis. During each survey, special care was given to avoid habitat disturbances in the remaining transects.

Data from these 20 stream transects and 80 terrestrial transects were separated into 5 transect groups according to the distance from the stream, namely stream transect (0 m from the stream) and 5, 10, 25, and 50 m transects far from the stream. These data were compared between check dam and non-check dam areas

6.2.3 Data analysis

6.2.3.1 Reptile assemblage

Proportional abundance of each reptile species in each area was used for the comparison of reptile species so that the high abundance species could be identified. This was calculated by dividing reptile density of each species by the total reptile density found in a particular area.

The reptile assemblage was divided into species diversity and composition. Rarefaction model was used to compare the reptile species richness since it could avoid the effect of unequal transect length between check dam and non-check dam areas (Magurran, 2004). Rarefaction value and its 95% confidence interval were calculated by EstimateS 8.2 program (Colwell, 2006). Afterward, the values of check dam and non-check dam were plotted as a function of sampling efforts. With this plot, significant difference in species diversity is indicated by an absence of overlap in the 95% confidence interval of rarefaction curves between check dam and non-check dam areas at the maximum sampling effort (Colwell et al., 2004). For the reptile composition analysis, dissimilarity matrix between check dam and non-check dam areas was constructed base on the Bray-Curtis distance measurement. Then, two dimensional ordination was plotted by using non-metric multidimensional scaling (NMDS). The data were also analyzed by analysis of similarity (ANOSIM) with 1,000 permutations to test for the significant difference in reptile composition between check dam and non-check dam areas. The R-statistics from ANOSIM indicates the dissimilarity in species compositions between two sites, and normally ranged from 0 (highly similar between groups) to 1 (highly different between groups). The following criteria (Clarke and Gorley, 2001) was used to interpret the data:

$R \geq 0.75$ indicates well separation between these two compositions.

$R = 0.74$ to 0.5 indicates separation with some overlap.

$R = 0.49$ to 0.25 indicates separation with strong overlap.

$R < 0.25$ indicates no difference between these two compositions.

The construction of the dissimilarity matrix, the ordination plot, and the analysis of similarity were run by using "vegan" package in R program (R Development Core Team, 2011).

6.2.3.1 Reptile distribution pattern

Data on abundance showed in this part were in the form of mean rank of abundance that can be calculated as follows. First, number of species found in each transect were combined to get the total sample number (N). Second, abundance of every species in every transect was sorted from the lowest to the highest. In this case, the rank of abundance would range from 1 (the lowest abundance) to N (the highest abundance). Finally, mean rank of abundance of each transects is calculated based on an average of rank number of every samples found in the particular transect.

The abundance of each reptile species was compared among the transect groups in both check dam and non-check dam areas by Kruskal-Wallis Test with nonparametic Tukey-type multiple comparisons at $p \leq 0.05$ (Zar, 1999). Difference in distribution pattern between check dam and non-check dam areas could be demonstrated by the following three scenarios. First, an abundance of a particular species has a significantly higher value in one or more transects in the check dam area and has a significantly higher value in another transect in the non-check dam area. Second, an abundance of a particular species was not significantly different among transects in the non-check dam area, but showed significantly higher value in one or more transects in the check dam area. Third, an abundance showed a significantly higher value in one or more transects in the non-check dam area but showed no significant difference among transects in the check dam area.

6.3 Results

6.3.1 Reptile assemblage

6.3.1.1 Reptile diversity

Total number of reptiles found at both check dam and non-check dam areas during the study period was 16 species (Table 6-1). Number of species found in the check dam area was 15, whereas number of species found in the non-check dam area was 10. The highly abundant species found in these two areas are *Mabuya macularia* and *Dixonius siamensis*.

The rarefaction curves of these 5 transect groups showed relatively similar results. The 95% confidence interval of rarefaction curves showed the overlap between check dam and non-check dam data at every transect group (Figure 6-1 to 6-5), suggesting that the reptile species richness were not significantly different between check dam and non-check dam areas at every transect.

Table 6-1 Proportional abundance of reptile in check dam and non-check dam areas.

Family/Species	Proportional abundance		
	Check dam	Non-check dam	Both areas
Gekkonidae			
Dixoneus siamensis	0.306	0.201	0.254
Hemidactylus frenatus	0.032	0.007	0.019
Gekko gecko	0.008	-	0.004
Agamidae			
Calotes mystaceus	-	0.013	0.007
Calotes versicolor	0.032	-	0.016
Scincidae			
Mabuya macularia	0.411	0.735	0.573
Riopa bowringii	0.097	0.017	0.057
Sphenomorphus maculatus	0.024	0.010	0.017
Typhlopidae			
Ramphotyphlops braminus	0.024	0.003	0.014
Xenopeltidae			
Xenopeltis unicolor	0.016	-	0.008
Colubridae			
Lycodon laoensis	0.008	-	0.004
Oligodon dorsolateralis	0.008	-	0.004
Ptyas korros	0.008	-	0.004
Pareas margaritophorus	0.008	0.003	0.006
Rhabdophis subminiatus	0.008	0.003	0.006
Viperidae			
Calloselasma rhodostoma	0.008	0.007	0.007
Total species richness	15	10	16

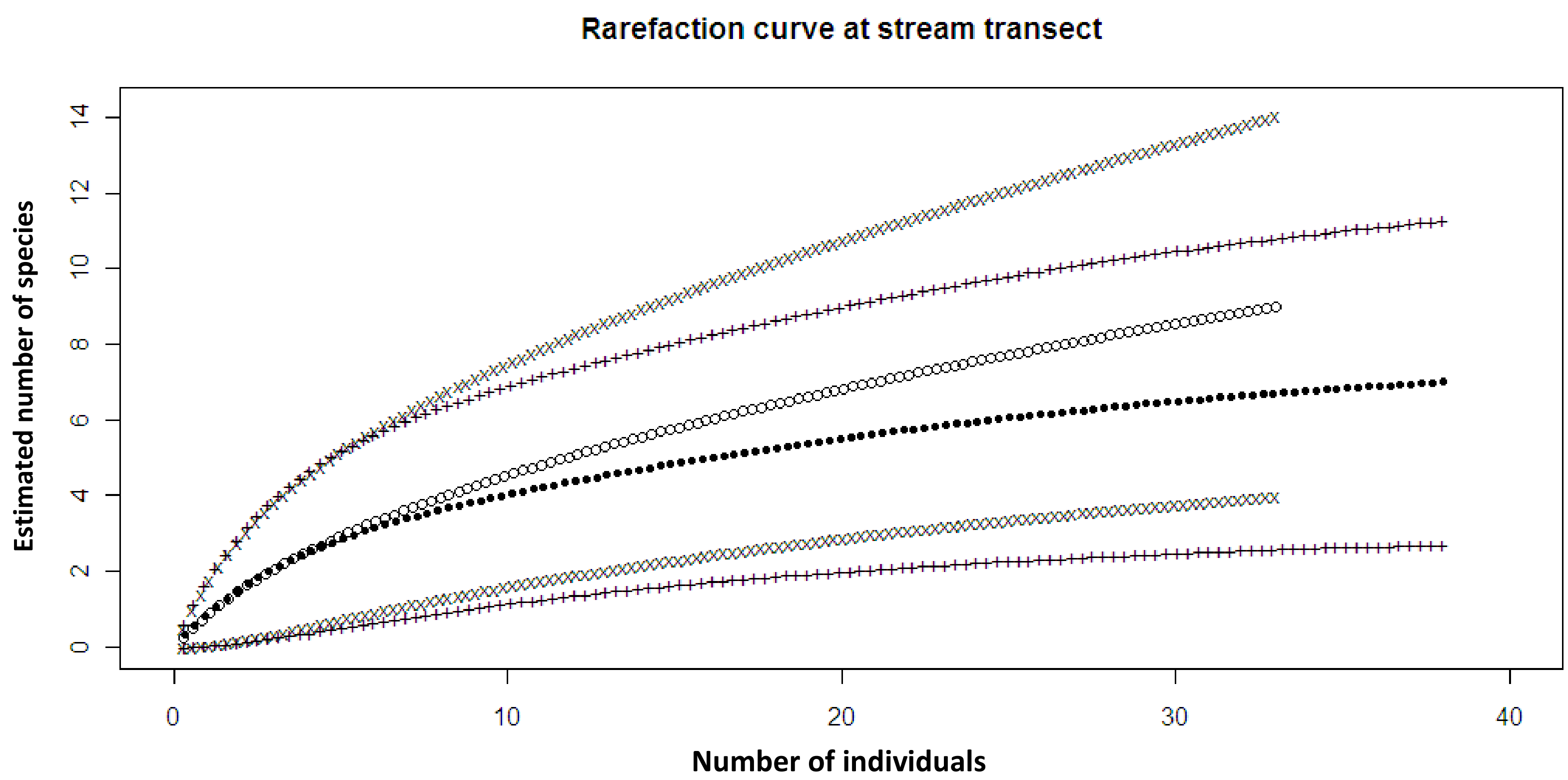

Figure 6-1 Comparison of species richness between check dam and non-check dam areas at the stream habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (●) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

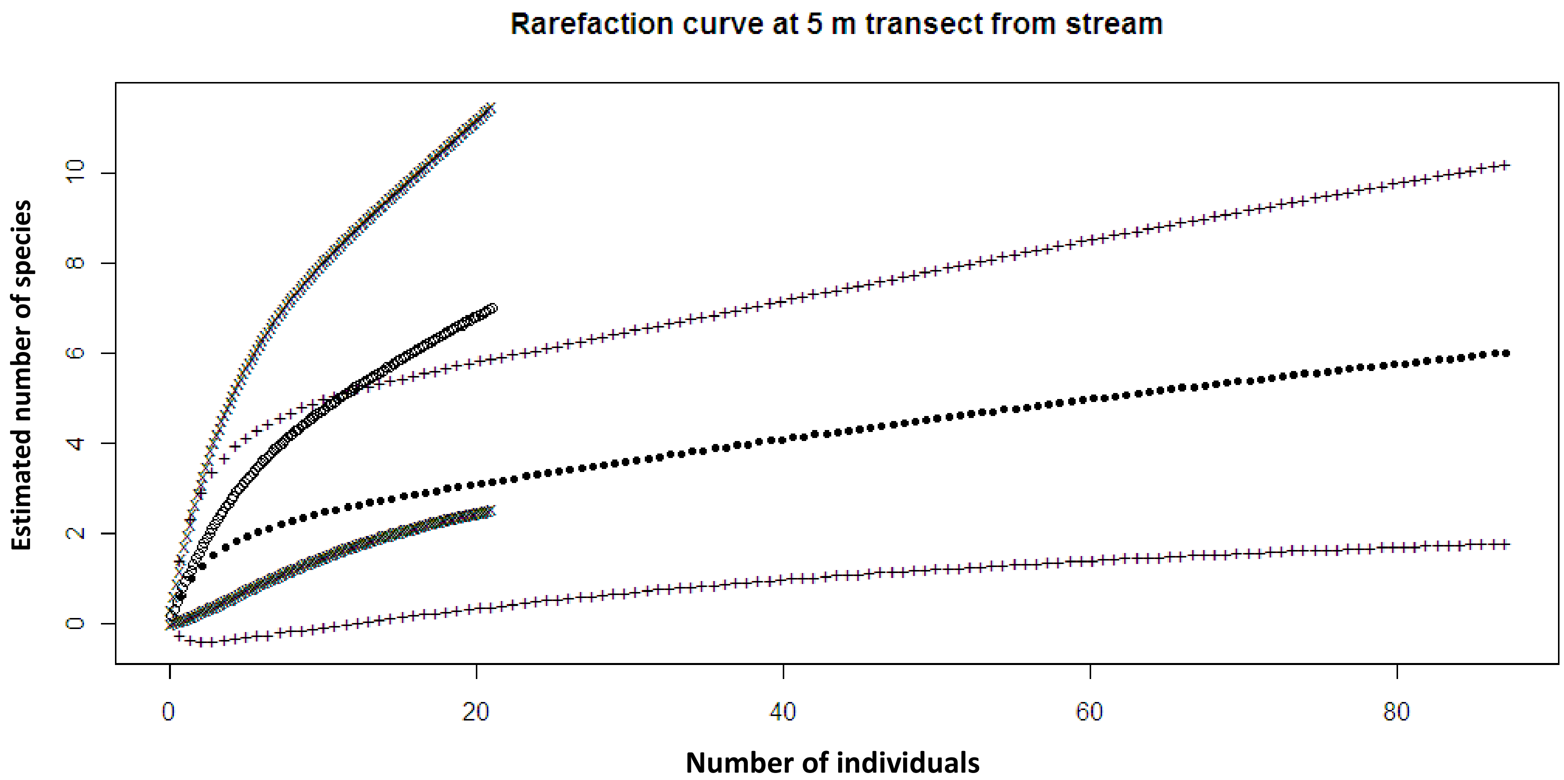

Figure 6-2 Comparison of species richness between check dam and non-check dam areas at the 5 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (●) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

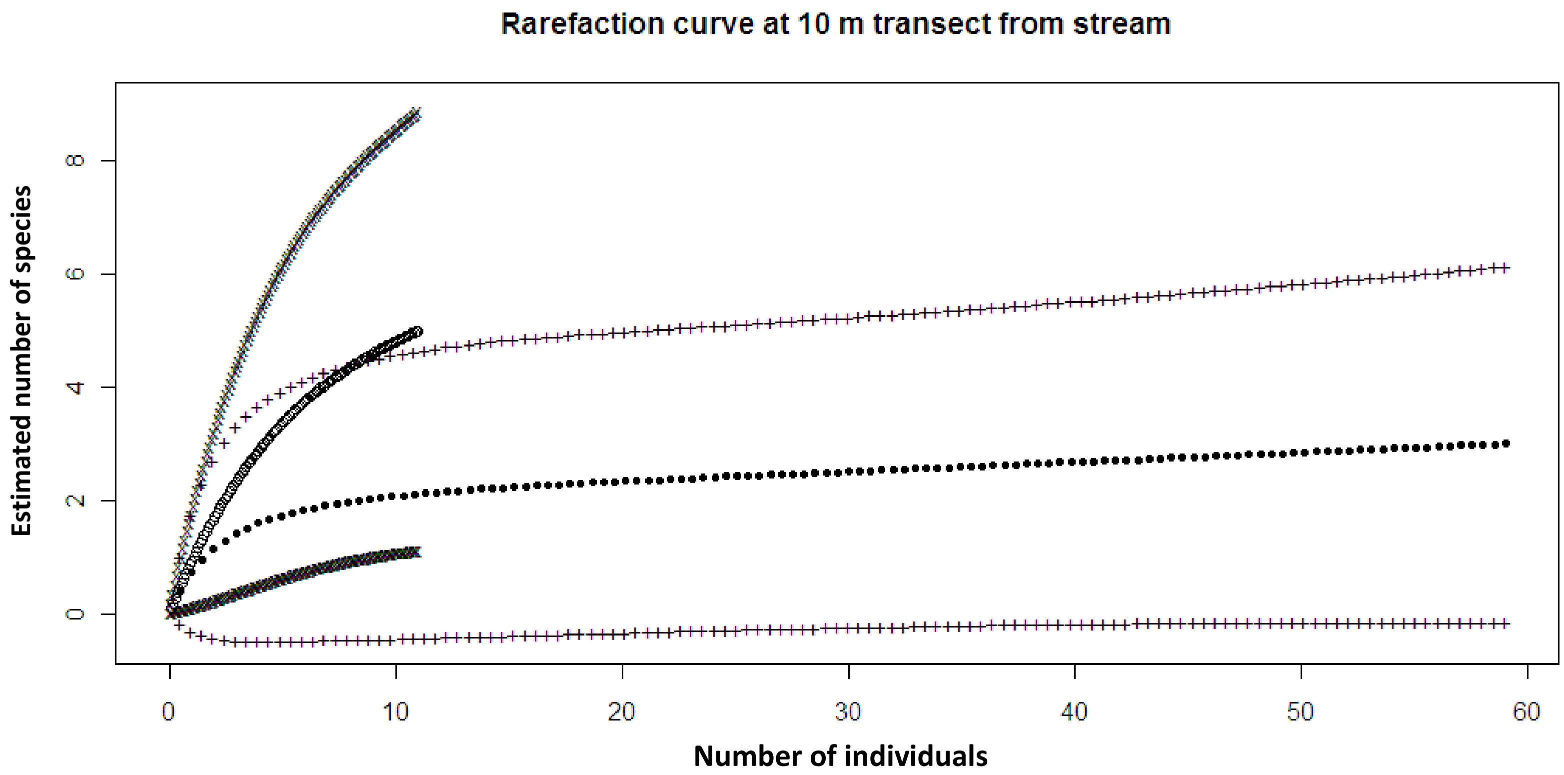

Figure 6-3 Comparison of species richness between check dam and non-check dam areas at the 10 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (•) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

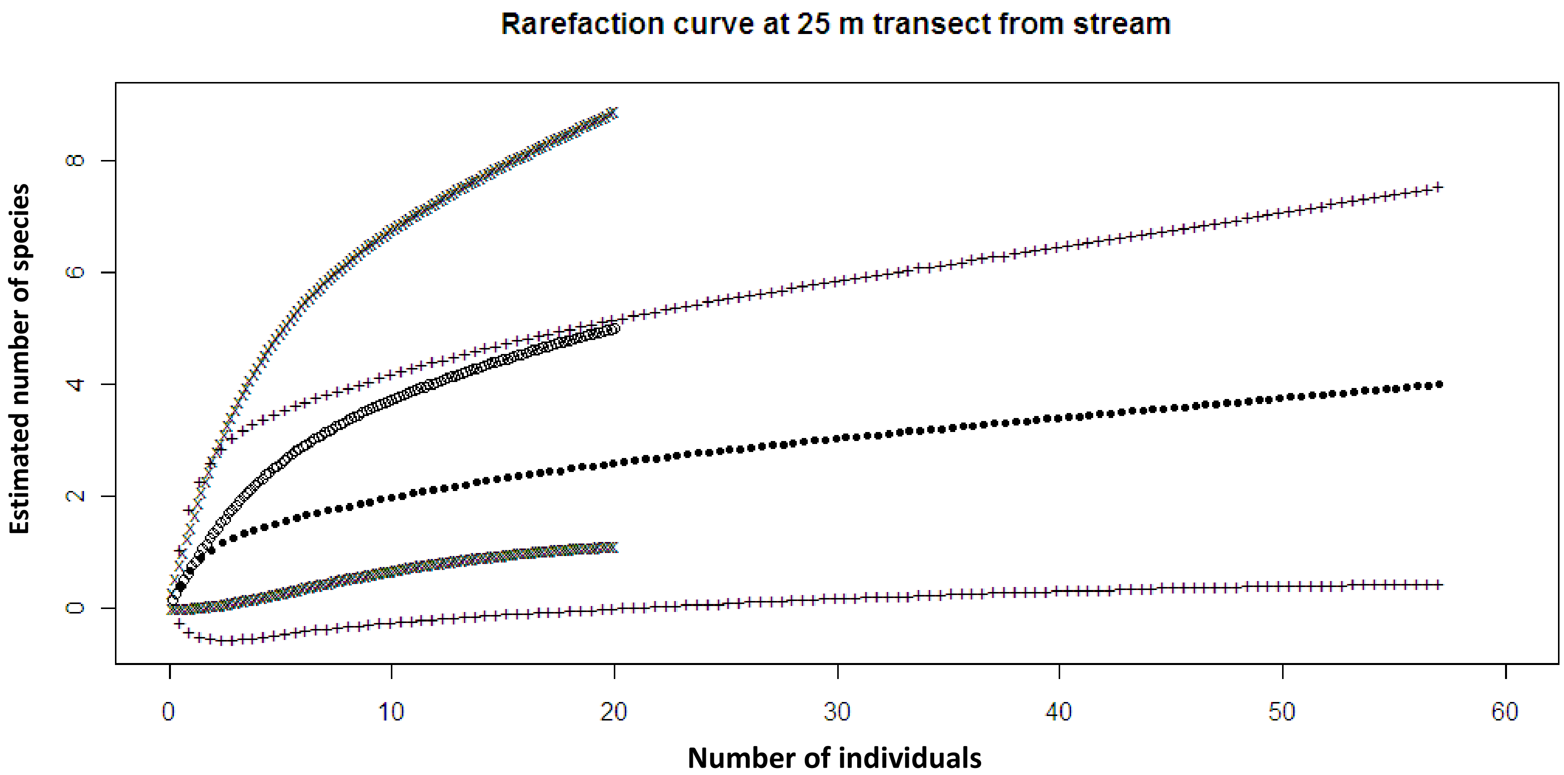

Figure 6-4 Comparison of species richness between check dam and non-check dam areas at the 25 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (●) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

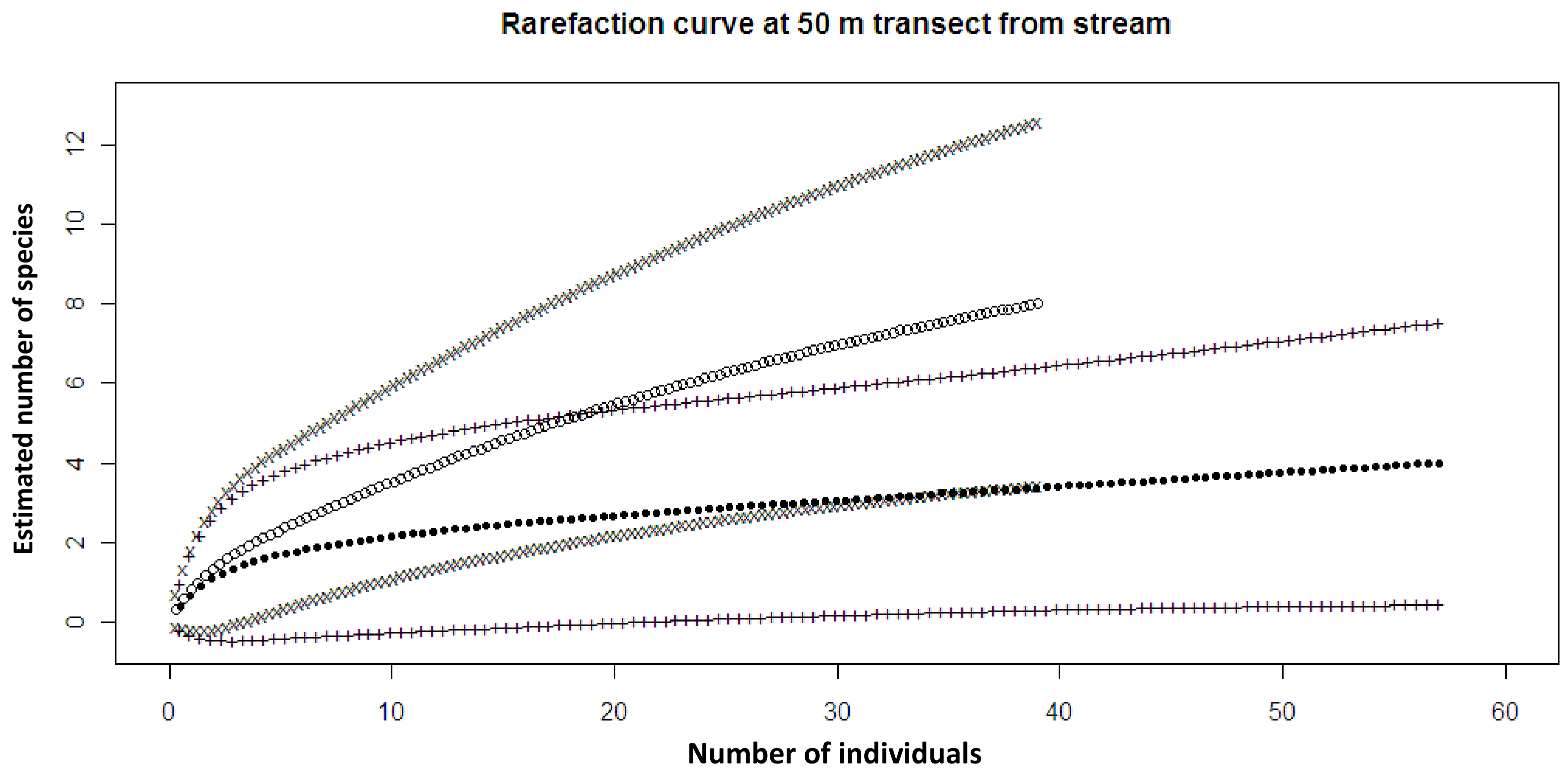

Figure 6-5 Comparison of species richness between check dam and non-check dam areas at the 50 m terrestrial habitat by rarefaction curve with 95% confidence interval. Opened dots (°) represent the check dam rarefaction curve. Close dots (●) represent the non-check dam rarefaction curve. X-mark (x) and plus (+) represent the 95% confidence interval of check dam and non-check dam curves, respectively.

6.3.1.2 Reptile composition

From the total of 16 species, 9 species of reptile were similarly found in both areas. Six species were exclusively found in the check dam area and another one species were found only in the non-check dam area. The NMDS plots indicated that the reptile compositions were similar between check dam and non-check dam areas at the stream and the 50 m terrestrial habitats (Figure 6-6 and 6-10). ANOSIM results also support this similarity (Table 6-2), showing R-values of the stream habitat of 0.14 ($p \leq 0.05$), and a very low R-value ($R=0.05$, $p>0.05$) in the 50 m terrestrial habitat. At 5 m, 10 m, and 25 m terrestrial habitats, however, NMDS plots indicated that the reptile compositions in the check dam area differ from the non-check dam areas with only small overlap between sites (Figure 6-7 to 6-9). These dissimilarities in reptile composition between check dam and non-check dam areas were also supported by ANOSIM (Table 6.2) in which the R-values indicates separation with some overlap ($R=0.50$ to 0.65, $p \leq 0.05$).

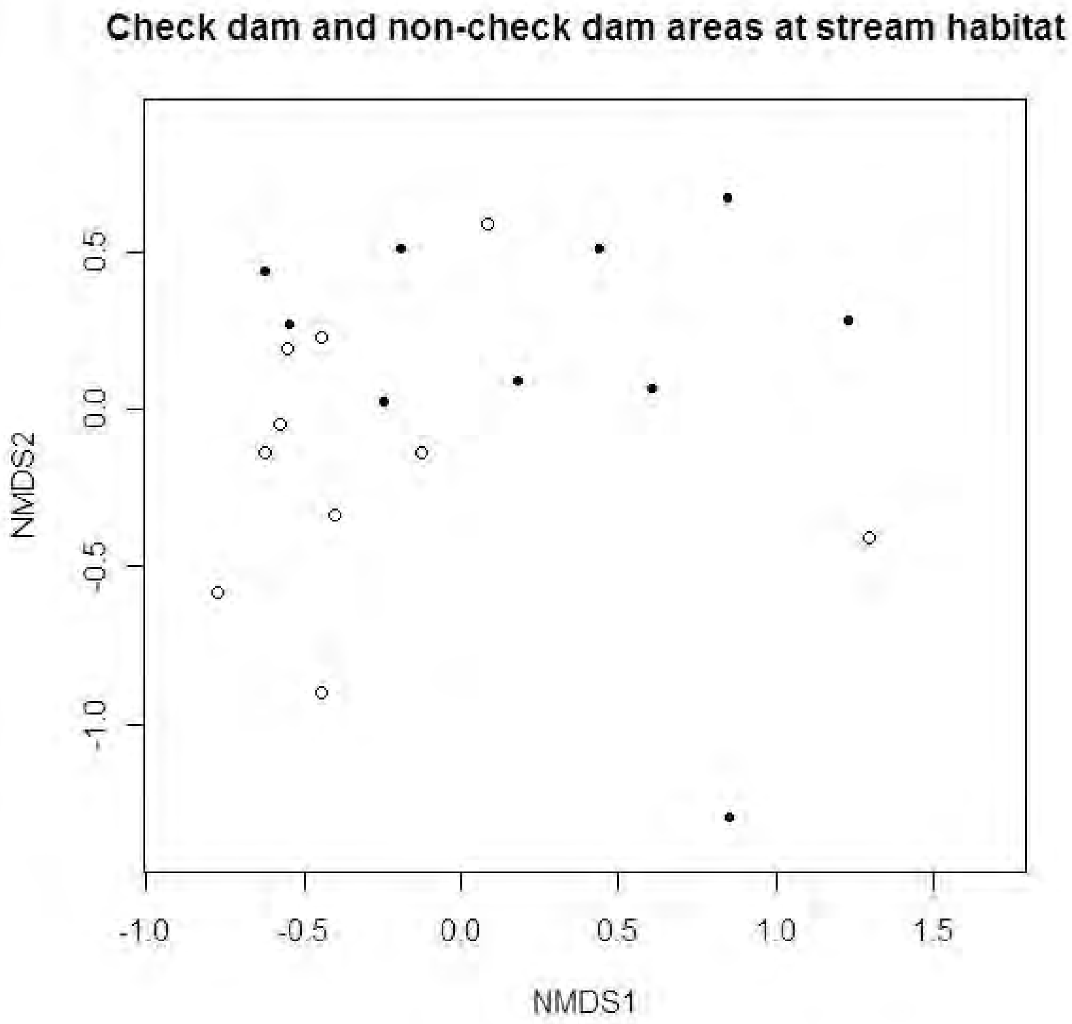

Figure 6-6 Two dimension NMDS plots of reptile composition at the stream habitat in check dam and non-check dam areas (stress=0.14). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

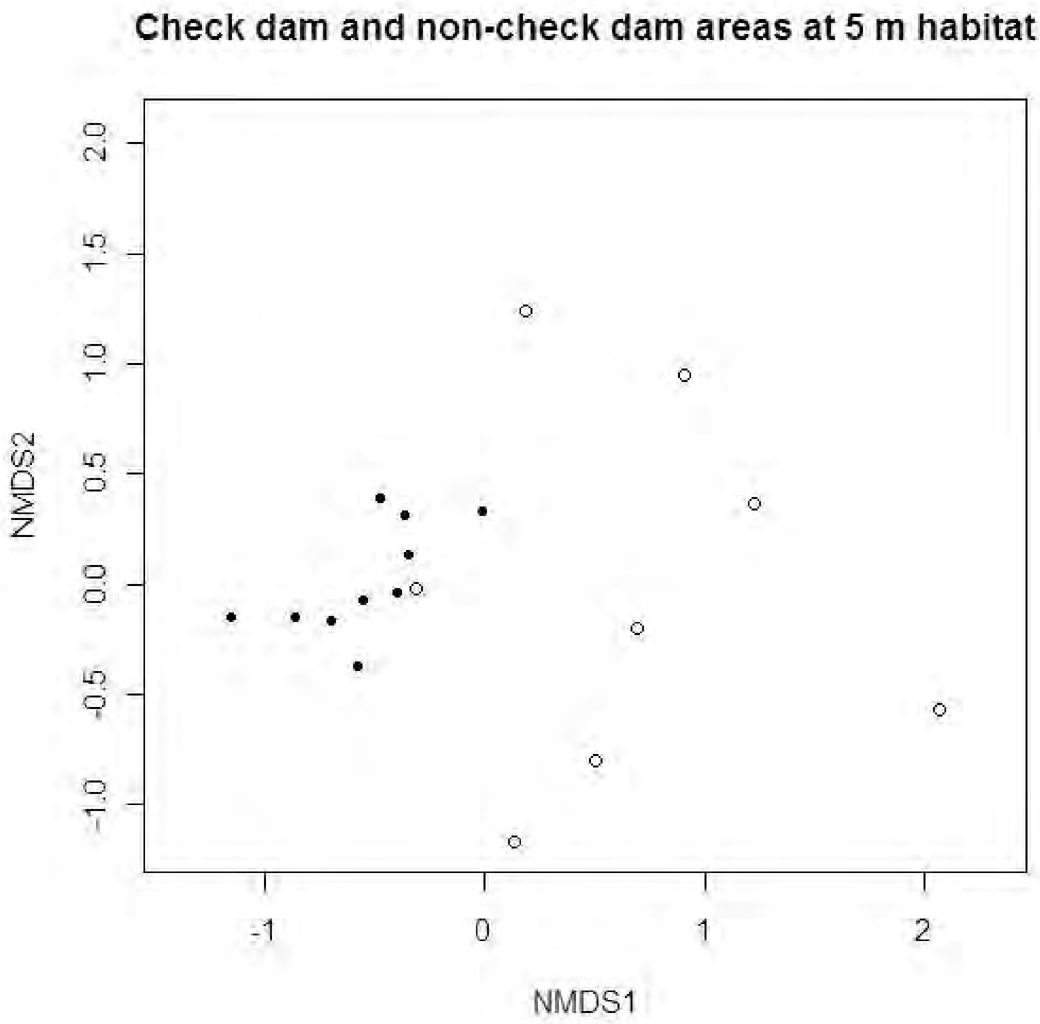

Figure 6-7 Two dimension NMDS plots of reptile composition at the 5 m terrestrial habitat in check dam and non-check dam areas (stress=0.11). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

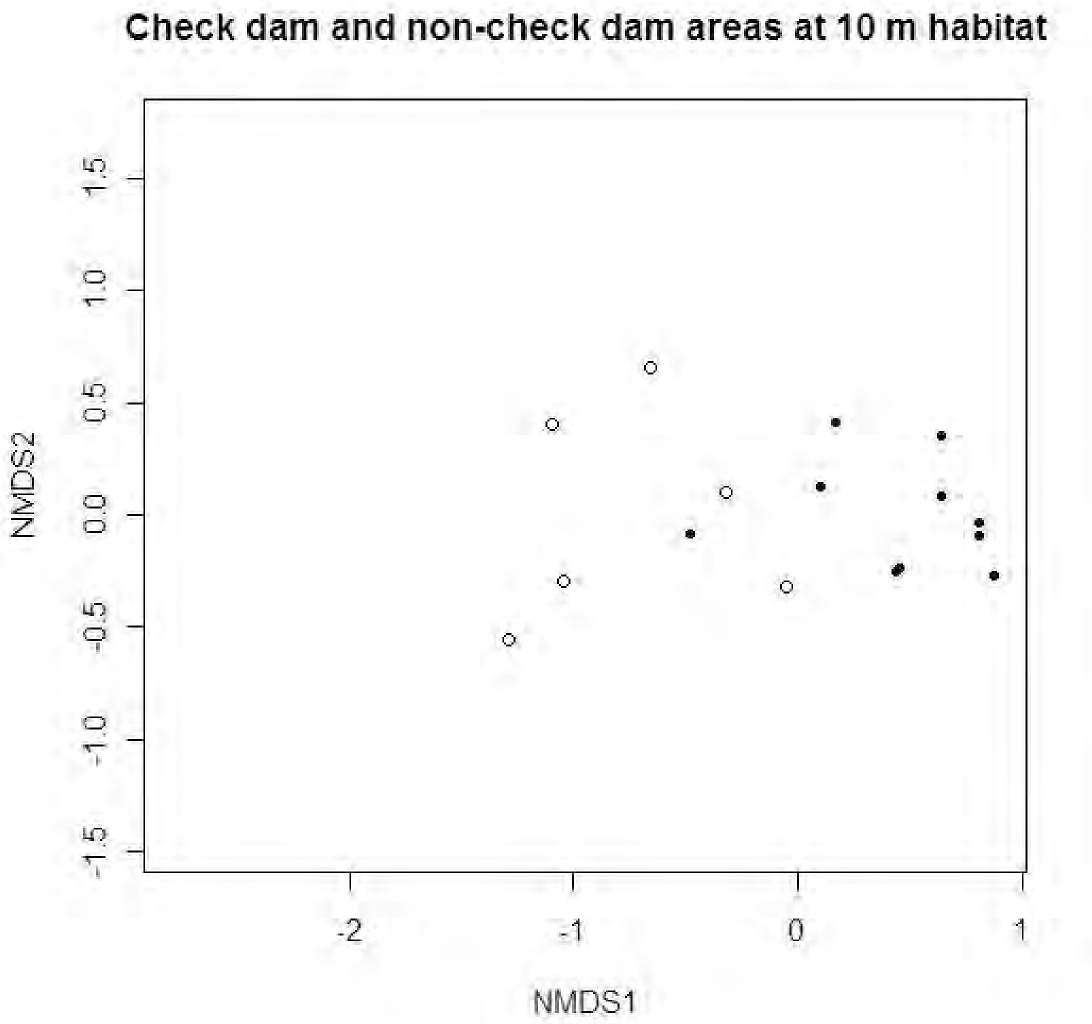

Figure 6-8 Two dimension NMDS plots of reptile composition at the 10 m terrestrial habitat in check dam and non-check dam areas (stress=0.08). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

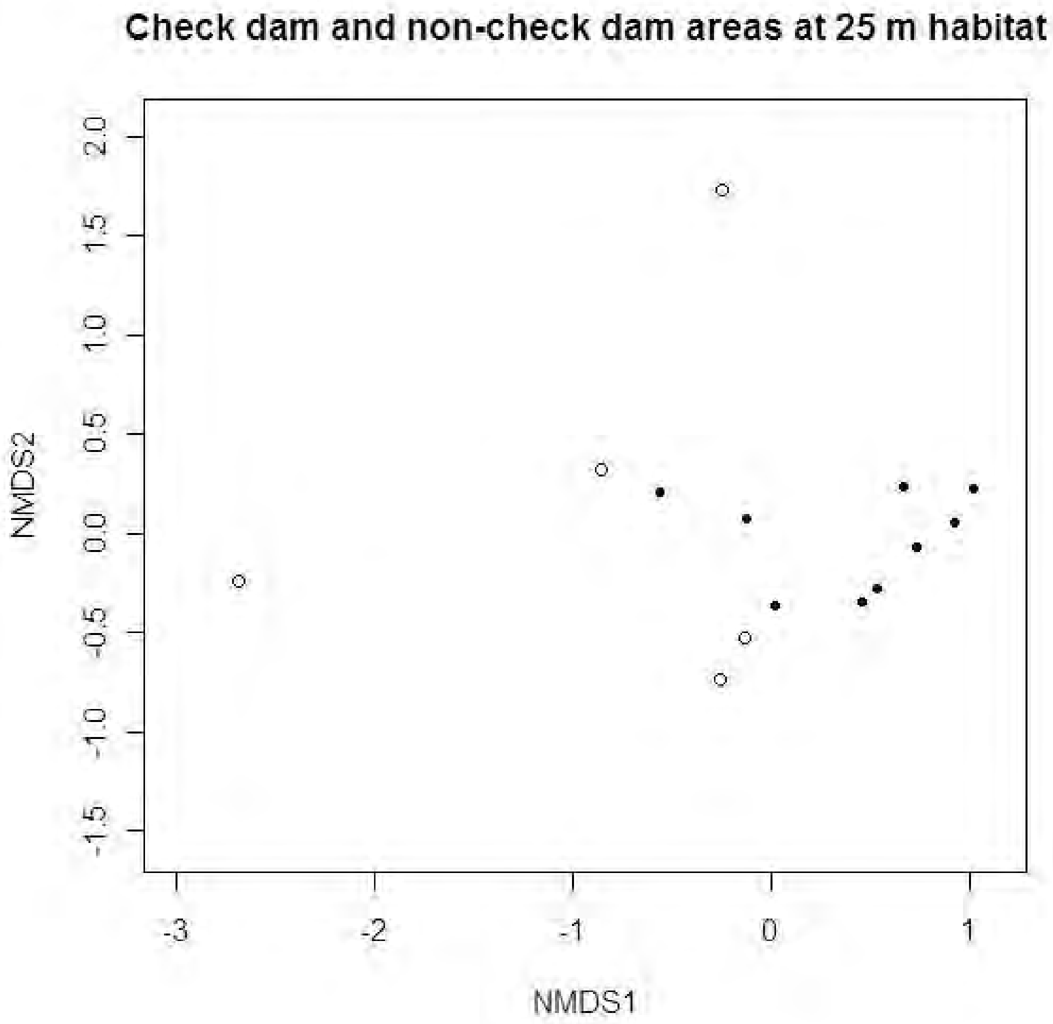

Figure 6-9 Two dimension NMDS plots of reptile composition at the 25 m terrestrial habitat in check dam and non-check dam areas (stress=0.03). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

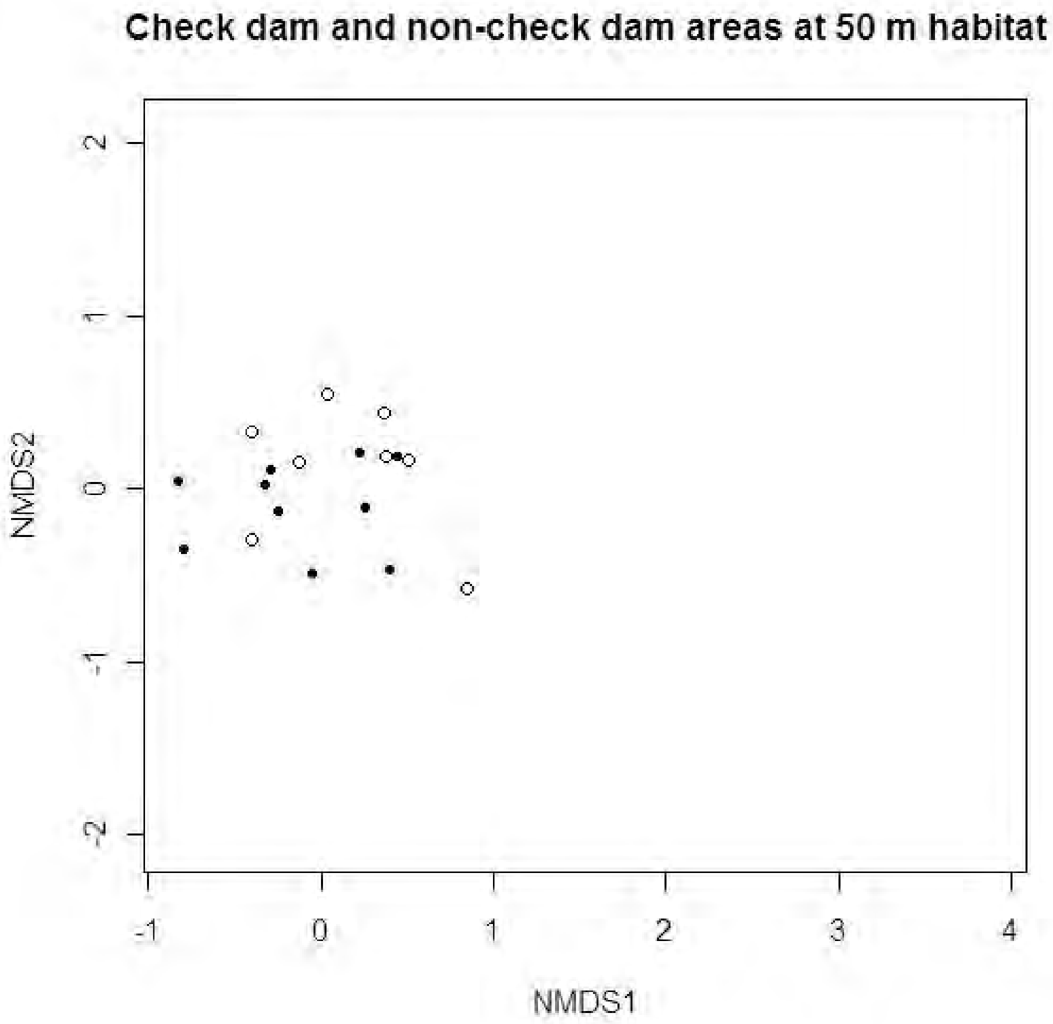

Figure 6-10 Two dimension NMDS plots of reptile composition at the 50 m terrestrial habitat in check dam and non-check dam areas (stress=0.09). Opened dots (°) represent the check dam points. Close dots (•) represent the non-check dam points.

Table 6-2 Comparison of reptile composition between check dam and non-check dam areas at stream and terrestrial habitats based on ANOSIM.

Statistics value	Habitats				
	stream	5 m terrain	10 m terrain	25 m terrain	50 m terrain
R	0.14	0.54	0.65	0.50	0.05
p	0.039	0.001	0.002	0.004	0.17

Remark: R $\geq$ 0.75 indicates well separation between these two compositions.
R = 0.74 to 0.5 indicates separation with some overlap.
R = 0.49 to 0.25 indicates separation with strong overlap.
R < 0.25 indicates no difference between these two compositions.

6.3.2 Reptile distribution pattern

From 16 reptile species found in both check dam and non-check dam areas, 9 species were commonly found in these 2 areas. Subsequently, the distribution patterns of these species in both check dam and non-check dam areas were further determined. Compared between check dam and non-check dam areas, no difference in distribution pattern was found in most of these species, except *Mabuya macularia*.

The abundances of *M. macularia* was not significantly different among transects in the check dam area, but the abundance can be divided into 3 significant groups in the non-check dam area (Figure 6-11). The lowest abundance was found in the stream transect. Then, the abundances were significantly higher at all 4 terrestrial transects.

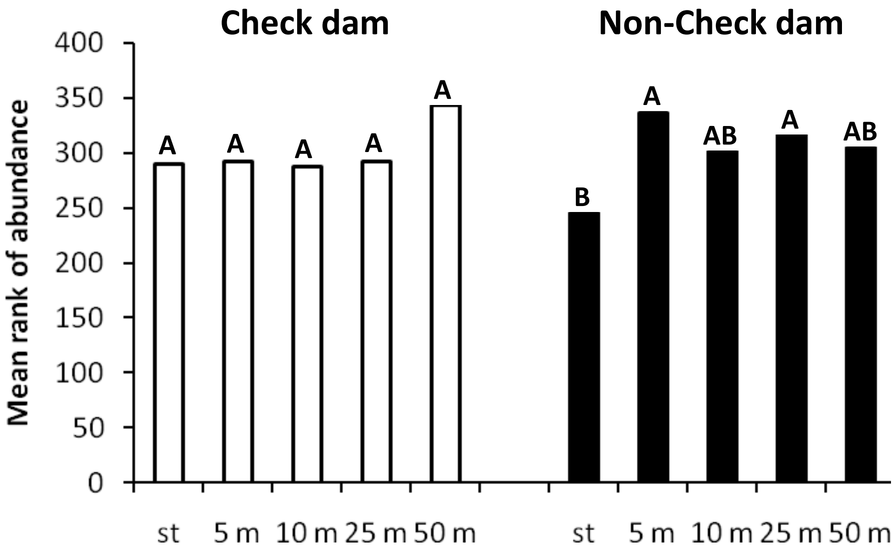

Figure 6-11 Distribution patterns of *M. macularia* among 5 transects at both check dam and non-check dam areas. White bar indicates the distribution pattern in the check dam area, and black bar indicates the distribution pattern in the non-check dam area. Difference in letter (A and B) indicate a significant difference at $p \leq 0.05$ among transect groups in each area.

6.4 Discussion

The results on environmental conditions study (Chapter III) clearly showed that the physical factors related to water (i.e. hydroperiod, number of water body, and water depth) were significantly different between check dam and non-check dam areas. Changes in these physical factors confirmed that check dam can prolong the presence of utilizable water in the area. However, an assumption that the prolonged hydroperiod in the ephemeral stream may affect reptiles that used this stream for heat absorption and sun basking seems to be challenged. The rarefaction curve indicated that reptile diversity was not significantly different between check dam and non-check dam areas in any 5 transects. Although the results from NMDS and ANOSIM indicated the difference in reptile compositions between these two areas at 5 m, 10 m, and 25 m terrestrial habitats, there were still some similarities in species compositions between these areas at the stream and the 50 m terrestrial habitats.

According to this 1-year survey, these 2 assemblage parameters indicated that the reptile assemblage in the stream habitat was not affected by the check dam albeit its effect on water pattern in the ephemeral stream. This may be due to the low level of disturbance caused by the check dam. The hydroperiod found in this study changed from 16.82% in the non-check dam area to only 31.48% in the check dam area. In addition, it is possible that the larger parts of the stream bed were still not covered by water. In an ideal condition when stream is filled with water to the maximum capacity of the check dam, the maximum depth of the stream would be equal to the check dam height, and every part of the stream bed should be covered by water. However, Table 3-1 shows that the mean water depth recorded at the deepest point in the check dam stream was only 11 cm. Given that maximum capacity of each check dam is equal to its height or around 1 m, it can be estimated based on the average water depth that the current capacity of the check dam was around 11% of total capacity. At this capacity, there were still many parts of the stream bed not covered by water that reptile can use for their activities.

Previous researches indicated that reptile assemblage can be affected by the plant community structure (Fitzgerald et al., 1999; Friend and Cellier, 1990; Vonesh, 2001). The preliminary survey found that there were some differences in plant community between check dam and non-check dam areas. In the non-check dam area, the plant community showed characteristics of the deciduous dipterocarp forest at all terrestrial habitats. For the check dam area, the plant community showed characteristics of the deciduous dipterocarp forest at 50 m terrestrial habitat, and the mixed deciduous forest at the remaining terrestrial habitat. Therefore, the difference in reptile composition between these 2 areas at 5 m, 10 m, and 25 m may be due to the difference in plant communities, not directly with the effect of the check dam.

In this study, minimal negative effect of the check dam on the existing reptile assemblage in this area was found, especially in the stream habitat. Since the study area is the forest patch located separately from other forests, the time required for new reptiles from other areas to establish in this habitat must be relatively long.

Therefore, to determine the effect of check dam on reptile assemblage, long-term monitoring is still need in order to account for the potential movement of other reptile species.

After the distribution patterns of reptiles were revealed, an assumption that reptiles would be affected by the check dam by distancing from the stream habitat in the check dam area seems to be unlikely. The results showed that the distribution patterns of most reptiles were not different between these areas except for the distribution pattern of only one species, *M. macularia*. Even for *M. macularia*, the distribution pattern showed an avoidance of the stream habitat only in the non-check dam area, whereas equal distribution within 5 transects was found in the check dam area. Previous researches concluded that the reptile distribution pattern can be influenced by vegetation covers (Friend and Cellier, 1990; Heyer, 1967; Vonesh, 2001). Since the forest community of these 2 study areas were not exactly the same, the difference in distribution pattern of *M. macularia* between these 2 areas may be due to the difference in the vegetation cover, not by the check dam.

Although the physical factor study indicated that the check dam can prolong the water period in this ephemeral stream, the reptile assemblage were not affected by this change. The distribution patterns of most reptile species were also not affected by the check dam. Therefore, it can be concluded base on this 1 year study that check dam can be used as an effective tool to prolong the water period in the ephemeral stream with minimal negative effect on the reptile assemblage and the distribution of most reptile species. However, based on the fact that this study area was disturbed by human activities in the past (see Chapter II), it is crucial to note that this conclusion was based on the reptile community that endured previous disturbance, but not the pristine community

CHAPTER VII

EFFECTS OF CHECK DAM ON REPTILE ASSEMBLAGE AND DISTRIBUTION ALONG EPHEMERAL STREAMS IN A DECIDUOUS FOREST AT NAN PROVINCE: A TEMPORAL COMPARISON BETWEEN PRE- AND POST-CHECK DAM PERIODS

7.1 Introduction

With an increasing trend of using check dam as means of water management in Thailand, it is essential to investigate and monitor the check dam effects on environment. Previous reports clearly showed that check dam can improve absorption rate of water in the stream (Watershed Conservation and Management Office, 2008), prolong hydroperiod (Watershed Conservation and Management Office, 2008), reduce sediment erosion (Huang et al., 2009; Xiang-zhou et al., 2004) and stabilize physical characteristics of the stream (Castillo et al., 2007; Liu, 1992; Solaimani, et al., 2008; Zeng et al., 2009). Although, reports on the effect of check dam on physical factors are available, there were only a few researches on the check dam effect on biological factors, especially on animal in the check dam area.

Among terrestrial vertebrates, reptile could be regarded as a susceptible species to change caused by the check dam. As ectothermic animals, reptiles cannot generate the heat required for maintaining their body temperature and need to depend on the heat from surrounding environment (Vitt and Caldwell, 2009). In natural habitat, reptiles living in vicinity of an ephemeral stream, where water is not permanent and canopy cover is minimal, could rely on the dried up stream bed as a basking or a heat conduction sites. This kind of ephemeral stream also happens to be the preferred choice for check dam construction site in Thailand (Department of Local Administration, 2008). As a result, the prolonged hydroperiod after the check dam construction may affect habitat utilization of the reptile and give rise to change in species diversity and distribution.

To monitor effect of habitat alteration, ecosystem health and function are frequently evaluated based on species assemblage or diversity, while response of animal to certain environmental change are normally monitored from the distribution pattern (Ricklefs and Miller, 2000). Therefore, reptile assemblage and distribution pattern were selected as the monitoring parameters in this study. In this part of the study, effects of the check dam were determined based on a temporal comparison between pre- and post-check dam periods in the same study area in order to lessen effect of different habitat characteristics. The objectives of this study include 1) to determine and compare the reptile assemblage, and 2) to determine and compare the distribution pattern of reptile along the ephemeral stream between pre- and post-check dam periods.

7.2 Methodology

7.2.1 Study site and survey period

This study was conducted at an ephemeral stream (stream B; Figure 2-1) at the Chulalongkorn University Forest and Research Station, Nan Province (UTM zone 47Q: N2051960-2054260 and E0688400-0690360) for 2 years during April 2009 to February 2011. In this stream, there was originally no check dam presented. Later on, check dams were constructed in the dry period of the stream during December 2009 to February 2010. This scheme allowed a systematic comparison of biotic components between pre-check dam and post-check dam periods. The survey period in this study began at the onset of wet season or the start of check dam functioning period and ended at the end of dry season. According to the climate diagram (Figure 3-2 in Chapter III), the pre-check dam period in this study was during April 2009–March 2010 and the post-check dam period was during May 2010–February 2011.

7.2.2 Reptile survey method

Two transect types were used for reptile surveys. The first type is a stream transect used for an aquatic habitat survey, and the second type is a terrestrial strip transect used for a terrestrial habitat survey.

7.2.2.1 Stream transect

Ten stream transects in stream B were used for reptile survey. In the pre-check dam period, the stream transect started from one planned check dam construction site to the next upstream check dam construction site (Figure 3-1). In the post-check dam period, the stream transect started from one check dam to the next upstream check dam or the maximum water level point of that check dam. Width of the transect was similar to the stream width, or approximately 2 m yet the length of transect was depended on the distance between two corresponded check dams.

7.2.2.2 Terrestrial strip transect

There were 40 terrestrial strip transects used for reptile survey. For each stream transect, there were 4 parallelled terrestrial strip transects with the perpendicular distance from the stream of 5, 10, 25, and 50 m (Figure 3-1). Length of each transect was equal to the vector length of the corresponding stream transect, while width of the transect was 2 m.

Reptiles were monitored in stream and terrestrial strip transects by active survey based on transect sampling method (Heyer et al., 1994). The surveys were conducted in each transect at every micro-habitats including in the water, on the bare ground, under leaf litter and on tree with height of less than 1.5 m. Reptiles found were identified to species and numbers of individuals were also recorded. In each month, the surveys were conducted for 16 consecutive days until every transect was studied. In each day, transects were randomly selected so that 3 transects were surveyed during the daytime (9:00-12:00) and other 3 transects were surveyed during the nighttime (19:00-22:00). During each survey, special care was given to avoid habitat disturbance in the remaining transects.

Data from these 50 transects were separated into 5 transect groups according to the distance from the stream, including stream transect (0 m from the stream) and terrestrial transects with distances of 5, 10, 25, and 50 m from the stream.

7.2.3 Data analysis

The data were analyzed separately according to the transect groups and compared between pre- and post-check dam periods.

7.2.3.1 Reptile assemblage

Proportional abundance of each reptile species in each area was used for the comparison of reptile species so that the high abundance species could be recognized. This value was calculated by dividing reptile density of each species by the total reptile density found in a particular area.

Reptile assemblage was separately analyzed into species diversity and composition. For the diversity, rarefaction model was used to compare the reptile species richness in order to prevent the effect of unequal length of the survey periods between pre- and post-check dam periods (Magurran, 2004). Rarefaction value and its 95% confidence interval were calculated by EstimateS 8.2 program (Colwell, 2006). Afterward, the values of pre- and post-check dam periods were plotted as a function of sampling efforts. With this plot, significant difference in species diversity is indicated by an absence of overlap in the confidence interval of rarefaction curves between pre- and post-check dam periods at the maximum sampling effort (Colwell et al., 2004). For the reptile composition analysis, dissimilarity matrix between pre- and post-check dam periods was constructed base on the Bray-Curtis distance measurement. Then, two dimensional ordination was plotted by using non-metric multidimensional scaling (NMDS). The data were also evaluated by analysis of similarity (ANOSIM) with 1,000 permutations to test for the significant difference in reptile composition between pre- and post-check dam periods. The R-statistics from ANOSIM indicates the dissimilarity in species compositions between these two periods, and normally ranges from 0 (highly similar between groups) to 1 (highly different between groups). The following criteria (Clarke and Gorley, 2001) was used to interpret the data:

R $\geq$ 0.75 indicates well separation between these two compositions.

R = 0.74 to 0.5 indicates separation with some overlap.

R = 0.49 to 0.25 indicates separation with strong overlap.

R < 0.25 indicates no difference between these two compositions.

The construction of the dissimilarity matrix, the ordination plot, and the analysis of similarity were run by using "vegan" package in R program (R Development Core Team, 2011).

7.2.3.2 Reptile distribution pattern

Abundance of reptile showed in this part were in the form of mean rank of abundance that can be calculated as follows. First, number of species found in each transect were combined to get the total sample number (N). Second, abundance of every species in every transect was sorted from the lowest to the highest. In this case, the rank of abundance would range from 1 (the lowest abundance) to N (the highest abundance). Finally, mean rank of abundance of each transects is calculated based on an average of rank number of every samples found in the particular transect.

The abundance of each reptile species in both pre- and post-check dam were compared among 5 transect groups by Kruskal-Wallis Test with nonparametic Tukey-type multiple comparisons at $p \leq 0.05$ (Zar, 1999). Three possible scenarios of difference in distribution pattern between pre- and post-check dam periods are listed as follows. First, the higher abundance of a particular species shift from one transect in the pre-check dam period to another transect in the post-check dam period. Second, an abundance of a particular species did not show any significant difference among transects in the pre-check dam period, but showed a significantly higher value in one or more transects in the post-check dam period. Third, an abundance of a particular species showed a significantly higher value in one or more transects of the pre-check dam period, but showed no significant difference among transects in the post-check dam period.

7.3 Results

7.3.1 Reptile assemblage

7.3.1.1 Reptile diversity

Overall, 13 reptile species were found at stream B in both pre- and post-check dam periods (Table 7-1). The species richness in pre- and post-check dam periods were equal at 10 species. The highly abundant species found in these two periods are *Mabuya macularia* and *Dixonius siamensis*.

The rarefaction curve showed similar results in every transect of both pre- and post-check dam periods. Overlap in the 95% confidence interval between pre- and post-check dam curves (Figure 7-1 to 7-5) indicated that the reptile species richness were not significantly different between these 2 periods at every habitat.

Table 7-1 Proportional abundance of reptile in pre- and post-check dam periods.

Family/Species	Proportional abundance in the area		
	Pre-check dam	Post-check dam	Both periods
Gekkonidae			
Dixoneus siamensis	0.201	0.245	0.223
Cosymbotus platyurus	-	0.005	0.003
Hemidactylus frenatus	0.007	0.068	0.037
Agamidae			
Calotes mystaceus	0.013	-	0.007
Scincidae			
Mabuya macularia	0.735	0.615	0.675
Riopa bowringii	0.017	0.021	0.019
Sphenomorphus maculatus	0.010	0.005	0.008
Typhlopidae			
Ramphotyphlops braminus	0.003	0.005	0.004
Xenopeltidae			
Xenopeltis unicolor	-	0.005	0.003
Colubridae			
Ptyas korros	-	0.005	0.003
Pareas margaritophorus	0.003	-	0.002
Rhabdophis subminiatus	0.003	-	0.002
Viperidae			
Calloselasma rhodostoma	0.007	0.026	0.016
Total species richness	10	10	13

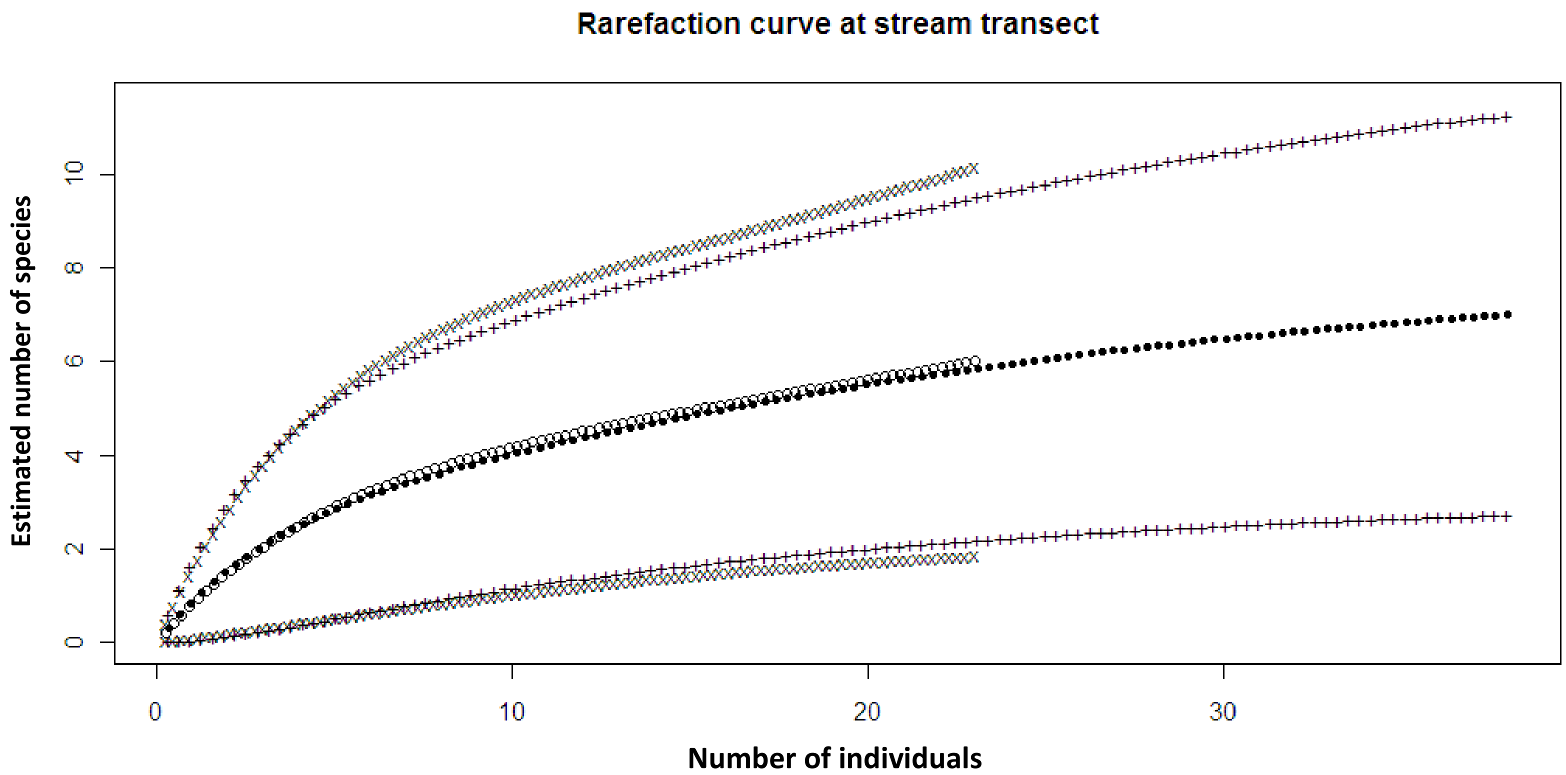

Figure 7-1 Comparison of species richness between pre- and post-check dam periods at the stream habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

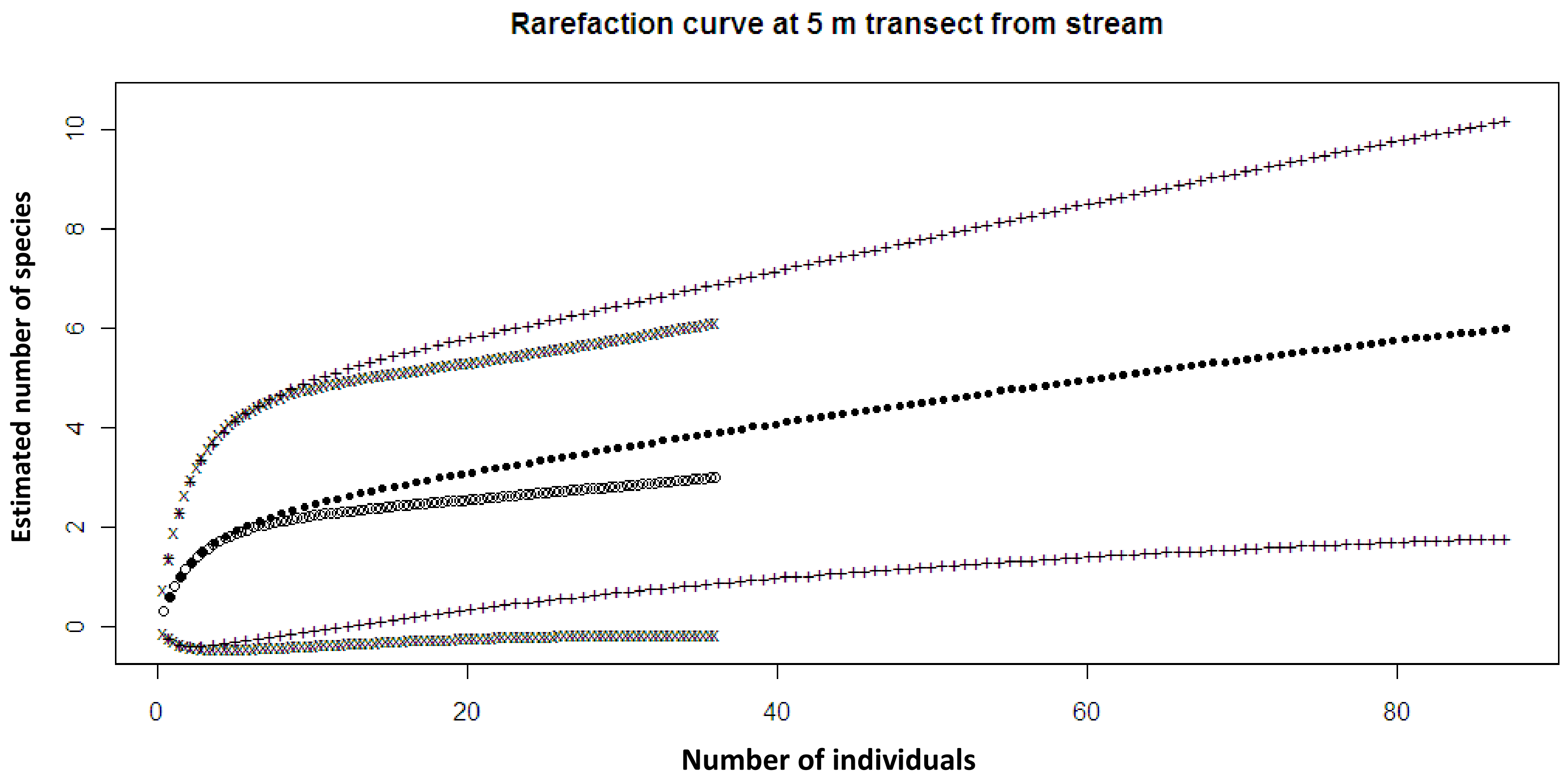

Figure 7-2 Comparison of species richness between pre- and post-check dam periods at the 5 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

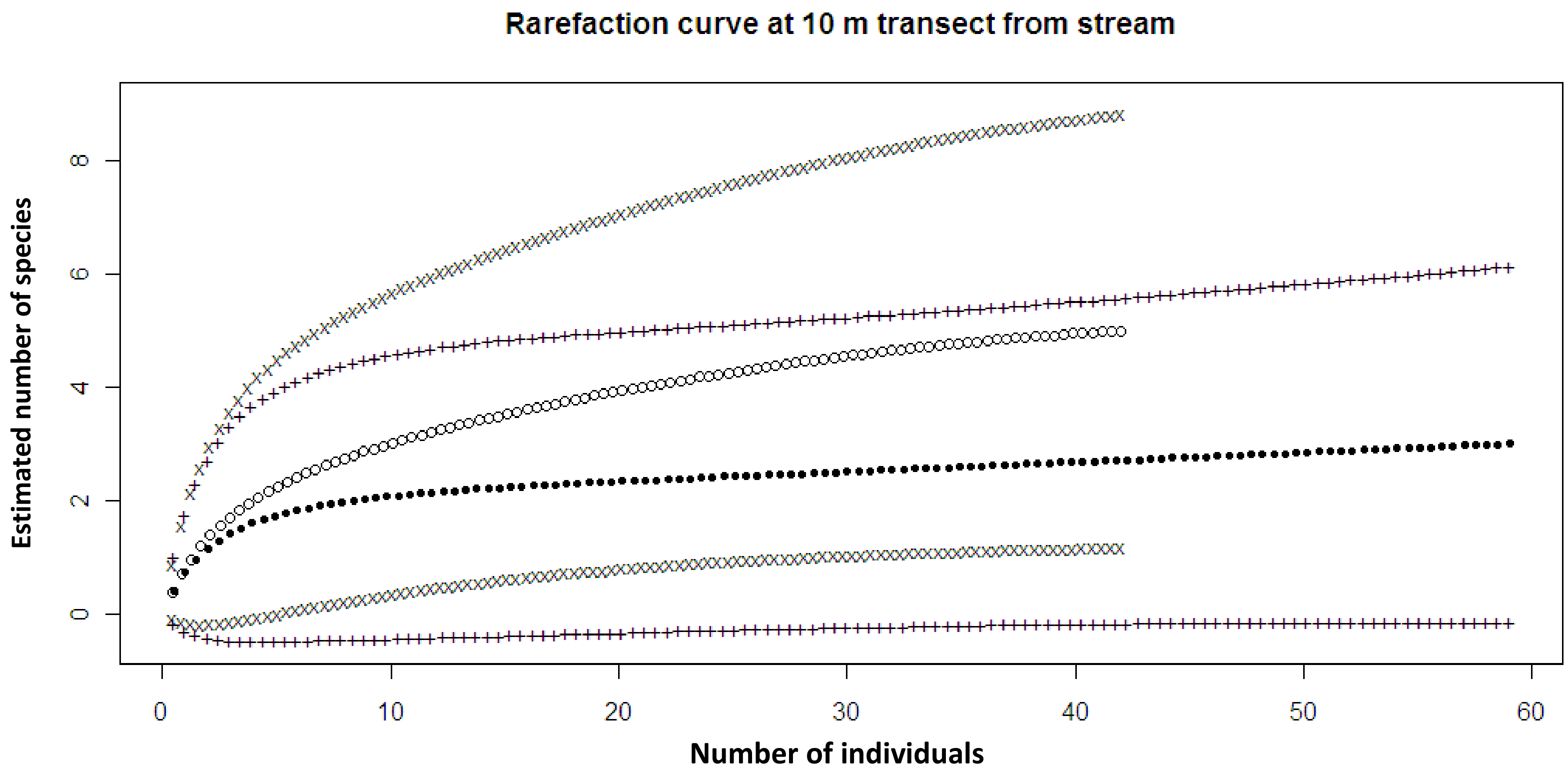

Figure 7-3 Comparison of species richness between pre- and post-check dam periods at the 10 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

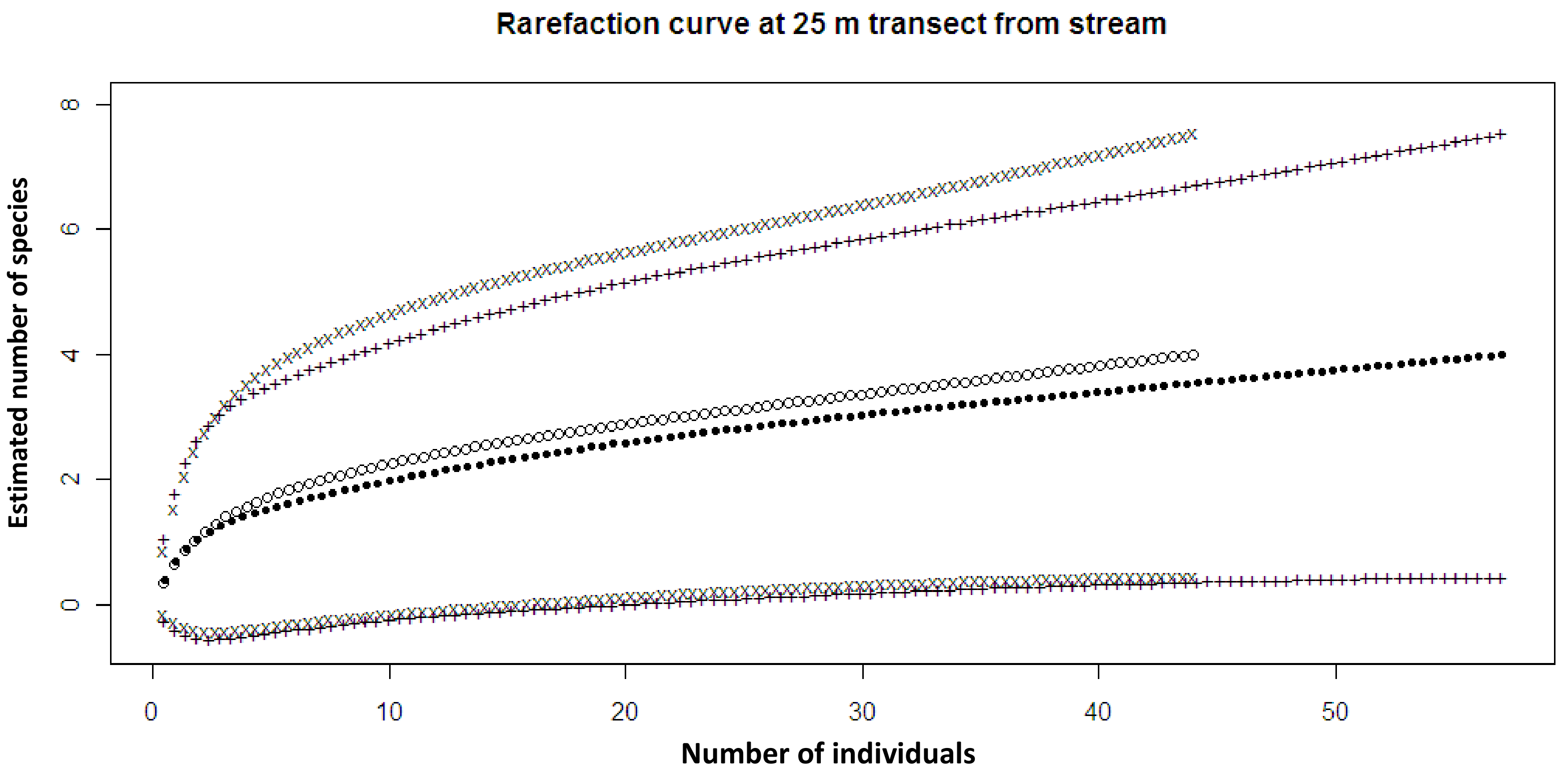

Figure 7-4 Comparison of species richness between pre- and post-check dam periods at the 25 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (●) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

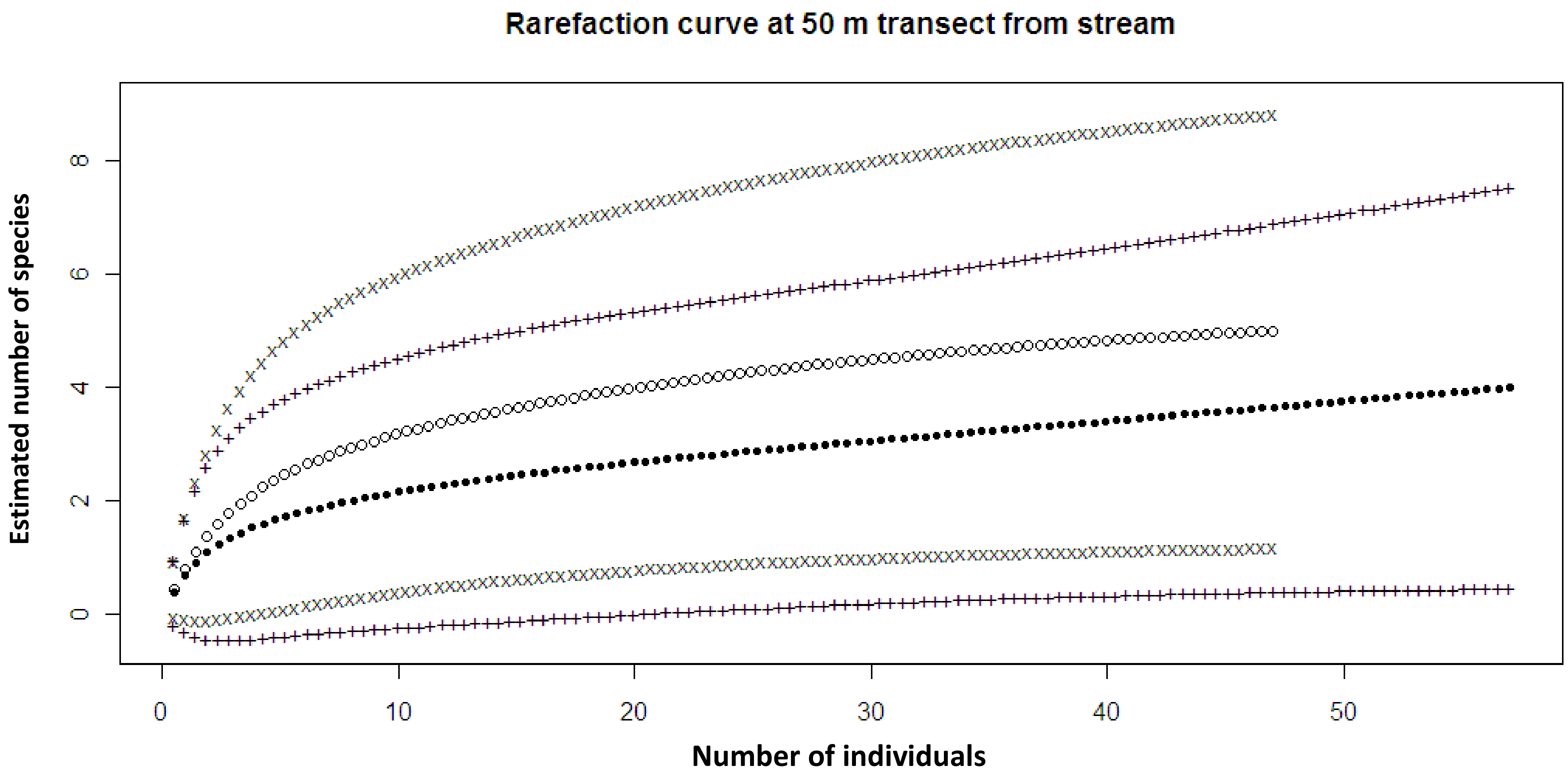

Figure 7-5 Comparison of species richness between pre- and post-check dam periods at the 50 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent the pre-check dam rarefaction curve. Opened dots (°) represent the post-check dam rarefaction curve. Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

7.3.1.2 Reptile composition

Among 13 reptile species found in both pre- and post-check dam periods of stream B, 7 species were similarly found in both periods. There were three species (*Calotes mystaceus*, *Pareas margaritophorus,* and *Rhabdophis subminiatus*) that solely found in the pre-check dam period, and other three species (*Cosymbotus platyurus*, *Xenopeltis unicolor,* and *Ptyas korros*) that solely found in the post-check dam period.

The NMDS plots indicated that reptile compositions were similar between pre- and post-check dam periods at all habitats (Figure 7-6 to 7-10). The results from ANOSIM (Table 7-2) also supported these findings (Table 7-2) showing very low R-value (-0.07 to 0.09) at the stream and 10 m, 25 m, and 50 m terrestrial habitats (p>0.05). R-value of 0.19 (p≤0.05) at the 5 m terrestrial habitat also indicated that reptile compositions were not different between these 2 periods.

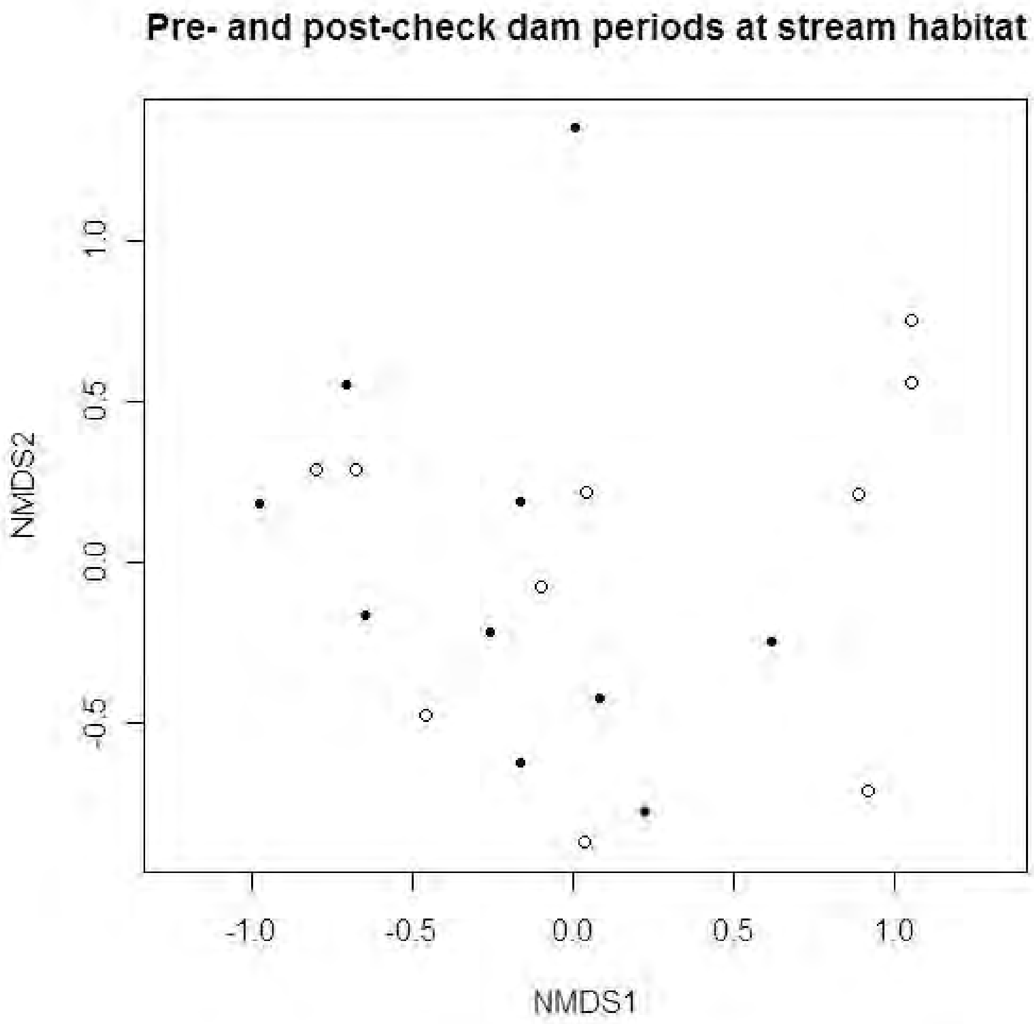

Figure 7-6 Two dimension NMDS plots of reptile composition at the stream habitat in pre- and post-check dam periods (stress=0.17). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

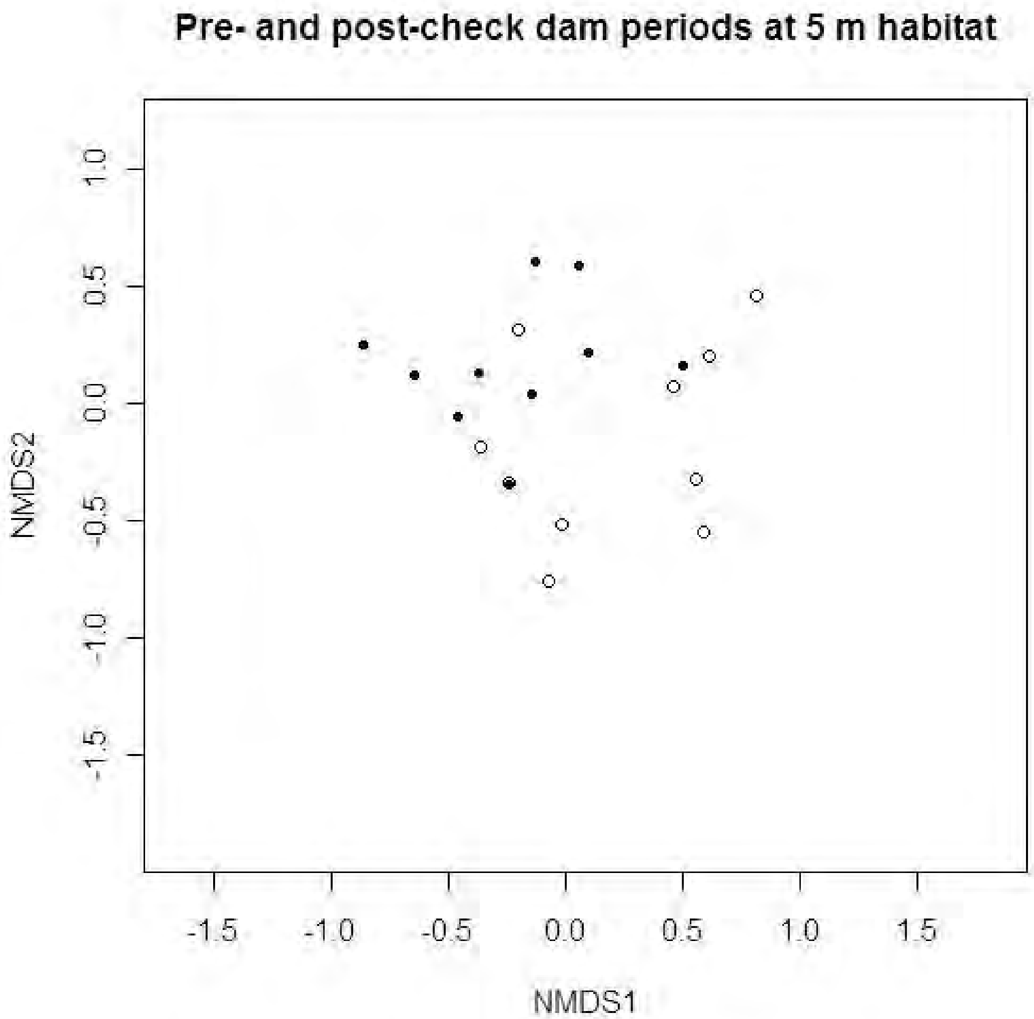

Figure 7-7 Two dimension NMDS plots of reptile composition at the 5 m terrestrial habitat in pre- and post-check dam periods (stress=0.08). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

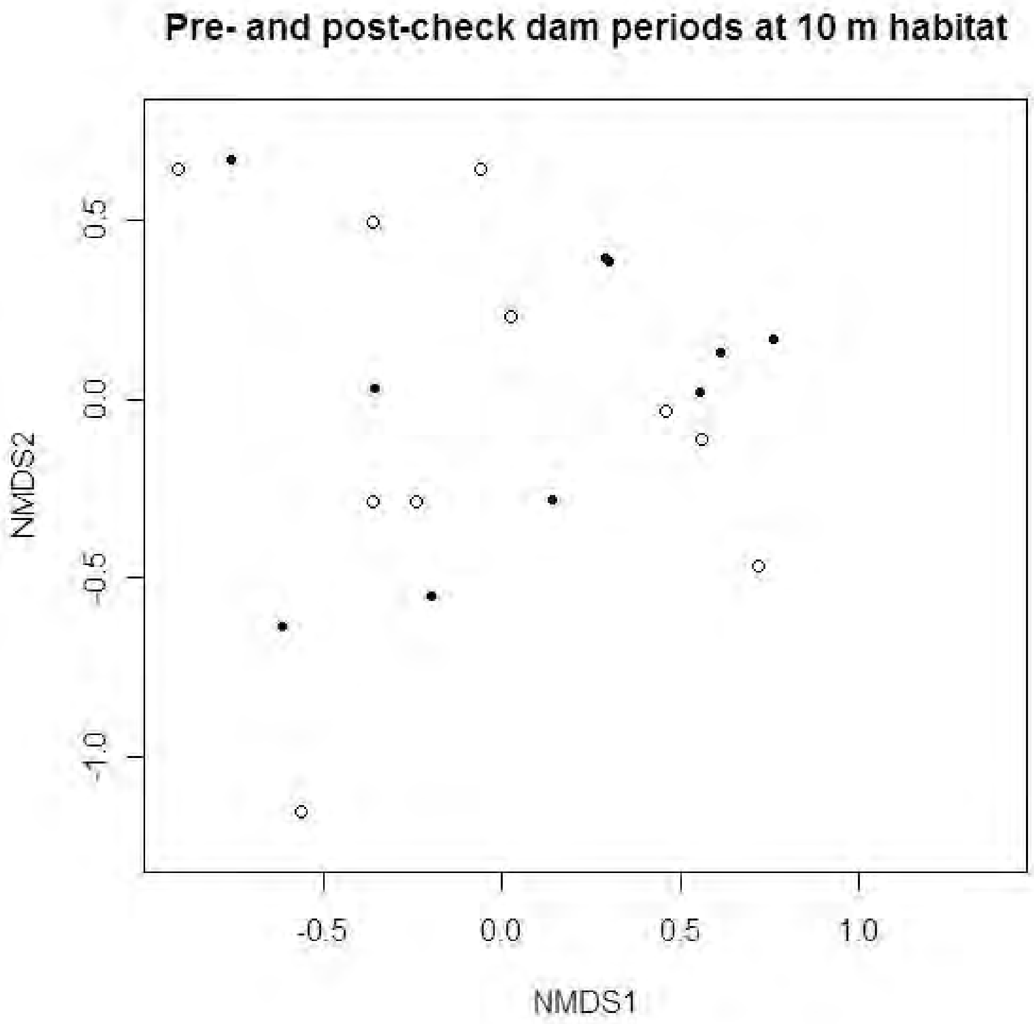

Figure 7-8 Two dimension NMDS plots of reptile composition at the 10 m terrestrial habitat in pre- and post-check dam periods (stress=0.09). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

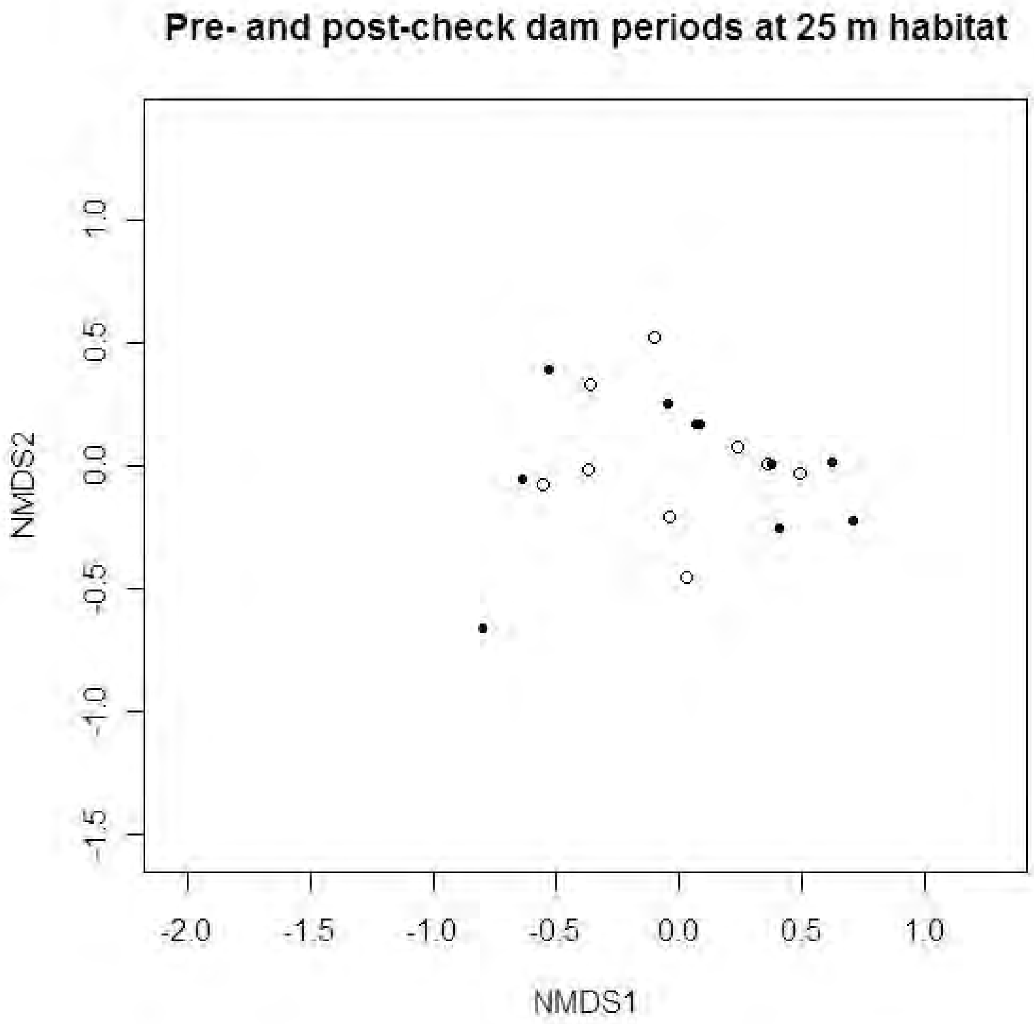

Figure 7-9 Two dimension NMDS plots of reptile composition at the 25 m terrestrial habitat in pre- and post-check dam periods (stress=0.06). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

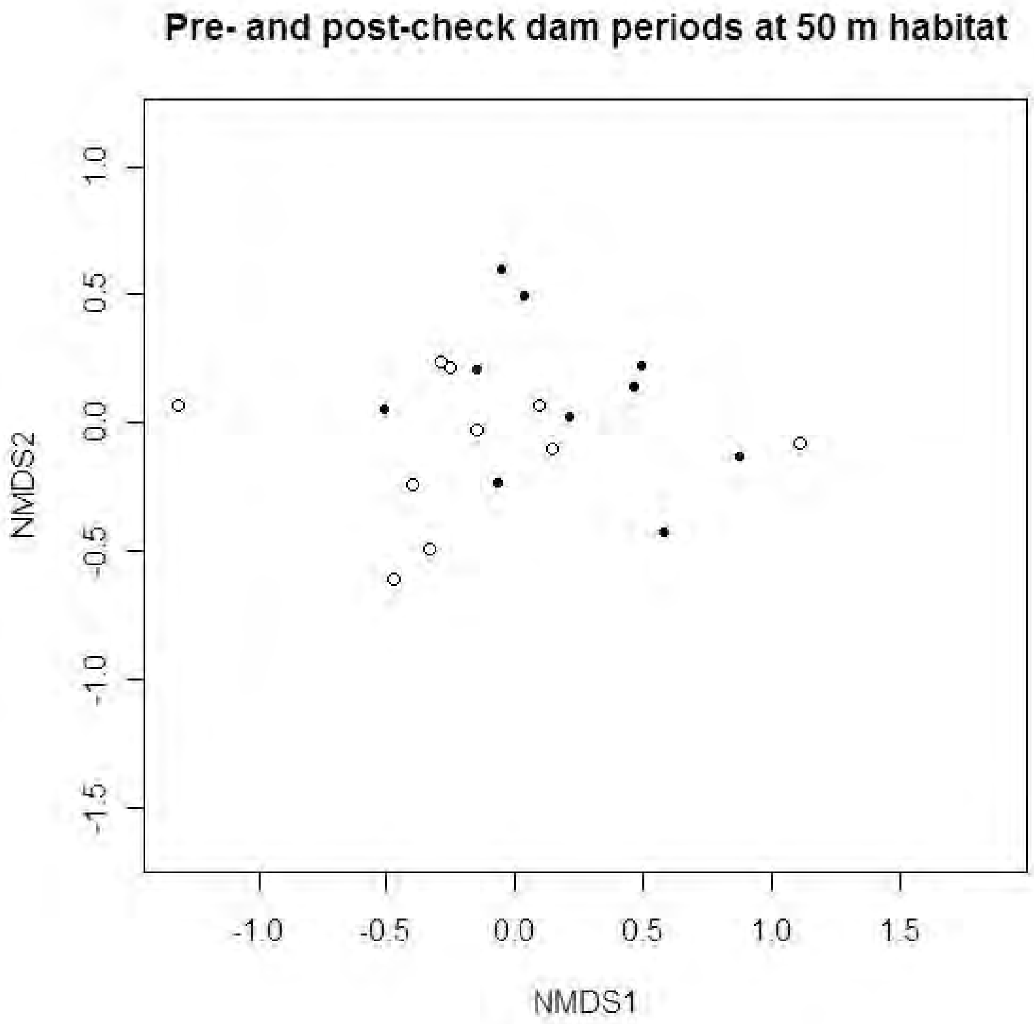

Figure 7-10 Two dimension NMDS plots of reptile composition at the 50 m terrestrial habitat in pre- and post-check dam periods (stress=0.10). Close dots (•) represent the pre-check dam points. Opened dots (°) represent the post-check dam points.

Table 7-2 Comparison of reptile composition between pre- and post-check dam periods at stream and terrestrial habitats based on ANOSIM.

Statistic value	Habitats				
	stream	5 m terrain	10 m terrain	25 m terrain	50 m terrain
R	-0.01	0.19	-0.07	-0.07	0.09
p	0.43	0.032	0.900	0.871	0.09

Remark: R $\geq$ 0.75 indicates well separation between these two compositions.
R = 0.74 to 0.5 indicates separation with some overlap.
R = 0.49 to 0.25 indicates separation with strong overlap.
R < 0.25 indicates no difference between these two compositions.

7.3.2 Reptile distribution pattern

Among 13 species of reptile found in this study, 7 species were commonly found in both pre- and post-check dam periods. As a result, these species were subjected to comparison for patterns of abundance among transects between pre- and post-check dam periods. It was found that the distribution patterns of 6 species were not affected by the check dam, and only the distribution pattern of *Mabuya macularia* showed the slight deviation possibly caused by the check dam.

The abundance of *M. macularia* can be divided into 3 significant groups in both pre- and post-check dam periods (Figure 7-11). The lowest abundance were commonly found at the stream transects in both pre- and post-check dam periods. However, the higher abundance groups were found to be slightly different between periods. In the pre-check dam period, the mid-range group composed of the 10 and 50 m terrestrial transects, while the highest abundance group composed of the 5 and 25 m terrestrial transects. In the post-check dam period, the mid-range group increased its member to include the 5, 10, and 50 m terrestrial transects, while the highest abundance group contained only the 25 m terrestrial transect.

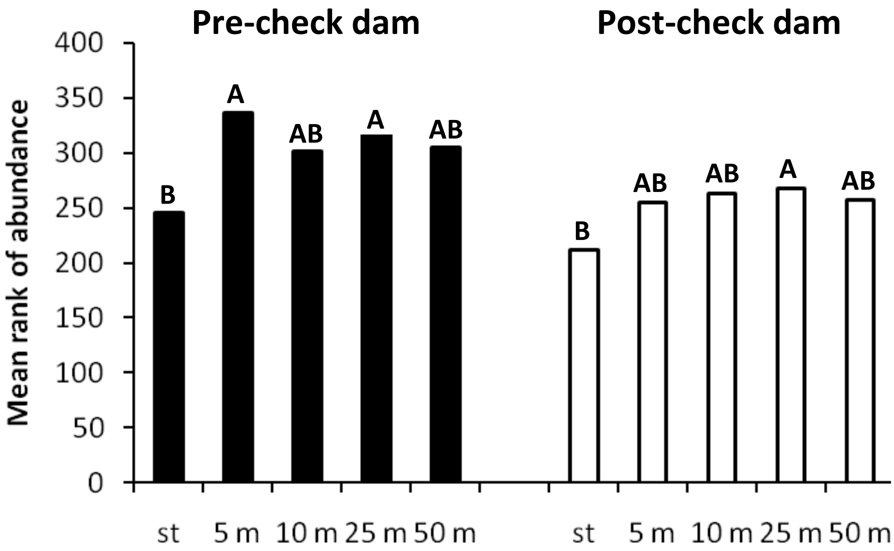

Figure 7-11 Distribution patterns of *M. macularia* among 5 transects in both pre- and post-check dam periods. Black bar indicates the distribution pattern in the pre-check dam period, and white bar indicates the distribution pattern in the post-check dam period. Difference in letters (A and B) indicates a significant difference at $p \leq 0.05$ among transects in each period.

7.4 Discussion

Although results from physical factor monitoring (Chapter III) indicated that check dam did prolong the hydroperiod of this stream, the results from reptile monitoring indicated that reptile assemblage seems to be not affected by the check dam. In the temporal comparison, rarefaction curve indicated that reptile diversity was not significantly different between pre- and post-check dam periods. The NMDS plots and results from ANOSIM also indicated that reptile compositions were similar between these 2 periods at every habitat.

Although the results of hydroperiod survey indicated that the check dam can prolong the hydroperiod from 16.82 % in the pre-check dam period to 48.68 % in the post-check dam period, this change was still not enough to interfere with reptile assemblage in this area. This is possibly due to the fact that larger parts of the stream bed were still not inundated. In an ideal condition when water is at the maximum capacity of the check dam, the depth of the stream would be equal to the check dam height or approximately 1 m, and every part of the stream should be covered by water. However, Table 3-5 shows that the mean water depth recorded at the deepest point in the post-check dam period was only 20.85 cm. Compared to the maximum capacity of 1 m depth, the mean water depth was only at 21 % of the maximum capacity of check dam. As a result, there was still plenty area of the stream bed that was still dry and available for reptiles to use for specific activities such as heat absorption and sun basking.

The distribution patterns of most reptile species were similar between pre- and post-check dam periods. Although, the distribution pattern of *M. macularia* showed the shift in abundance among transect groups, the general pattern of distribution in both pre- and post-check dam periods appear to be similar. The lowest abundance of *M. macularia* was similarly found at the stream habitat and the higher abundance was similarly found at the terrestrial habitat in both periods.

Previous research showed that the distribution pattern of herpetofauna can be influenced by soil moisture content of the habitat (Vonesh, 2001). In the current study, the soil moisture content at all terrestrial transects was not significantly different between pre- and post-check dam periods (Table 3-6, Chapter III). It is possible that the similarity in soil moisture content contributed to the similar distribution patterns between pre- and post-check dam periods of most reptile species.

Overall, these results indicated that changes in physical factors caused by the check dam did not affect reptile assemblage and distribution pattern. It can be concluded base on this 2-year data that check dam could be considered as an effective way to prolong the availability of water and moisture in the area with minimal negative effect to reptile assemblage and distribution. However, given the fact that this study area was disturbed by human activities in the past (see Chapter II), it is essential to note that this conclusion was based on the reptile community that survived previous disturbance, but not the pristine community.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

In this study, a systematic field research was carried out to examine effects of check dams in ephemeral streams on some physical and biological components of the ecosystem. Presence and absence of the check dam was used as an independent factor, while changes in physical factors, assemblage, and distribution pattern of amphibian and reptile were used as dependent variables. Effects of the check dam were determined based on 1) spatial comparison between check dam and non-check dam areas during the same period and 2) temporal comparison between pre- and post-check dam periods of the same study site.

Significant changes in physical factors related to the water pattern, including hydroperiod, water depth, and number of water body were evident in both spatial and temporal comparisons, indicating that the check dam can prolong the water period in the ephemeral stream. However, difference in soil moisture content between check dam and non-check dam areas, and difference in leaf litter moisture content between pre- and post-check dam periods appeared to be due to vegetation covers or weather pattern, rather than the check dam itself.

Using one of the most moisture-sensitive terrestrial vertebrates as a bioindicator, the results from the rarefaction curves indicated that amphibian species richness were not affected by the check dam in both spatial and temporal comparisons. As for the species compositions, NMDS plots and results of ANOSIM also indicated that amphibian compositions in the terrestrial habitats were not affected by the check dam in both spatial and temporal comparisons. In the stream habitat, although the amphibian compositions were not different between check dam and non-check dam areas, the species composition seemed to be affected by the check dam in the temporal comparison. This discrepancy could be due to the higher degree of difference in water related physical factors in the temporal comparison (pre- vs. post-check dam periods) than those in the spatial comparison (check dam vs. non-check dam areas).

It is of importance to note that the distribution patterns of 2 amphibian species in the spatial comparison and 4 species in the temporal comparison were significantly affected by the check dam. *O. martensii* and *M. fissipes* showed the higher abundances at the stream habitat in the check dam area compared to those at the natural stream with no check dam. Comparison between before and after check dam construction revealed that, in addition to *O. martensii* and *M. fissipes*, *F. limnocharis* and *M. heymonsi* also showed the higher abundances at the stream habitat as a result of the check dam. Since the distribution patterns of these amphibian species are greatly related to water and moisture, this suggested that the prolonged hydroperiod caused by the check dam can produce the high moisture habitat to support the high abundance of some amphibians at the stream and adjacent area.

As animals that rely on optimal moisture and temperature habitats for certain life history attributes, reptiles were expected to be affected by alterations of ephemeral streams after check dam construction. However, the results of rarefaction curves, NMDS plots, and ANOSIM indicated that the reptile assemblage was not affected by the check dam. Besides, differences in reptile composition at some terrestrial habitats in the spatial comparison were rather due to the effect of difference in plant community between these 2 areas. Although the distribution pattern of 1 reptile species, *M. macularia,* was different between check dam and non-check dam conditions in both spatial and temporal comparisons, these changes seemed to be due to the difference in the vegetation cover between 2 areas in the spatial comparison, and possibly related to increased leaf litter moisture contents in the temporal comparison. The results from both comparisons did not indicate the negative effect of check dam on the reptile distribution.

Based on this 2-year study, it can be concluded that species richness, diversity and composition of amphibian and reptile were not affected by the check dam. Albeit some different distribution pattern of certain amphibians and reptiles as a result of the check dam, the distribution pattern of the majority of species were not affected by the check dam. Based on the study with the susceptible group of animals to the check dam effects, the overall results indicate that the check dam can be regarded as the effective measure to prolong water availability with minimal short-term impact on biotic community in the ephemeral stream habitat.

However, it is very importance to note that this study area was disturbed by human activities in the past (*see* Chapter II). As a result, the existing animal community represents group of animals that could withstand prior disturbance, but not the pristine animal community. Therefore, the current conclusion that most amphibian and reptile were not affected by the check dam may differ from results from other study conducted in the primary forest. It is thus essential to note that the check dam construction in the primary forest is still needed to be avoided until more data on the effect of check dam on biotic component in the primary forest is available.

It is crucial to note that implications of this research to the general water management strategy are needed to be done with two cautionary notes on time and space as well. Firstly, the conclusion of the current study was based on a 2-year study period. In a much longer time, the check dam effect on amphibian and reptile assemblage could be gradually accumulated and resulted in dramatic change afterward. Therefore, to conclude the long-term effect of check dam on biotic community in the area, the long-term monitoring program is still needed to be conducted. Secondly, this study was conducted in only 2 ephemeral streams. In order to conclude the effect of check dams on amphibian and reptile assemblages in a broader sense, studies on this aspect are needed to be conducted in a larger number of streams with varying degree of hydroperiods, including the permanent streams

For future study of this kind, the appropriate bioindicator species is needed. In this study, it was found with great confidence that the distribution patterns of *O. martensii* and *M. fissipes* were changed by the check dam in both spatial and temporal comparisons. Therefore, it is recommended that these 2 amphibian species should be considered as effective bioindicator species for the study on the effect of check dam on biotic components at the population level in the future.

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Appendix

Appendix A

Photographs of Herpetofauna Found in This Study Area

(Photograph by Ratchata Phochayavanich unless stated otherwise)

Amphibian

Bufo macrotis

Fejervarya limnocharis

Hoplobatrachus rugulosus

Limnonectes pileatus

Occidozyga lima

Occidozyga martensii

Rana lateralis

Chirixalus doriae

Polypedates leucomystax

Calluella guttulata

Kaloula pulchra

Microhyla berdmorei

Microhyla butleri

Microhyla heymonsi

Microhyla fissipes

Microhyla pulchra

Micryletta inornata

Reptile

Dixoneus siamensis

Cosymbotus platyurus

Hemidactylus frenatus

Gekko gecko

Mabuya macularia

Sphenomorphus maculatus

Ramphotyphlops braminus

Xenopeltis unicolor

Lycodon laoensis

Oligodon dorsolateralis

Ptyas korros

Pareas margaritophorus

Rhabdophis subminiatus

Calloselasma rhodostoma

Calotes mystaceus

Calotes versicolor

APPENDIX B

Research Dissemination

Published Article

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Scientific Research

Check Dams in an Ephemeral Stream in a Tropical Deciduous Forest Extend Water Period with Minimal Effect on Reptile Assemblage

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ABSTRACT

Although numerous check dams have been constructed in many countries, and its effect on physical factors were well documented, only a few reports were available on its effect on biotic component in adjacent area. This research aims to address effects of the check dam on reptile assemblage in an ephemeral stream based on an assumption that reptile live in the stream and adjacent area may be susceptible to prolonged hydroperiod after check dam construction. Ten stream transects and 40 terrestrial strip transects, including 5, 10, 25, and 50 m from the stream, were used to monitor reptile diversity and composition in a deciduous forest of northern Thailand during April 2009 to February 2011. Physical factors related to water pattern in the stream and the terrestrial habitats were also collected. Results on physical factors indicated that the water pattern and soil moisture in the stream, as well as leaf litter moisture in the terrestrial habitat were increased as a result of the check dam. However, rarefaction curve indicated that reptile diversity was not significantly different between pre- and post-check dam periods in every transect. Moreover, Morisita's index of similarity indicated that reptile composition between pre- and post-check dam periods was approximately the same (86% - 100%). These results indicated that reptile assemblage was not affected by the check dam. It can be concluded based on data of one year after the check dam construction that check dam can effectively prolong water and moisture to the habitat with minimal effect on reptile assemblage in the area.

Keywords: Check Dam; Reptile; Diversity; Composition; Nonpermanent Stream

1. Introduction

Intergovernmental Panel on Climate Change (IPCC) has reported that many regions of the globe may become susceptible to prolonged period of drought due to the problem of climate change [1]. There are numerous management methods to solve this problem. Some methods, such as dam constructions, are well understood for their effects on environment. However, check dam or small dam constructed across a gully or stream is one of the drought management methods with less information on its effect on the environment, especially on biotic component.

Check dams are constructed in order to 1) reduce the velocity of water flows, 2) monitor and entrap sedimentation, 3) increase infiltration of water into the surrounded soil, 4) increase the vegetation, and 5) reduce the flood peak discharge [2]. Check dams were made from very diverse materials such as low price materials (bamboo, wood, log, clay, rock, etc.) or high cost concrete, making it varied in life span [3]. Check dams are constructed in many countries throughout the world [4-9]. In Thailand, check dam has been initially and successfully implemented in rural areas according to the advice of His Majesty the King of Thailand since it is regarded as a simple method for local people to construct by themselves with minimal investment, yet effective enough to prolong the surface water period. As a result, many governmental office and private sectors have participated in the check dam constructions throughout the country.

Although numerous check dams have been built, there are still few reports on the potential effect of the check dam on environment. At a river habitat, Shieh *et al.* [10] concluded that check dam not only changes the physical characteristics of the river but also have negative impacts on biodiversity of the river. However, most check dam construction in Thailand was at a non-permanent (ephemeral) primary order or secondary order stream [3], not a river. In this habitat type, the check dam can increase absorption rate of underground water and the stream hy-

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droperiod [11]. Treepatanasuwan and Ploychareon [12] also reported that numbers of seedlings and saplings in the dry evergreen forest in the check dam construction area were higher than those in the area with no check dam. Since data on biotic factor is still limited, determination of the check dam effect on the biotic community is needed to be conducted.

Since reptile is an ectothermic animal that relies on environmental sources for heat gain, its daily activity is more restricted than an endothermic tetrapod [13]. In an ephemeral stream habitat, a less dense canopy cover and an availability of dry stream bed provide a perfect place for the reptile to gain heat from stream bed conduction and sun basking. In the presence of check dam, the prolonged water period in the ephemeral stream could reduce an occurrence of this dry stream bed and may affect the reptile assemblage in the check dam area. In this study, therefore, reptile assemblage (*i.e.* diversity and composition) was used as a monitoring parameter to detect effect of the check dam on biotic components between pre- and post-check dam construction periods.

2. Materials and Methods

2.1. Study Site

This study was conducted at the Chulalongkorn University Forest and Research Station [CFRS], a 300 hectare area located at Lai Nan sub-district, Wiang Sa district, Nan province in northern part of Thailand (UTM zone 47Q: N2051960-2054260 and E0688400-0690360) (**Figure 1**). An average total annual rainfall during 2000 - 2009 was 1159.6 mm, and mean air temperature and relative humidity in that duration were 26.5˚C and 76.2%, respectively. A deciduous forest is major vegetation in this area [14]. Most of the streams in this area are ephemeral streams that are filled only during the wet season. Even in the wet season, water in the stream is flowing only during a heavy rain, and become standing water and dries out only a few days later.

2.2. Study Period

This study was carried out for 2 years during April 2009 to April 2011. The study periods were divided into pre- and post-check dam periods. Each study period began at the onset of wet season or the start of check dam functioning period and ended at the end of dry season. Amount of rainfall and average air temperature were used to determine wet and dry seasons by plot into the climate diagram [15]. The month which has the total rainfall higher than twice of the average air temperature was indicated as the wet season. According to this data, the pre-check dam period was during April 2009 to March 2010 (12 months) and the post-check dam period was during May 2010 to February 2011 (10 months; **Figure 2**).

2.3. Check Dam Construction Scheme

In the study area, stream B has showed many characters suitable as reptile habitat. For example, it has a lot of rocks, leaf litters, and wood particles at the stream bed, the stream bank is not too high, and the stream slope is not too steep. Therefore, stream B was selected as the study stream. Ten check dams were constructed in the dry season during December 2009 to February 2010. The

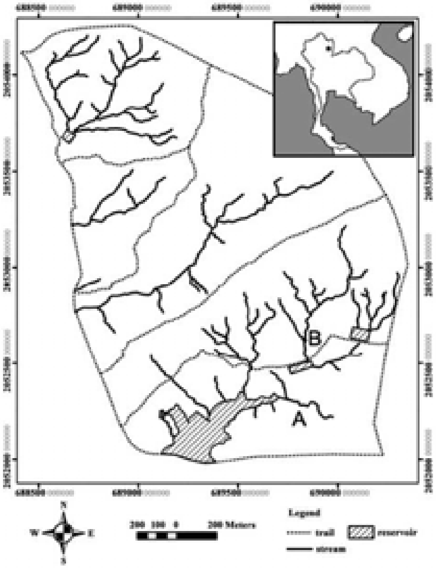

Figure 1. Map of the Chulalongkorn University Forest and Research Station, Nan province, northern Thailand (picture modified from [14]). B indicated the study stream.

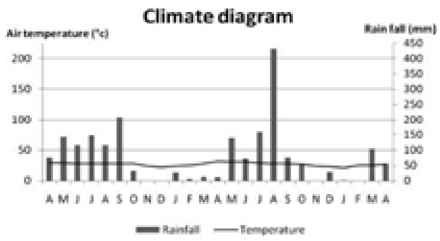

Figure 2. Climate diagram or climograph during the study period started from April 2009 to April 2011.

check dam height was designed to be similar to height of the stream bank (around 1 m) in order to trap the water at maximum level without flooding on the stream bank habitat. Location of the upstream check dam was determined by the maximum level of the down-stream check dam (**Figure 3**). Therefore, distance between 2 check dams depended on the stream slope. The check dams were constructed in continuously fashion until the end of the stream.

2.4. Physical Factor

Monthly total rainfall and average air temperature were collected from the nearest meteorological station. Numbers of days that water body was present in the stream were recorded to determine the hydroperiod and presented as percentage of the study period. Water depth was measured by measuring tape. Numbers of water body presented in the stream were also recorded. Leaf litter and soil were collected at each surveyed terrestrial transect. Their wet and dry weights were measured to determine the percentage of water content.

2.5. Reptile Survey

Reptile assemblages were surveyed in 2 periods including the pre- and the post-check dam construction periods. Two transect types were used for monitoring reptile assemblages including a stream transect and terrestrial strip transects.

Ten stream transects were designated in the stream B. Each stream transect started from one position of the planned check dam construction site (in pre-check dam period) or a check dam (in post-check dam period) to the next check dam (or the next check dam construction site). Width of the stream transect was similar to the stream width, or approximately 2 meters.

For each stream transect, there were 4 terrestrial strip transects paralleled to the stream transect with perpendicular distance of 5, 10, 25, and 50 meters from the stream transect. Therefore, there were 40 terrestrial strip transects grouped in to 4 groups according to the distance from the stream transect.

The active survey based on transect sampling [16] was used to detect reptile along both stream and terrestrial strip transects. Reptiles in the water, on the bare ground,

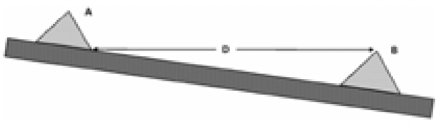

Figure 3. Diagram of check dam showing the distance between check dams. A: upstream check dam; B: downstream check dam; D: distance between check dam.

under the leaf litter and on the tree with height less than 1.5 meters were recorded from these transects. Reptiles were identified to species and numbers of individuals of each species were recorded. For each day, the total of 3 transects were surveyed during day time (9:00-12:00) and other 3 transects were surveyed during night time (19:00-22:00). The selection of these transects were on random basis. During each survey, special care was given to avoid habitat disturbance in the remaining transects. In each month, the surveys were conducted for 16 consecutive days until every transect was studied.

2.6. Data Analysis

Data were grouped according to type of transect and compared between pre- and post-check dam periods. Hydroperiod, water depth, and number of water body in the stream transect, and leaf litter and soil moisture contents in each terrestrial transect were compared between pre- and post-check dam periods by Mann-Whitney *U*-test (see [17] for review).

Reptile assemblage was divided into reptile diversity and composition. Since the survey durations were different between the pre-check dam (12 months) and post-check dam (10 months) periods, a rarefaction model was used to compare reptile diversity between these periods. Rarefaction value and its 95% confidence interval were calculated by EstimateS 8.2 program [18]. Afterward, the values of pre- and post-check dam were plotted as a function of sampling efforts. With this plot, significant difference in species diversity is indicated by an absence of overlap in the confidence interval of rarefaction curves between pre- and post-check dam period at the maximum sampling effort [19].

Reptile composition between pre- and post-check dam periods was analyzed by Morisita's index of similarity. According to Wolda [20], Morisita's index of similarity is regarded as the best overall measure of similarity with minimal dependence on sample size (see [21] for review).

3. Results

3.1. Physical Factors

Several changes in physical factors were found after check dam construction. **Table 1** shows that hydroperiod in the post-check dam period was longer than the pre-check dam period, and numbers of water body and water depth in the post-check dam period were higher than the pre-check dam period. Overall data of both soil and leaf litter moisture content in the post-check dam period were significantly higher than those in the pre- check dam period (**Tables 2** and **3**). However, pair-wise comparison of each transect shows that the soil moisture content was significantly different between pre- and post-check dam period only at the stream transect. On the contrary, comparison on the leaf litter moisture content revealed significant difference only at terrestrial transects.

3.2. Reptile Assemblage

Ten species of reptile were found in both pre- and post-check dam periods (**Table 4**). The number of species found in each transect ranged from 3 to 7 species with similar numbers of species between pre- and post-check dam periods.

Table 1. Mean ± SD of hydroperiod, number of water body, and water depth comparing between pre- and post-check dam periods.

Physical factors	Pre-check dam	Post-check dam
Hydroperiod (%)	16.82 ± 12.64	48.68 ± 12.82*
Number of water body	0.22 ± 0.48	0.75 ± 0.89*
Water depth (cm)	2.12 ± 5.17	20.85 ± 26.87*

Remark: An asterisk (*) indicates a significant difference from pre-check dam at $p \leq 0.05$.

Table 2. Soil moisture content at each transect in pre- and post-check dam periods.

Transect	Soil moisture content	
	Pre-check dam	Post-check dam
Stream	10.98 ± 8.73	20.70 ± 15.09*
5 m	9.74 ± 7.84	10.58 ± 6.79
10 m	9.14 ± 6.98	10.36 ± 7.24
25 m	8.22 ± 7.08	9.59 ± 7.58
50 m	8.24 ± 6.66	8.91 ± 6.42
Overall	9.20 ± 7.49	11.13 ± 9.05*

Remark: An asterisk (*) indicates a significant difference from pre-check dam at $p \leq 0.05$.

Table 3. Leaf litter moisture content at each transect in pre- and post-check dam periods.

Transect	Leaf litter moisture content	
	Pre-check dam	Post-check dam
Stream	38.99 ± 32.70	35.73 ± 19.82
5 m	50.69 ± 46.14	65.66 ± 54.04*
10 m	47.87 ± 38.89	62.52 ± 52.34*
25 m	39.57 ± 32.66	52.20 ± 41.14*
50 m	45.50 ± 39.36	57.65 ± 43.47*
Overall	44.74 ± 38.61	56.73 ± 46.37*

Remark: An asterisk (*) indicates a significant difference from pre-check dam at $p \leq 0.05$.

At the stream transects, the rarefaction curves of pre- and post-check dam periods (**Figure 4**) show an almost complete overlap between 95% confidence interval of these 2 curves, indicating that the reptile diversity was not significantly different between these 2 periods in the stream habitat.

The rarefaction curves of pre- and post-check dam periods at the 5, 10, 25 and 50 m terrestrial transects (**Figures 5-8**) show varying degree of overlap between 95% confidence interval of these 2 curves, indicating that the reptile diversities were not significantly different between these 2 periods at any of these terrestrial habitats.

Morisita's index of similarity indicated that the overall reptile composition was very similar (98%) between pre- and post-check dam periods (**Table 4**). Moreover, the similarity in reptile composition at each terrestrial transect was also very similar between pre- and post-check dam period (90% - 100%). The degree of similarity was also high (86%) in the stream habitat, a habitat with greatest change as a result of the check dam.

Table 4. Total number of reptiles found at each transect in pre- and post-check dam periods.

Transect	Species richness		Morisita's index of similarity
	Pre-check dam	Post-check dam	
Stream	7	6	0.86
5 m	6	3	1.00
10 m	3	5	1.00
25 m	4	4	0.99
50 m	4	5	0.90
Overall	10	10	0.98

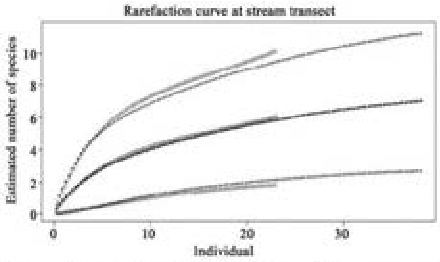

Figure 4. Comparison of species richness between pre- and post-check dam periods at stream habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent pre-check dam rarefaction curve; Opened dots (°) represent post-check dam rarefaction curve; Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post- check dam curves, respectively.

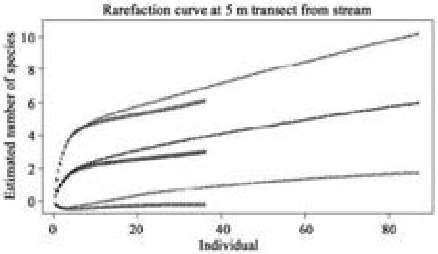

Figure 5. Comparison of species richness between pre- and post-check dam periods at 5 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent pre-check dam rarefaction curve; Opened dots (°) represent post-check dam rarefaction curve; Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

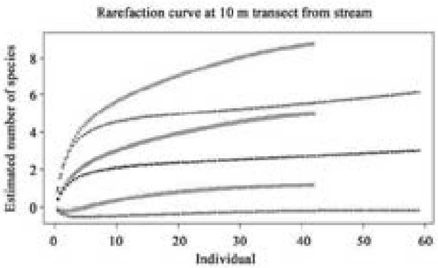

Figure 6. Comparison of species richness between pre- and post-check dam periods at 10 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent pre-check dam rarefaction curve; Opened dots (°) represent post-check dam rarefaction curve; Plus (+) and x-mark (x) represent the 95% confident interval of pre- and post-check dam curves, respectively.

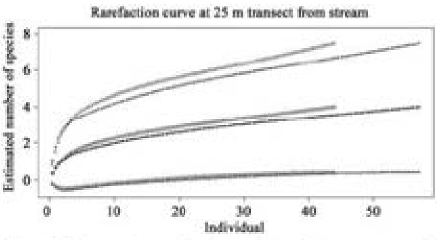

Figure 7. Comparison of species richness between pre- and post-check dam periods at 25 m terrestrial habitat by rarefaction curve with 95% confident interval. Close dots (•) represent pre-check dam rarefaction curve; Opened dots (°) represent post-check dam rarefaction curve; Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

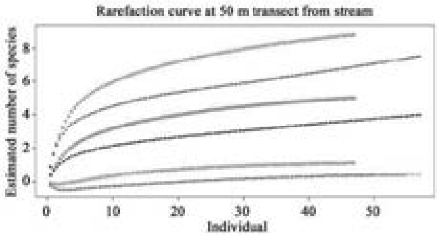

Figure 8. Comparison of species richness between pre- and post-check dam periods at 50 m terrestrial habitat by rarefaction curve with 95% confidence interval. Close dots (•) represent pre-check dam rarefaction curve; Opened dots (°) represent post-check dam rarefaction curve; Plus (+) and x-mark (x) represent the 95% confidence interval of pre- and post-check dam curves, respectively.

4. Discussion

The check dam clearly affect the water pattern of this ephemeral stream by changing the physical factors related to water including the hydroperiod, number of water body, and water depth. These physical factors confirmed that check dam can prolong the presence of utilizable water in the area. However, an assumption that the prolonged hydroperiod in this ephemeral stream may affect reptiles that used this ephemeral stream for specific purpose such as heat absorption and sun basking seems to be challenged. The results from the rarefaction curves in every stream and terrestrial transects indicated that reptile diversities were not significantly different between pre- and post-check dam periods. Moreover, the results from the Morisita's index of similarity indicated that the reptile composition in every transect was almost the same between pre- and post-check dam periods. According to this 1-year data, these 2 assemblage parameters indicated that the reptile assemblage was not affected by the check dam albeit its effect on water pattern in this stream.

Although the hydroperiod in the post-check dam period (48.68%) are much longer than those in pre-check dam period (16.82%), data on water depth showed that there were still large part of the stream bed that were not covered by water. **Table 1** shows that the mean water depth in post-check dam period is 20.85 cm. Normally, the water depth was recorded at the deepest point of the stream transect, usually located in front of the check dam. Given that maximum capacity of each check dam is equaled to its height or around 1 meter, it can be estimated based on the average water depth that the current capacity of the check dam was around 21% of total capacity. At this mean capacity of 21%, there were some parts of the stream bed that were not covered by water. As a result, reptile can still use this habitat for their activities with small impact from the check dam.

Previous research reported that soil moisture is the significant positive factor for prediction of the presence of herpetofauna species [22]. The current results indicate no significant difference in soil moisture content at every terrestrial transects between pre- and post-check dam periods. Therefore, this may be the cause of the similarity in reptile assemblage between these 2 periods at the terrestrial habitat.

Plant community structure can also affect the reptile assemblage [22-24]. However, there was no evidence of plant community change during this 1 year period. Long term study is needed in order to determine the effect of check dam on plant community structure and its potential link to reptile assemblage.

In addition to the above reason, this 1-year period after check dam construction may be too short to see an establishment of new reptile species from other areas. Moreover, since the study area is not connected to other forest patches, the time required for such establishment must be relatively long.

5. Conclusion

This study reported and confirmed that presence of check dams in ephemeral stream in a deciduous forest can prolong the presence of exploitable water in the area. Comparison on biotic component using reptile as monitoring species showed no evidence of the check dam effect on the existing reptile diversity and composition in this area. It can be conclude that check dam is the way to prolong the utilizable water in the area with minimal effect on the reptile assemblage. However, long term monitoring is still needed in order to determine the effect of check dam on the reptile assemblage in the long period.

6. Acknowledgements

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PRELIMINARY REPORT ON EFFECTS OF CHECK DAMS ON AMPHIBIAN ASSEMBLAGE ALONG STREAMS IN A DECIDUOUS FOREST IN NAN PROVINCE, THAILAND

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(with two text-figures)

ABSTRACT.– Numerous check dams have been built in Thailand, resulting in the transformation of many environments. However, there are only a few reports on the assemblage of vertebrates in check dam areas. In this study, we compared amphibian assemblages in check dam and non-check dam areas in a deciduous forest at Nan Province, Thailand, between April to June 2009. Our preliminary data revealed that 15 species in four families (Bufonidae, Dicroglossidae, Rhacophoridae and Microhylidae) inhabit these areas. Shannon index indicate that diversity between these areas was close in both aquatic (2.06 vs. 1.89) and terrestrial (1.72 vs. 1.87) habitats. Amphibian composition between these areas were also similar in both aquatic (69%) and terrestrial (64%) habitats. Abundances of six species in aquatic habitat and two species in terrestrial habitat were higher in check dam than those in non-check dam area. At this stage, check dams seem to have no effect on amphibian assemblage, albeit the higher abundance of some species. Therefore, it can be concluded based on this 3-month data, check dams effectively prolong water availability, with few negative effects on the biological community of the areas.

KEY WORDS.– Amphibian composition, diversity, check dam, deciduous forest, ephemeral stream, Thailand.

INTRODUCTION

Drought is a serious annual problem in many parts of Thailand and other countries in south-east Asia. The Intergovernmental Panel on Climate Change (IPCC) reported that some regions of the world have become susceptible to prolonged periods of drought, due to climate change (World Health Organization, 2008). Check dam construction has become a popular management method to prolong the hydroperiod in ephemeral streams and to dissipate moisture into adjacent soil. Higher moisture may contribute to both expanding agricultural areas and to serve as a conservation tool for recovering disturbed forest. Check dams are small dams constructed across a gully or stream in order to: i) reduce the velocity of water flows, ii) monitor and entrap sedimentation, iii) increase infiltration of water into the surrounded soil, iv) increase vegetation, and v) reduce floods (Gray and Leiser, 1982; Solaimani, et al., 2008). Check dams can be made from diverse materials such as low price local materials (bamboo, wood, log, clay, rock, etc) or high cost concrete, resulting in varying range of their life span (Department of Local Administration, 2008). In Thailand, the check dam method has been initially and successfully implemented in rural areas according to the advice of His Majesty, the King of Thailand, since it is regarded as simple enough for local people to construct by themselves, with minimal investment, yet effective enough to prolong the surface water period. As a result, many governmental offices and private sector businesses have participated in check dam construction throughout the country. From 1994 to 2007, the Watershed Conservation and Management Office of the National Park, Wildlife and Plant Conservation Department have constructed approximately 72,000 check dams across the protected areas of Thailand. Nonetheless, there has been little scientific investigation into the potential effects of these dams on the ecosystem. According to the Watershed Conservation and Management Office (2008), check dam construction can reduce the rate of water flow, increase the absorption rate of underground water, and also increase the stream hydroperiod or the duration of the surface water present in the area after the rainy season. Studying the effect of check dam on riparian plant community, DeBano and Heede (1987) concluded that the prolonged hydroperiod by the check dam allowed sedges and willows to become established and to develop into a dense riparian community. Treepatanasuwan and Ploychareon (2006) also reported that numbers of seedlings and saplings in dry evergreen forests within check dam construction areas were higher than in areas with no check dams. Moreover, previous researches conducted in wetlands with different hydroperiod indicate an association with tadpole communities (Torrence, 2007) and also the reproductive success of amphibians (Kolozsvary, 1998).

Although environmental factors are reportedly influenced by check dams, there is no strong scientific evidence to confirm the effects of check dams on species living in their vicinity. Chulalongkorn University has started the construction of 100 check dams in the University Forest and Research Station, Nan province, northern Thailand. This construction project provides an ideal experimental system to investigate the effects of check dams on ecological processes, over both short and long term period.

According to Magurran and McGill (2011), quantifying the biological diversity over space or time is useful to explain natural patterns, as well as to manage and plan the policy for the sustainable use of natural resources. Since amphibians are sensitive to environmental changes (Hopkins, 2007) and their taxonomic status in Thailand is relatively clear (Khonsue and Thirakhupt, 2001), their biological diversity was selected as the monitoring parameter for this study. The objective of this study is to compare the amphibian assemblage, diversity and abundance, and to determine the similarity in species composition between the check dam and non-check dam areas.

MATERIALS AND METHODS

Study area.– This study was conducted at the Chulalongkorn University Forest and Research Station [CFRS], a 300-ha area located at Lai Nan Sub-district, Wiang Sa District, Nan Province in northern Thailand (UTM zone 47Q: N2051960–2054260 and E0688400–0690360; Fig. 1). The mean of the total annual rainfall during 1993–2002 was 1,334.5 mm per annum. The mean air temperature and relative humidity over that duration were 25.9°C and 78%, respectively. According to the mean air temperature and the total amount of rainfall, the season can be divided into wet season (April to September) and dry season (October to March) (unpublished data). This area is covered by deciduous forest comprising of two plant communities: deciduous dipterocarp and mixed deciduous forest (Dumrongrojwatthana, 2004). According to Kutintara (1999), the wildlife compositions in the mixed deciduous and deciduous dipterocarp forests in Thailand are similar due to the similarity in plant community structure.

Check dam construction scheme.– When this study was started, 27 check dams had been constructed at the Chulalongkorn University Forest and Research Station. Two streams within the CFRS that exhibited similar physical characteristics, and separated by a distance of ca. 500 m, were selected as study sites. The major difference between the two streams selected was the presence of 13 check dams along a stream (designated Stream A) compared to no check dams along the other stream (Stream B). As both streams are located in the same broad forest classification and are in close proximity, the amphibian assemblages could be presumed to be similar under unmodified conditions. Both stream "A" and "B" are located in deciduous forest and the distance from each other is ca. 500 m, therefore the natural population of amphibians is expected to be the same. At stream "A", the check dam construction was completed in 2008, while 10 check dams at the stream "B" were constructed between December 2009–March 2010 (dry period). During the wet season, the stream was filled with flowing water only during periods of heavy rain, and subsequently, contained standing water, and dried out 1–2 weeks later. The water in the stream ran dry in the dry season, even in the check dam streams. Therefore, the check dam had no effect

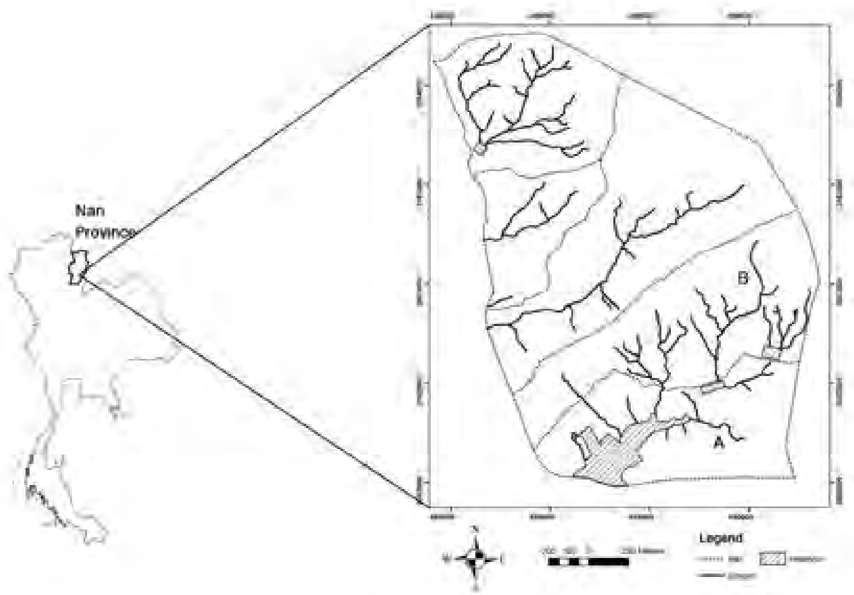

FIGURE 1: Map of the Chulalongkorn University Forest and Research Station, Nan Province, northern Thailand (modified from Dumrongrojwatthana, 2004). A: Stream with check dam construction completed in 2008, B: Stream with check dam construction scheduled in the dry period of 2009–2010.

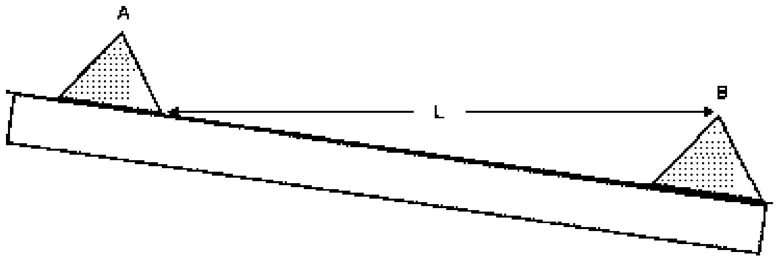

FIGURE 2: Diagram of check dam showing the distance between check dams. A: upstream check dam, B: downstream check dam, L: distance between check dams.

on the environment during this period.

The check dam height was designed to be similar to that of the bank of the stream in order to trap the water at the maximum level of that stream without flooding the stream edge habitat. The distance between check dams was determined by the maximum water level point downstream of check dam (Fig. 2). The check dams were constructed in a continuous fashion to the end of the stream. The mean and range value of check dam height, distance between check dams, stream width, and maximum area of water between check dam and non-check dam stream are shown in Table 1.

Amphibian survey methods.– Two types of transects including 1) stream transect for aquatic habitat and 2) strip-transect for terrestrial habitat, were used in the check dam and non-check dam areas.

Stream transect: Ten stream transects were established in each stream. Each stream transect was started from one check dam (in check dam stream) or planned check dam construction site (in non-check dam stream) to the next check dam (or construction site) or the maximum water level point of that check dam. The width of the stream transects were similar to the stream width, or ca. 2 m and the length of transects were equal to the distance between check dams (Table 1).

Strip transect: Four permanent strip-transects, measuring 2 m in width were located parallel to each stream transect with the perpendicular distance of 5, 10, 25 and 50 m, respectively, from the stream.

Active survey based on transect sampling (Heyer et al., 1994) was used to detect amphibians along both stream and strip transects. Amphibians in the water, on exposed ground, under leaf litter and on tree with height less than 1.5 m were recorded from these transects. Each survey begun at the start point of the transect to the end, and transect distance was dependent on distance between check dams. Amphibians were identified to the species level, and number of individuals for each species were recorded. The number of individuals for each species was divided by the total area (m^2) of transect and recorded for data analysis. For each area, a total of three transects were surveyed by day (09:00–12:00 h) and another three transects were applied by night (19:00–22:00 h) on each day of sampling. The selection of these transects were made randomly. During each survey, special care was taken to avoid habitat disturbance in the remaining transects. The surveys were conducted for 16 consecutive days until every transect was completed. In this preliminary report, data for the first three months (April 2009 to June 2009), were analyzed.

Data analysis.– The data was separated into two groups: stream transect and the combined data of four terrestrial transects, due to the similarity in amphibian composition within transects (unpublished data). Amphibian diversity in each transect was determined by Shannon index [H'] (Magurran and McGill, 2010), since it is the only diversity measurement method that met the required five of six criteria (Buckland et al., 2005; Magurran and McGill, 2010). Since the percentage of similarity or Renkonen Index is relatively unaffected by sample size and species diversity, this index was used to determine the similarity in amphibian composition between check dam and non-check dam areas (see Krebs, 1999, for review). The abundance of each amphibian species was compared between check dam and non-check dam areas using Mann-Whitney *U*-test.

RESULTS AND DISCUSSIONS

A total of 15 amphibian species was found from both check dam and non-check dam areas. They belong to four families: Bufonidae, Dicroglossidae, Rhacophoridea and Microhylidae.

According to the Shannon Index and species richness, amphibian diversities in the check dam and non-check dam areas were similar (Table 2). Similar results were found with separate analyses between aquatic and terrestrial habitats. Shannon Index and species richness indicated that in both habitats, amphibian diversities were also close between check dam and non-check dam areas (Table 2).

Similarity in species composition.– The percentage of similarity indicated that amphibian composition between the check dam and non-check dam areas were similar in the aquatic, terrestrial and overall habitats (Table 3).

In aquatic habitats, the abundance of six amphibian species- *Occidozyga lima, O. martensii, Polypedates leucomystax, Microhyla fissipes, M. heymonsi* and *M. pulchra* in the check dam area

TABLE 1: Mean and range of value of check dam height, distance between check dams or length of stream transect, stream width, and maximum area of water body in check dam and non-check dam stream.

Characteristics	Check dam stream	Non-check dam stream
Check dam height (m)		
mean ± SD	0.81 ± 0.20	-
(range of value)	(0.40–1.00)	-
Distance between check dams /length of stream transect (m)		
mean ± SD	33.24 ± 0.11	25.30 ± 8.99
(range of value)	(11.35–75.85)	(15.85–47.85)
Stream width (m)		
mean ± SD	2.53 ± 0.56	1.81 ± 0.56
(range of value)	(1.85–3.45)	(1.15–3.05)
Maximun area of water body		
mean ± SD	81.21 ± 43.63	47.54 ± 25.56
(range of value)	(21.00–140.32)	(18.23–98.09)

TABLE 2: Comparison of amphibian diversity between check dam and non-check dam areas in aquatic, terrestrial, and overall habitats.

Habitat	Shannon index (Species richness)	
	Check dam area	Non-check dam area
Aquatic	2.06 (11)	1.89 (11)
Terrestrial	1.72 (11)	1.87 (11)
Overall	2.04 (12)	2.02 (14)

TABLE 3: Similarity in amphibian species compositions between check dam and non-check dam areas.

Habitat	Percentage of similarity (%)
Aquatic habitat	69
Terrestrial habitat	64
Overall habitat	71

TABLE 4: Abundance of each amphibian species (individual/m^2) and the total number of species in the aquatic habitat comparing between check dam and non-check dam areas by Mann-Whitney *U*-test. * indicates a significant difference at $p \leq 0.05$.

Family	Species	Check dam (mean ± SD)	Non-check dam (mean ± SD)
Bufonidae	*Ingerophrynus macrotis*	0.0014 ± 0.0050	0.0008 ± 0.0024
Dicroglossidae	**Occidozyga lima*	0.0034 ± 0.0119	0.0003 ± 0.0017
	**Occidozyga martensii*	0.0087 ± 0.0133	0.0049 ± 0.0130
	Limnonectes pileatus	0 ± 0	0.0008 ± 0.0025
	Fejervarya limnocharis	0.0012 ± 0.0045	0.0006 ± 0.0033
Rhacophoridae	**Polypedates leucomystax*	0.0033 ± 0.0109	0 ± 0
Microhylidae	*Kaloula pulchra*	0.0009 ± 0.0030	0 ± 0
	Micryletta inornata	0.0158 ± 0.0330	0.0053 ± 0.0082
	Microhyla berdmorei	0 ± 0	0.0002 ± 0.0009
	**Microhyla fissipes*	0.0109 ± 0.0165	0.0034 ± 0.0073
	**Microhyla heymonsi*	0.0037 ± 0.0062	0.0008 ± 0.0034
	**Microhyla pulchra*	0.0026 ± 0.0050	0.0009 ± 0.0036
	Microhyla butleri	0.0026 ± 0.0057	0.0068 ± 0.0109
Total number of species	13	11	11

were significantly higher than those in the non-check dam area (Table 4). In terrestrial habitats, the abundance of two amphibian species- *Ingerophrynus macrotis* and *Microhyla fissipes* in the check dam area were significantly higher than those in the non-check dam area (Table 5).

This preliminary report compare the parameters of amphibian community between the longer hydroperiod area (check dam area) and the shorter hydroperiod area (non-check dam area). According to the Shannon Index, typically used to determine the amphibian diversity, and the percentage of similarity, a parameter used to determine the similarity in species compositions between these areas, both assemblage parameters did not show a difference between check dam and non-check dam areas. Although some research conducted in wetland with different hydroperiod indicated that hydroperiod is an important factors affecting the composition of lentic amphibian communities (Kolozsvary, 1998; Torrence, 2007), our results from ephemeral streams seems to be different from these previous studies.

This study also compared the abundance of each amphibian species between these two areas. The hydroperiod is one of the important factors determining the duration for tadpoles to complete their metamorphosis (Skidds and Golet, 2005). The results from this study indicated that the abundances of six amphibian species in the aquatic habitat and two amphibian species in the terrestrial habitat were higher in the check dam area than those in the non-check dam area. This may be because the check dam area has a longer hydroperiod and also larger water body than the non-check dam area. As a result, amphibians in the non-check dam area could have lower breeding opportunity than those in the check dam area. With the prolonged reproductive activities of amphibian in the check dam area, the possibility to find them in this area was higher than in the non-check dam area. In addition, many tadpoles were found in the water body during this study (unpublished data). Directly linked to the check dams, many water bodies and longer hydroperiod

TABLE 5: Abundance of each amphibian species (individual/m^2) and the total number of species in the terrestrial habitat comparing between check dam and non-check dam areas by Mann-Whitney *U*-test. * indicates a significant difference at $p \leq 0.05$.

No.	Family	Species	Check dam (mean ± SD)	Non-check dam (mean ± SD)
	Bufonidae	**Ingerophrynus macrotis*	0.0029 ± 0.0048	0.0007 ± 0.0017
	Dicroglossidae	*Occidozyga martensii*	1.1 0.0006	0 ± 0
		Limnonectes pileatus	0.00004 ± 0.0002	0 ± 0
		Fejervarya limnocharis	0.0005 ± 0.0014	0.0003 ± 0.0012
	Rhacophoridae	*Polypedates leucomystax*	1.2 0.0006	0 ± 0
		Chirixalus doriae	0 ± 0	0.0001 ± 0.0007
	Microhylidae	*Calluella guttulata*	0 ± 0	0.0001 ± 0.0007
		Kaloula pulchra	0.0004 ± 0.0014	0.0002 ± 0.0009
		Micryletta inornata	0.0018 ± 0.0024	0.0021 ± 0.0035
		Microhyla berdmorei	0 ± 0	0.0001 ± 0.0005
		**Microhyla fissipes*	0.0072 ± 0.0073	0.0032 ± 0.0037
		Microhyla heymonsi	0.0017 ± 0.0037	0.0026 ± 0.0061
		Microhyla pulchra	0.0003 ± 0.0009	0.0001 ± 0.0007
		Microhyla butleri	0.0007 ± 0.0014	0.0027 ± 0.0054
Total number of species		14	11	11

were found in the check dam stream, while only a few water bodies and shorter hydroperiod were found in the non-check dam stream. Therefore, the check dam area tends to have higher ability to support the reproductive activity of amphibians than the non-check dam area.

Check dam seems to have no negative effect on the amphibian assemblage, instead, there was an obserbed higher abundance of some amphibian species in the check dam area. Although amphibians are highly sensitive to changes in moisture level, these results indicate that effect of check dams on amphibian assemblage is minimal. Therefore, it can be concluded based on this 3-month data, that check dam is an effective way of prolonging the water period with minimal effect to the biological community existing at the site.

Currently, field work is being conducted to collect year-round data. It is expected that once seasonal variations in amphibian assemblage throughout the year and physical factors related to moisture pattern are included in the data analysis, the short-term effect of check dam on the amphibian assemblage can be understood. Moreover, long-term study on the effects of check dam on other ecological aspects is required in order to account for effects of the check dam to the ecosystem. Ecological monitoring of this kind can be used as an important tool for the management of natural resources.

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Oral Presentation

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Effects of Check Dam on Amphibian Assemblage along the Stream in a Deciduous Forest in Nan Province, Northern Thailand

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Abstract

To compare the amphibian assemblages in the check dam and non-check dam streams, two ephemeral streams in the deciduous forest, in the Chulalongkorn University Forest and Research Station were selected based on the similarity in stream characteristics. Eleven check dams were selected from check dam stream and eleven planned check dam construction sites were selected from non-check dam stream. Stream transects and strip-transects were used to sampling amphibians in both streams during April to June 2009. Stream transects were located between the check dams or planed check dam construction sites and strip-transect were located parallel to each stream transect. The transect width was approximately 2 m depending on the average value of the stream width. Shannon index indicated that amphibian diversity between check dam and non-check dam streams were closed in both aquatic (2.06 vs. 1.89) and terrestrial (1.72 vs. 1.87) habitats. Amphibian compositions between these two streams were also quite similar in both aquatic (69%) and terrestrial (64%) habitats. However, in the aquatic habitat the abundances of 3 amphibian groups in the check dam stream were higher than those in the non-check dam stream and in the terrestrial habitat, the abundances of 2 amphibian groups in the check dam stream were higher than those in the non-check dam one. According to these results, it should not be concluded the effect of the check dam on the amphibian assemblage yet. To get the reliable answer, the sampling should be continually conducted until the seasonal variations in amphibian assemblage are included.

Oral Presentation

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Preliminary report on influences of check dam on amphibian assemblage along distance gradient from the stream edges in the deciduous forest in Nan province, Thailand

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Abstract

Recently, numerous check dams constructed across stream have been built in Thailand to extend the hydroperiod and allow more moisture to be dissipated from the stream to the adjacent area. Many environmental factors are known to be changed after the construction, especially soil moisture content along edges of the stream. However, there are few reports on the vertebrate assemblage and distribution near the check dam. Among terrestrial vertebrate, amphibian is regarded as the most sensitive animal to moisture changes. Therefore, in this study, we aim to compare amphibian assemblage patterns along the distance gradient from the stream edges between the check dam and non-check dam areas. Eleven check dams or planned check dam construction sites were selected from two ephemeral streams in a deciduous forest at the Chulalongkorn University Forest and Research Station, Nan Province. Stream transects located between the check dams or the planned construction sites and four strip-transects located parallel to each stream transect with the perpendicular distance from the stream transect of 5, 10, 25, and 50 m were used for visual encounter surveys during May to October 2009. The amphibian assemblage patterns including the species diversity and composition will be presented. Pair-wise comparison in each transect groups along the distance gradient from the stream edges will be performed to examine check dam-related difference in amphibian assemblage. The overall effect of the check dam on amphibian assemblage pattern will be discussed.

Oral Presentation

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ผลของฝายชะลอความชุ่มชื้นต่อการชุมนุมของสัตว์สะเทินน้ำสะเทินบก ตามแนวลำธารในป่าผลัดใบในจังหวัดน่าน

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คำสำคัญ : ฝายชะลอความชุ่มชื้น, ลำธารชั่วคราว, ความหลากหลายด้านชนิด, องค์ประกอบด้านชนิด, สัตว์สะเทินน้ำสะเทินบก

บทคัดย่อ

ฝายชะลอความชุ่มชื้น เป็นฝายขนาดเล็กที่สร้างเพื่อกั้นทางไหลของน้ำหรือลำธารขนาดเล็ก ฝายถูกสร้างขึ้นเป็นจำนวนมากในประเทศไทยตั้งแต่ทศวรรษที่ผ่านมา มีการรายงานว่าปัจจัยทางกายภาพหลายปัจจัยเปลี่ยนแปลงไปหลังจากที่มีการสร้างฝาย อย่างไรก็ตาม มีการรายงานค่อยข้างน้อยเกี่ยวกับผลของฝายที่มีต่อปัจจัยทางกายภาพ โดยเฉพาะอย่างยิ่งผลที่มีต่อสัตว์ที่อาศัยอยู่บริเวณที่มีการสร้างฝาย เมื่อพิจารณาจากสัตว์ในกลุ่มสัตว์ที่มีกระดูกสันหลังทั้งหมด พบว่าสัตว์ในกลุ่มสัตว์สะเทินน้ำสะเทินบกเป็นสัตว์ที่มีความไวต่อการเปลี่ยนแปลงความชุ่มชื้นมากที่สุด ดังนั้นการศึกษาในครั้งนี้จึงใช้การชุมนุมของสัตว์กลุ่มนี้ในการติดตามการเปลี่ยนแปลงที่เกิดขึ้น การศึกษาผลของการฝายที่มีต่อการชุมนุมของสัตว์สะเทินน้ำสะเทินบกครั้งนี้ใช้การเปรียบเทียบการชุมนุมของสัตว์กลุ่มนี้ระหว่างพื้นที่ที่มีการสร้างฝายและไม่มีการสร้างฝาย ในพื้นที่ป่าเพื่อการศึกษาวิจัยของจุฬาลงกรณ์มหาวิทยาลัยที่จังหวัดน่าน ศึกษาการชุมนุมของสัตว์โดยใช้เส้นทางสำรวจตามแนวลำธาร โดยในแต่ละลำธารมี เส้นทางสำรวจตามแนวลำธารจำนวน 10 เส้นทางและ เส้นทางสำรวจบนบกจำนวน 40 เส้นทางที่อยู่ห่างจากแนวลำธารเป็นระยะทาง 5, 10, 25, และ 50 เมตร จดบันทึกชนิดสัตว์ที่พบและจำนวนสัตว์ที่พบในแต่ละชนิด รวมทั้งบันทึกระยะเวลาการปรากฏของน้ำ ความชื้นดิน และความชื้นของเศษซากพืช เปรียบเทียบและวิเคราะห์ข้อมูลดังกล่าวโดยใช้ข้อมูลทุกเดือนตั้งแต่ เดือน เมษายน 2552 จนถึง เดือนมีนาคม 2553 แม้ว่าปัจจัยทางกายภาพบางปัจจัยจะมีความแตกต่างกันเกิดขึ้นระหว่าง 2 พื้นที่ แต่จากดัชนีความหลากชนิดของ Simpson แสดงให้เห็นว่าความหลากชนิดมีค่าใกล้เคียงกันในเกือบจะทุกกลุ่มเส้นสำรวจ การวิเคราะห์การจัดกลุ่มแสดงให้เห็นว่าการองค์ประกอบของสัตว์กลุ่มนี้มีความคล้ายคลึงกันระหว่างทั้ง 2 พื้นที่ แม้ว่าจะพบความแตกต่างขององค์ประกอบของสัตว์เกิดที่บริเวณถิ่นที่อยู่อาศัยบริเวณลำธารแต่จะพบเพียงช่วงฤดูฝนเท่านั้น ดังนั้นจากข้อมูลทั้งหมดแสดงให้เห็นว่า แม้ว่าสัตว์สะเทินน้ำสะเทินบกจะมีความไวต่อการเปลี่ยนแปลงความชุมชื้นมากการชุมนุมของสัตว์กลุ่มนี้ได้รับผลกระทบเพียงเล็กน้อยจากฝาย ดังนั้นการสร้างฝายจึงอาจเป็นวิธีการหนึ่งที่สามารถยืดระยะเวลาการปรากฏของน้ำผิวดินได้โดยที่มีผลกระทบน้อยต่อสัตว์ในระบบนิเวศนั้น

EFFECTS OF CHECK DAM ON AMPHIBIAN ASSEMBLAGES ALONG STREAMS IN A DECIDUOUS FOREST AT NAN PROVINCE

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Key words : check dam, non-permanent stream, species diversity, species composition, amphibian

Abstract

Check dam or a small dam constructed across gully or small stream has been constructed in a large number in Thailand since the last decade. Many physical factors were reported to be changed after the check dam construction. However, there are only a few reports on the effect of check dams on the biotic factors, especially on the animal living in the check dam area. Since, among the terrestrial vertebrate, amphibian is the most sensitive to the moisture change, its assemblages were used as the monitoring parameters in this study. The effects of check dam on the amphibian assemblages were addressed by comparing the assemblage parameters between check dam and non-check dam streams at the Chulalongkorn University forest and research station at Nan province. Ten stream transects and 40 strip transects with perpendicular distance of 5, 10, 25, and 50 m from the stream were designated in each stream. Amphibian were surveyed and recorded for species and number of individual in each species. The physical factors including hydroperiod and leaf litter and soil moisture contents were collected during the surveys. The monthly data from April 2009 to March 2010 were analyzed and compared. Although, some physical factors were different between check dam and non-check dam areas, Simpson's index of diversity indicated that the amphibian diversities were alike between these areas at most of the transects. Cluster analysis of assemblage parameters also indicated that the amphibian compositions at the terrestrial habitats were similar between check dam and non-check dam areas. Difference in amphibian composition between these streams were found only at the stream habitat and only briefly during the wet season. Overall, the results indicate that although amphibian is highly sensitive to the moisture, their assemblages were barely affected by the presence of the check dam. Therefore, check dam could be considered as an efficient way to extend the surface water period with minimal effects to the animals in ecosystem.

BIOGRAPHY

Mr. Ratchata Phochayavanich was born on November 5, 1983. He received his Bachelor's Degree of Science (Forestry) in the option of Wildlife and Range Science from the Department of Forest Biology, Faculty of Forestry, Kasetsart University in 2005. He got his M.Sc. in Zoology from the Department of Biology, Faculty of Science, Chulalongkorn University (CU) in 2008 under support by the John D. and Catherine T. MacArthur Foundation under the collaboration between Field Museum of Natural History, Chicago, USA and the Department of Biology, Faculty of Science, CU. He has published two articles related to his Master's research in the Journal of Wildlife in Thailand (2008) and Zoological Studies (2010). He has started his doctoral study in the Biological Sciences Program (Ecology), Faculty of Science, CU since 2008. During his study, he has spent two years for field research at Nan Province as part of the CU Academic Development Plan to encourage graduate students to acquire first hand experience in field environment as well as gain perspectives on the country's need in real life situations. He has given two oral presentations in the international conferences including the 1st Conference of Biology of the Amphibians in the Sunda Region, South-East Asia, Kuching, Malaysia (2009) and the 14th Biological Science Graduate Congress, Bangkok, Thailand (2009). He has also completed two international training courses including the 9th Regional Training Course on Wetland Ecology and Management in the Lower Mekong Basin, Penang, Malaysia (2011) and the International Training Course: New Trends and Methodology in Animal Ecology and Conservation Biology, Peking, China (2011).