SPECIES DIVERSITY AND DISTRIBUTION OF MANGROVE GASTROPODS IN TBT CONTAMINATED AREAS AT CHONBURI PROVINCE BY GIS

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SPECIES DIVERSITY AND DISTRIBUTION OF MANGROVE GASTROPODS IN TBT CONTAMINATED AREAS AT CHONBURI PROVINCE BY GIS

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ABSTRACT

The objectives of this research were to study the species diversity and distribution of mangrove gastropods in three study areas - Samet, Laemchabung, and Chuksamet (Chonburi province). Also, gastropods and soils were analyzed for TBT concentrations by GC-MS. All data, such as species diversity and distribution of gastropods, soil structure, and TBT accumulation in gastropods and soil, were compared and reported using GIS.

In all three study areas, only 21 epifauna gastropod species were found. Littorinidae and Ellobiidae were the most diverse families in this study. The diversity index and evenness were highest at Chuksamet and lowest at Samet. However, the highest similarity index was between Samet and Laemchabung. *Assiminea brevicula*, *Melanoides tuberculata*, and *Clithon oualaniensis* were the dominant species at Samet, Laemchabung, and Chuksamet, respectively. The distribution pattern was mostly clustered in all three study areas. Furthermore, the highest and lowest TBT accumulations in all tissue samples were found at Laemchabung and Samet, respectively ($p<0.05$). This study did not show the imposex in female snails even though TBT accumulations were found at low concentration. However, TBT accumulation in soil samples were the highest at Laemchabung (10.52±2.82 ng/g) and the lowest at Chuksamet (1.56±0.24 ng/g) ($p<0.05$). The Pearson Correlation demonstrated the relationship between physical factor values and TBT concentrations in soil and diversity index ($p<0.05$).

This study showed the low TBT accumulation in the all gastropod tissues and soil samples at every study area. Thus, the findings of this study could be used as foundational information for future studies, and could also be used to encourage the protection of the mangrove environment.

KEY WORDS : SPECIES DIVERSITY/ SPECIES DISTRIBUTION/
MANGROVE GASTROPODS/ TBT ACCUMULATION/ GIS

185 pp.

ความหลากหลายและการกระจายตัวของหอยฝาเดียวในป่าชายเลนบริเวณที่มีสาร TBT ปนเปื้อน จ.ชลบุรี โดยระบบสารสนเทศภูมิศาสตร์ (SPECIES DIVERSITY AND DISTRIBUTION OF MANGROVE GASTROPODS IN TBT CONTAMINATED AREAS AT CHONBURI PROVINCE BY GIS)

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บทคัดย่อ

วัตถุประสงค์ของการวิจัยนี้เพื่อศึกษาความหลากหลายและการกระจายตัวของหอยฝาเดียวในป่าชายเลนบริเวณตำบลเสม็ด ท่าเรือแหลมฉบังและท่าเรือจุกเสม็ด จ.ชลบุรี นอกจากนี้ยังมีการวิเคราะห์ลักษณะดินและปริมาณสาร TBT ที่ปนเปื้อนในดินและเนื้อเยื่อหอย โดยใช้ GC-MS จากนั้นทำการเก็บและเปรียบเทียบข้อมูลต่างๆ เช่นความหลากหลายของหอยฝาเดียว ลักษณะดิน การสะสมของ TBT ในดินและเนื้อเยื่อ โดยใช้การวิเคราะห์ทางสถิติและแสดงผลโดยใช้ระบบสารสนเทศภูมิศาสตร์

ในการศึกษาครั้งนี้พบหอยฝาเดียวทั้งหมด 21 ชนิด หอยในแฟมิลีลิทโทรินิดีและเอลโลบิดี พบมากที่สุด จากข้อมูลการศึกษาทางนิเวศวิทยาพบว่า การกระจายตัวของหอยฝาเดียวส่วนใหญ่เป็นแบบกลุ่ม ค่าความหลากหลายและความสม่ำเสมอพบสูงสุดที่จุกเสม็ดและต่ำสุดที่เสม็ด ค่าความคล้ายคลึงพบสูงที่สุดที่แหลมฉบังและเสม็ด หอย *Assiminea brevicula*, *Melanoides tuberculata* และ *Clithon oualaniensis* เป็นชนิดที่พบมากที่สุดที่เสม็ด แหลมฉบัง และจุกเสม็ด ตามลำดับ ส่วนการวิเคราะห์ปริมาณ TBT พบว่า ปริมาณ TBT ที่สะสมในเนื้อเยื่อพบมากที่สุดที่แหลมฉบังและต่ำสุดที่เสม็ดอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) ซึ่งการทดลองนี้ไม่พบการเกิด imposex ถึงแม้ว่าจะพบการสะสมปริมาณสาร TBTในปริมาณน้อยก็ตาม ในขณะที่การสะสมปริมาณ TBT ในดินพบมากที่สุดที่แหลมฉบัง (10.52 ± 2.82 ng/g) และต่ำที่สุดที่จุกเสม็ด (1.56 ± 0.24 ng/g) อย่างมีนัยสำคัญทางสถิติ ($p<0.05$) จากการวิเคราะห์หาค่าความสัมพันธ์ระหว่างปัจจัยทางกายภาพกับปริมาณ TBT ที่สะสมในดิน และกับความหลากหลายของหอยฝาเดียว เป็นไปอย่างมีนัยสำคัญทางสถิติ ($p<0.05$)

จากผลการวิจัยนี้แสดงให้เห็นว่ามีปริมาณ TBTที่สะสมอยู่ในหอยฝาเดียวและในดินบริเวณสถานที่เก็บตัวอย่างทั้งสามแหล่งในปริมาณต่ำ ซึ่งการศึกษาในครั้งนี้สามารถใช้เป็นฐานข้อมูลเบื้องต้น เพื่อนำไปศึกษาประยุกต์ใช้และกำหนดค่ามาตรฐานของสารTBTเพื่ออนุรักษ์สิ่งแวดล้อมต่อไปในอนาคต

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LIST OF ABBREVIATIONS

SL	=	Shell length
SW	=	Shell width
AL	=	Aperture length
AW	=	Aperture width
SL	=	Spire angle

CHAPTER I
INTRODUCTION

Mangrove forests are highly productive and ecologically important. Mangrove productivity is influenced by species composition, age, competition, substrate, wave action, and bird action as well. Mangrove ecosystems are typically characterized as based on a detrital food web, and a grazing food web. As with most ecosystems, many intricate plant and animal relationships exist in mangrove forest and provide homes to variety of marine and terrestrial organisms such as mollusk, shrimp, blackish fish species, and bird species. It also provides a food source for many organisms within the ecosystems and depends on other organisms for pollination, reproduction, and nutrient attainment. Furthermore, mangrove trees have a close relationship with the soil, the soil surrounding mangrove tree tends to be anoxic with a thin layer of an aerobic zone. NH_3 in the soil is oxidized by aerobic bacteria into nitrate ions through the anoxic layer. Some nutrients however are obtained via marine modes. Since mangroves are closer to the water, decomposition occurs at a greater rate due to the shredding action of crabs and amphipods and also produces the highest detritus, which is a food source for many organisms. The peat that produced by mangroves increases the acidity of the surrounding area. This action tends to dissolve limestone bedrock and eventually through microbial activity, produces the characteristic sulfur smell found in mangroves. Consequently, any environmental hazardous waste that exposed to terrestrial environments drains into mangroves and estuaries. Aside from the typical environmental issues, these habitats are threatened to a greater degree by exploitation as well as by aquaculture, establishment of industrial estates and urban development projects. Mangroves all over the world have suffered from loss of habitat and contamination. Much of these are due to deforestation for aquaculture, fisheries and contamination from industrial estates and other sources that affect to many animals. Mangrove systems in addition to natural obstacles, face additional obstacles created by humans in the form of super fisheries, oil spills and other development activities. In order to understand the threats faced by mangroves, analysis of the biological mangrove system must be fully understood.

Chonburi province, is located between 100°50' N to 101° 43' and 12° 35' to 13° 36' in the eastern part of Thailand. Its area and number of population are 4,363.0 km^2 and 977,000, respectively. Major land use includes paddy, cassava, sugarcane, pineapple, and orchard. Beside, rubber plantations and mangrove forests are also found. The overall geographic feature of Chonburi province can be divided as follows: long ranges of mountainous areas almost in the middle of the province from the Northwest to the Southeast, with the areas about the height of up to 200 m above the sea level in the east part; areas close to the sea in the west part of the province, under narrow plain lands along the seacoast and small mountains in some parts, as well as some irregular seacoasts and low lands of muddy and mangrove forests.

Organotins have been developed into important industrial and agricultural commodities since 1960. Tributyltin (TBT), a cation whose formula is (C_4H_9) $3Sn^+$, is regarded as the most toxic organotin to marine organisms, and has been referred to as the most toxic substance and being deliberately released in the marine environment (Mee and Fowler, 1991). TBT is used as an antifouling agents in paints applied on boats and fishnet, lumber preservatives, and slimicides in cooling system (Clark *et al.*, 1988; Hall and Pinkney, 1985; Kinnetic Laboratory, 1984). TBTO (tributyltin oxide) is a biocidal preservative for wood, cotton textiles, paper, paints and stains. It is also added as an anti-fouling agent in numerous formulations of marine paint products. Organotin-based paints have seen service on boats of all sizes, from small yachts to supertankers, thereby ensuring the global dispersion of TBT throughout the marine environment, from the coastal zone to the open ocean. These compounds are persistent in the marine environment owing to their slow degradation rates and consistent flux (Michel and Averty, 1999). It is considered as an aquatic pollutant due to its harmful effects on non-target marine organisms, particularly the mollusks. Restrictions on the use of antifouling paints on ship of less than 25 m in total length have been implemented in most Europe, United States, Australia, New Zealand, and Canada (Evan *et al.*,

1995) except in most Asian countries (Horiguchi *et al.*, 1994). Recently, the Marine Environmental Protection Committee of the International Maritime Organization (IMO) has recommended a ban on the application of TBT-based antifouling paints from 2003 and absolute ban from 2008 which is possibly in developed nations. But it is still largely used in developing countries in Asia, Africa and South America without any control measures.

The mollusk species that are found in the mangroves are important components and sometime assumed as an indicator of the ecosystem. They can be described as species that are associated with tropical estuarine areas, and are able to survive in mangroves at the limit of their ecological range and evolved within a specific mangrove ecosystem. Usually, mangrove mollusks are bivalves and gastropods. They are easy to collect and enumerate because normally living from four to six years and not moving much from its birth place. Bivalves are typically found in the intertidal or subtidal zone and gastropods found in all the fauna zones of the mangrove forests from the high tree zone to burrowing in mud flats. Therefore, they have to adapt themselves to live in their suitable environments in mangrove forest especially contaminated by pollutions such as heavy metals, polycyclic aromatic hydrocarbons, and organotin compounds, etc. Mollusks were highly sensitive to TBT even when they were exposed to 0.06 to 2.3 ppb and they could get rid of TBT from their bodies very slowly. Therefore, they were concerned as appropriate bioindicators for TBT pollution.

Geographic Information System (GIS) is a computer system for capture, store, check, integrate, manipulate, analyze, and display data related to position of the earth’s surface or the coordinate system. These may be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image on a map and a record in an attribute table. GIS can relate otherwise disparate on the basis of common geography, revealing hidden patterns, relationships, and trends that are not readily apparent in spreadsheets or statistical packages, often creating new information from existing data resources. Thus, GIS has been recognized as an important tool for planning and management in many fields especially natural resources, and environment such as management of wild and scenic rivers, recreation resources, floodplains, wetlands, agricultural lands, aquifers, forests, and wildlife, etc.

CHAPTER II
OBJECTIVES

The objectives of the present study were:

1. to study the species diversity and distribution of gastropods in the epifauna of Samet, Laemchabung, and Chuksamet;
2. to study the soil structure in each study area in related to the ecological data and TBT accumulation;
3. to study the TBT accumulations in gastropods and soils of each study area;
4. to compare all the data (species diversity and distribution of gastropods, soil structure; and TBT accumulation in gastropods and soil) using GIS.

CHAPTER III
LITERATURE REVIEW

Mangrove forests are one of the important types of natural forest found in the intertidal zone of tropical and subtropical regions of the world (Tomlinson, 1986; Ricklefs and Latham, 1993). They are important as an estuarine nutrient-cycling processes as well as have important role in stabilizing the sediments deposited by physical processes. Human uses mangrove forests at various purposes (Table 3-1). Besides, they are the food source and habitat for invertebrates, fishes, amphibians, reptiles, birds and, mammals (Odum and Mclvor, 1990).

Table 3-1. The values of selected mangrove benefits.

Benefit	Value (USD$/ha/yr)	Value (USD$/ha/50 yr)	Source	Location
On-site sustainable fisheries	126	6,300	Ruitenbeek(1992)	Irian Jaya
On-site crustacean and mollusk harvests	126	6,300	Nielson (1998)	Vietnam
On-site sustainable harvest, all products	500	12,500	Cabahug (1986)	Philippines
Fish products	538	26,900	de Leon and While	Philippines
Vicinity fish harvests	1,071	53,550	Cabahug (1986)	Philippines
Vicinity shrimp harvests	254	12,700	Cabahug (1986)	Philippines
Vicinity mollusk harvests	675	33,750	Cabahug (1986)	Philippines
Vicinity crab harvests	720	36,000	Cabahug (1986)	Philippines
Off-site fisheries	189	9,500	Christensen (1982)	Asia
Off-site fisheries (managed)	147	7,350	Sathirathai (1998)	Thailand
Off-site fisheries (open)	92	4,600	Sathirathai (1998)	Thailand
Other products (e.g. fruits, thatch)	435	21,750	Sathirathai (1998)	Thailand
Sustainable forestry	756	37,800	Gammage (1994)	El Salvador
Charcoal	378	18,900	Sathirathai (1998)	Thailand
Biodiversity (capturable)	20	1,000	Ruitenbeek (1992)	Irian Jaya
Total direct use value	2,505	125,250	Sathirathai (1998)	Thailand
Waste assimilation	7,833	391,600	Lal (1990)	Fiji

3.1 Mangrove fauna

Animals from both the marine and terrestrial environments can be found in the mangroves. Mangrove animals live successfully under highly variable salinity regimes (Chapman, 1976). Mangrove species are diverse and abundant as follows: 22 species of gastropods and 4 species of bivalves, 15 shrimp species, 30 crab species, 38 insect species, 72 fish species, 24 reptile species, 35 mammal species, and 88 bird species and so on (Aksornkoae, 1999). Among invertebrates, mollusks are often selected for investigation because they are one of the dominant groups of the mangrove community and play a significant ecological role in the structure and function of mangrove systems (Berry, 1963; Coomans, 1969; Sasekumar, 1974; Frith *et al*., 1976; Wells and Slack-Smith, 1981; Well, 1983; Macintosh *et al*., 2002; Ashton *et al*., 2003). They form important links between the primary detritus at the base of the food web and consumers at higher tropic levels; the most important group in terms of number of species, density and biomass (Macintosh *et al*., 2002). Mangrove mollusks usually found bivalves and gastropods. The record of common seashell of Singapore showed 25 species of nine families of gastropods and eight species of six families of bivalves were found (Tan and Chou, 2000). Three major families of gastropods were mainly found in the mangrove forest: Ellobiidae, Littorinidae and Potamididae (Brown, 1971; Frith *et al*, 1976; Reid, 1986; Wells, 1983; Ellison, 1999; Ng and Sivasothi, 1999; and Tan and Chou, 2000). Moreover, some gastropods in the families Amphibolidae, Haminoeidae, Molongnidae, Nassaridae, Muricidae, Neritidae, Littorinidae, Assimineidae, Potaminidae and Cerithiidae were usually found in mangrove habitats. Snails of the families Neritidae and Ellobiidae were the most abundant mollusks in mature forests, whereas Littorinidae, Assimneidae and Potamididae species were more representative of the younger plantation sites. However, studies of mollusk communities in mangroves were numerous but there were few quantitative data on the diversity, density and biomass of mollusk in mangrove forest (Wells, 1984; 1986; 2001; Wells and Slack-Smith, 1981; and Ashton *et al.*, 2003).

3.2 Tributyltin compounds

In sea water, TBT exist mainly as a mixture of chloride, hydroxide, aquo complex, and carbonate complex (Laughlin *et al.*, 1986). They exhibit varying degrees of toxicity towards a broad range of organisms and accordingly have seen widespread applications as biocides (Blunden and Evans, 1990). The solubility of TBT compounds in water was influenced by such factors as the oxidation-reduction potential, pH, temperature, ionic strength, concentration and composition of the dissolved organic matter (Clark *et al.*, 1988; Corbin 1976). The need to determine BT levels in sediments was illustrated by the fact that TBT had a low aqueous solubility and high affinity for particulate matter, providing a potential to penetrate into the benthic environment (Langston and Pope, 1995). Page *et al.*, (1996) found that quantity of TBT in sediments depended on the size of particulate matter. They reported the 2x increase in percentage of silt and clay in sediments containing TBT. High levels of TBT in sediments were observed to be highly associated with marinas, mooring and shipyard hull washing/refinishing activities (Langston *et al.*, 1987; Ko *et al.*, 1995; Page *et al.*, 1996). Furthermore, the carbon-tin covalent bond did not hydrolyze in water (Maguire *et al.*, 1983, 1984), and the half-life of photolysis due to sunlight was greater than 89 days (Maguire and Tkacz, 1985; Seligman *et al.*, 1986). Biodegradation was the major breakdown pathway for TBT in water and sediments with half-lives of several days to weeks in water, and from several days to months or more than a year in sediments (Clark *et al.*, 1988; de Mora *et al.*, 1989; Lee *et al.*, 1987; Maguire 2000; Maguire and Tkacz 1985; Seligman *et al.*, 1986, 1988, 1989; Stang and Seligman 1986; Stang *et al.*, 1992). Half-life of TBT in the marine water was short, about a week (Seligman *et al.*, 1988), whereas that in sediments was about 3.5 years (Batley, 1996). Breakdown products include dibutyltins (DBT), monobutyltins (MBT) and tin with some methyltins detected when sulfate reducing conditions are present (Yonezawa *et al.*, 1994).

3.3 Toxicity of TBT to marine organisms

Marine organisms are potentially at the alarm risk of TBT exposure due to the ability of TBT partition in sediments. Evans and Laughlin (1984) found that larvae mud crabs, *Rhithropanopeus harrisii* exposed to 14.60 μg/L TBT for 15 days reduced their developmental rates and growth. Newton *et al.* (1985) exposed embryos of the California grunion, *Leuresthes tenuis* with 74 µg/L TBT for 10 days which caused a 50% reduction in hatching success. In rainbow trout, eggs were killed within 10-12 days when exposed to 5 ppb TBT. At lower levels, no death occurred, but blood and liver metabolism changes were noticed, gill epithelium was destroyed, and mitochondia were swollen and broken (Department of the Environment, 1986). Growth reduction and liver changes also occurred in young trout exposed to low levels of tributyltin chloride. In addition, the corneal membranes of the rainbow trouts' eyes were destroyed by TBTO (U.S. Environmental Protection Agency, 1986).

Mollusks were one of the most TBT-sensitive groups of invertebrates (Bryan and Gibbs, 1991). Generally, the larva was more sensitive to TBT than the adult. Abnormal shell development was observed in the embryonic stage of the eastern oyster, *Crassostrea virginica* expose to 0.77 µg/L TBT for 48 hours (Roberts 1987). Lapota *et al*. (1993) found that the blue mussel, *Mytilus edulis,* exposed in 0.050 µg/L TBT for 48 hours reduced shell growth. Waldock and Thain (1983) reported on the reduction of shell size and thickening of the upper shell valve of Pacific oyster exposed to 0.1460 µg/L TBT for 56 days. Laughlin *et al*. (1987, 1988) reported on a significant decrease in growth of hard clam, *Mercenaria mercenaria,* larvae exposed in 0.01 µg/L TBT for 14 days. This was because the veliger larvae could not change to the pediveliger larvae (Alzieu, 1991; Widows and Page, 1993). In addition, shell malformation, lack of reproduction, and poor weight gain in the adult oysters were found (Alzieu, 1986; Ruiz, *et al*., 1996).

TBT at an ambient concentration of just a few nanograms per liter had the potential to cause a genital disorder in adult females marine snails by having the superimposition of male characteristics on females. This phenomenon was widely known an imposex (Smith, 1971), or pseudohermaphroditism (Jenner, 1979). The effects of imposex depends on the species. Fioroni *et al,* (1991) found imposex in 63 genera and 118 species of mollusks. In *Nucella lapillus,* in Great Britian, the growth of vas deferens blocked the ovipore of the female to release egg capsules from the capsule gland and rendered the female effectively sterile (Evans *et al*., 1996) and this type of imposex resulted population decline (Gibbs and Bryan, 1986). In *Ocenebra erinacea*, the morphological response to TBT was manifested as a split bursa copulatrix and capsule gland (Gibbs *et al*., 1990). While in other gastropods, such as the mud snail, *Ilyanassa obsoleta*, reproductive system was seemingly unaffected, although females posses a penis (Gibbs and Bryan, 1986; Smith, 1981). Ellis and Pattisina (1990) recorded 100% of imposex in different muricids from Indonesia, Singapore, and Peninsula Malaysia. Since then more extensive imposex surveys have been conducted in Southeast Asia and high imposex levels have been reported from major harbors and areas with shipyards in Indonesia (Evan *et al.,* 1995), Singapore (Tan, 1997), Taiwan (Liu and Suen, 1996), Korea (Shim *et al*., 2000), Malaysia (Swennen *et al*., 1997), and Thailand (Kan-atireklap *et al*., 1997; Bech, 1998). These findings indicated that TBT contamination in Southeast Asia was a major concern (Bech, 2002). Therefore, the presence of masculinized female snails (imposex) might be used as a bioindicator of the presence of toxicologically significant levels of organotin compounds (Davies *et al*., 1987).

At the molecular level, TBT interfered with hormone metabolism, most probably by an inhibition of the cytochrome P450-dependent aromatase which converted androgens to estrogens (Matthiessen and Gibbs, 1998; Bettin *et al*., 1996; Morcillo *et al*., 1999). Feral and Le Gall (1982) showed that TBT inhibited the release of a neuroendocrine factor from the pleural ganglia, which was responsible for the suppression of penis formation in females, thus resulting in imposex development. Besides, the neurohormone APGWamide could induce imposex in *Ilyanassa obsoleta* (Oberderster and Cheek, 2001). Furthermore, malformations of the pallial genital tract in female periwinkle, *Littorina littorea*, that were closely related to the TBT contamination, were described for the first time (Bauer *et al*., 1995). This phenomenon was termed as intersex. It was defined as a disturbance of the phenotypic sex determination between gonad and genital tract that was exhibited male features on female pallial organs (inhibition of the ontogenetic closure of the pallial oviduct), or female sex organs were supplanted by the corresponding male formations causing female sterility. This caused periwinkle populations to decline, but were not likely to become extinct, as long as aqueous TBT levels were not beyond mortality threshold concentrations for the planktonic veliger larvae (Matthiessen, 1995).

3.4 Applications of remote sensing and GIS in mangrove research

Remote sensing applications, with the concerted efforts of the space scientist during the past decades, have proved very useful in resource surveys and management activities. These techniques have been applied successfully in forestry, agriculture, disaster mitigation and management, flood and drought monitoring, land use and land cover mapping, urban planning, mineral targeting, environmental impact assessment, and coastal zone mapping etc. The first systematic studies of epsilon scale species richness by overlaying a grid (10^4 to 10^7 ha in size) onto range maps and tabulate the presence or absence of each species. This study was done on mammals (Simpson, 1964), birds (Cook, 1969), and reptiles and amphibians (Kiester, 1971). Other researchers had overlaid the original vector range maps rather than converted them to a grid (Terborgh and Winter, 1983). Geographic information system (GIS) technology now provided capability to overlay digital versions of range maps and automatically tallied richness in vector format (e.g., Jones and Stokes Associates 1989). Inventories of existing levels and spatial patterns of biodiversity were urgently required to formulate short term management strategies, to develop and test scientific hypotheses, and to serve as baseline data in monitoring (Lubchenco *et al*., 1991). Therefore, the remote sensing and geographic information systems would be a valuable tool in support of inventory and monitoring of the habitats and biodiversity. Remote sensing studies relevant to the field of sustainable development in tropical coastal ecosystems in developing countries have been performed (Dahdouh-Guebas *et al*., 2002; De La Ville *et al.*, 2002; Jayatissa *et al*., 2002; Kairo *et al*., 2002; and Verheyden *et al*., 2002). Using these case-studies as examples of current remote sensing and GIS applications, they showed how remote sensing and GIS could be applied, developed and integrated in a sustainability framework to fulfill the local and global aims and needs. Moreover, they illustrated how air- and space-borne high resolution imagery could help in identifying species or areas from a fundamental point of view, indicating the priority importance for protection and conservation for development, and sustainable exploitation.

Mangrove ecosystem, is fragile but yet highly productive, is constantly undergoing changes (seasonal/short-term and/or succesional/long-term) due to its dynamic nature through various natural and biotic influences. Hence, an accurate and up-to-date information based on the status of mangrove vegetation, continually overtime, is a prerequisite for the sustainable management of mangrove forests. The required information cannot be obtained with traditional field surveys to be made inside the mangrove swamps as they are extremely difficult. Remote sensing and geographic information system serve as valuable aids in providing fast, efficient and accurate information to detect the changes and impacts as well. The information thus gained can be utilized for the effective planning, research and management of mangrove forests so as to save these delicate and highly valuable ecosystems for posterity and sustainable utilization. Mangrove ecosystems require research with respect to the high spatio-temporal dynamism in land use and land cover patterns (marine and coastal changes), in order to assess and predict the extent of anthropogenic impacts or environmental changes.

This includes changes in population structure of floral and faunal assemblages, in biodiversity and ecosystem functioning, and in the complexity of their regulation (biocomplexity), and in ethno-biological uses. An excellent tool that is increasingly important in the detection, description, and quantification and monitoring of those changes is remote sensing, which, in combination with geographic information systems and fieldwork, is an effective assessment tool. Surachai *et al*. (2000) concluded that remote sensing appears to be a significant tool for assessment and monitoring of coastal zone resources, especially mangrove forest. In addition, planning and management of forest land use was easily and effectively conducted using GIS. Lerio and Boromthanarat (2003) stated that diverse resources, environmental, and legal data from various Participatory Rural Appraisal (PRA) and other sources could be organized through the use of the GIS and provide analysis to design a developmental scheme for mangrove management. Moreover, their study showed that PRA integrated GIS was a useful tool to draw the local knowledge of the people about the resource by allowing the different stakeholders in the local community to contribute, evaluate and plan for the local mangrove resource. Further study showed that the local people were familiar with the mapping technique and they gave integrated information, which might be used rapidly to provide summary information to integrate the plan for local mangrove management.

CHAPTER IV
MATERIALS AND METHODS

4.1 Study areas

Three study areas of mangrove forests along the coast line were selected for TBT study as follows: Samet, Samet Subdistrict, Muang District; Laemchabung, Laemchabung Subdistrict, Sriracha District; and Chuksamet, Samaesan Subdistrict, Sattahip District, Chonburi Province (Figure 4-1). The surveys of the three mangrove forests were conducted using GPS (Magellan SporTrak Geographic Positioning System Receiver) and the ground control points (GCPs) for image registration, classification, and post-classification process were obtained (Figures 4-2 to 4-4). All samples were collected on May 4, 18, and 25, 2005 at Laemchabung, Samet, and Chuksamet, respectively. The study sites were divided into five transverse zones. Zone 1 was at the intertidal area along the shoreline. Zone 2-5 were next to zone 1 and were more toward land or connected to the land, especially zone 5. Each zone was 10 m apart and was subdivided into five sampling sites that were 10 m apart at Laemchabung and Chuksamet while at Samet, each zone was 25 m apart and was subdivided into five sampling sites that were 25 m apart. Therefore, there were a total of 25 sampling sites. At each sampling site, 1 m^2 plot was made by four PVC pipes at four corners, and the physical factors were measured as follows; soil pH, and soil temperature by the pH meter of soil, water pH, and water temperature by the pH meter of water, the salinity of water by hand refractometer, and air temperature and humidity by hygrometer.

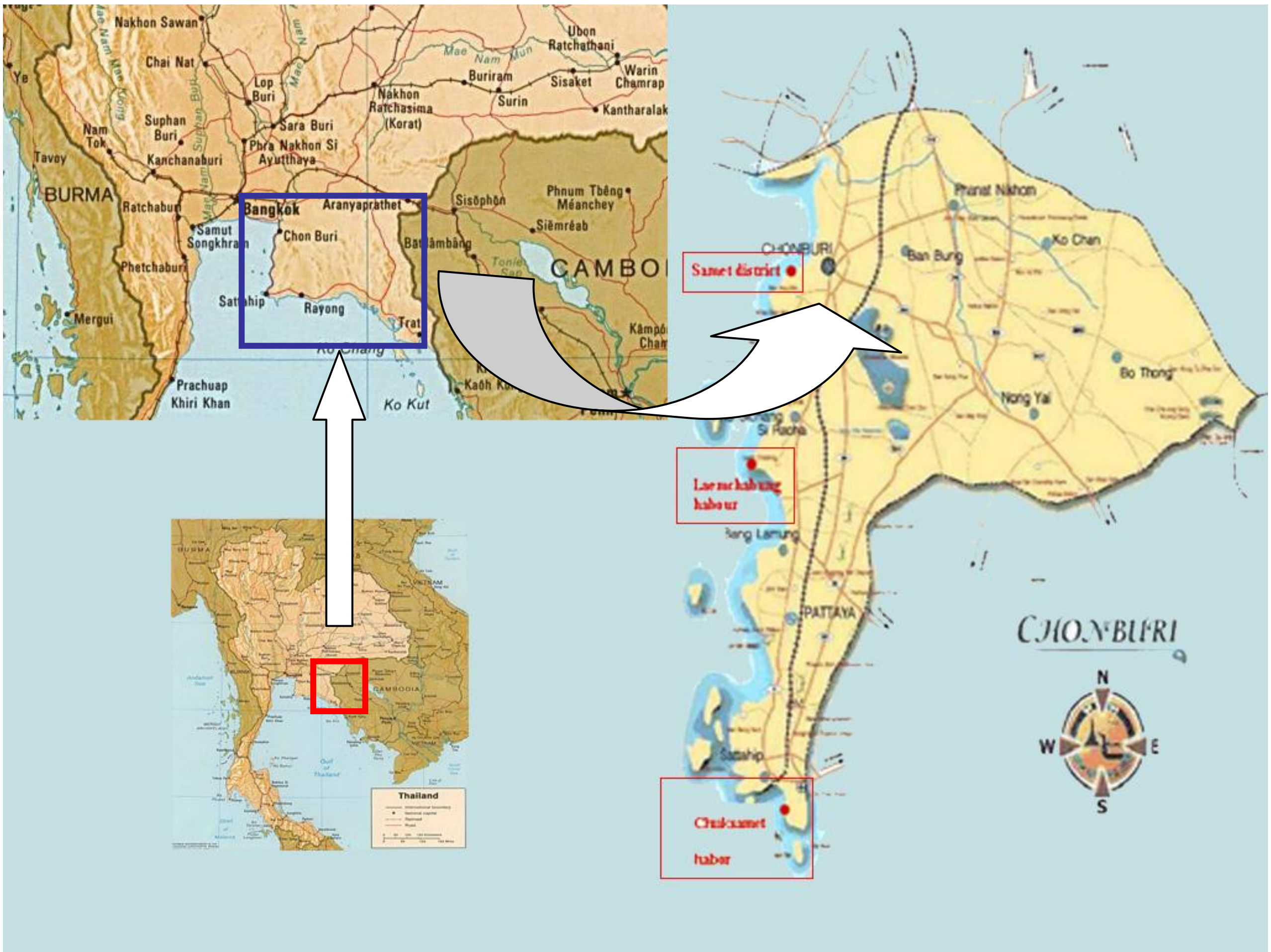

Figure 4-1. Map showing three study areas.

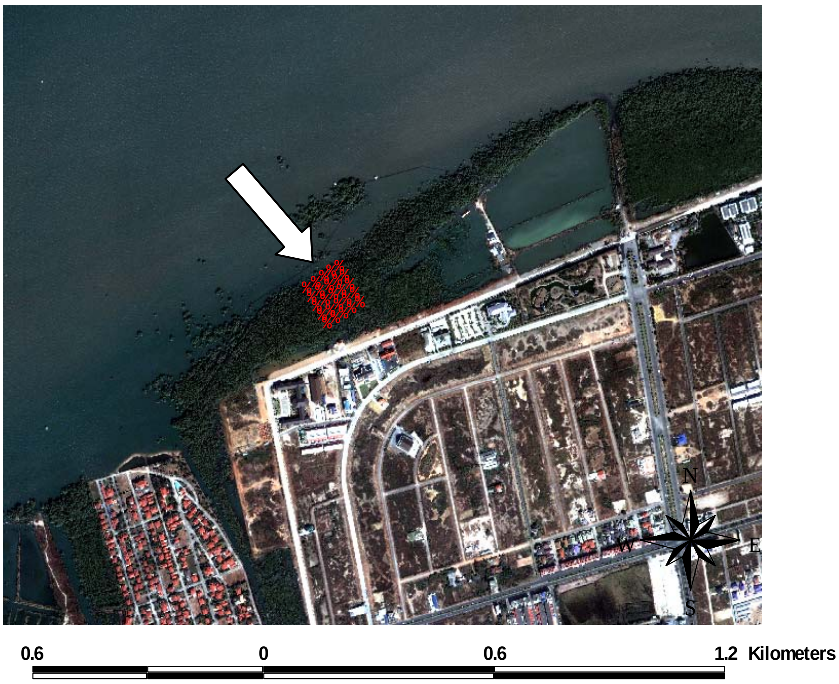

Figure 4-2. Quickbird image of study site at Samet District (see the arrow).

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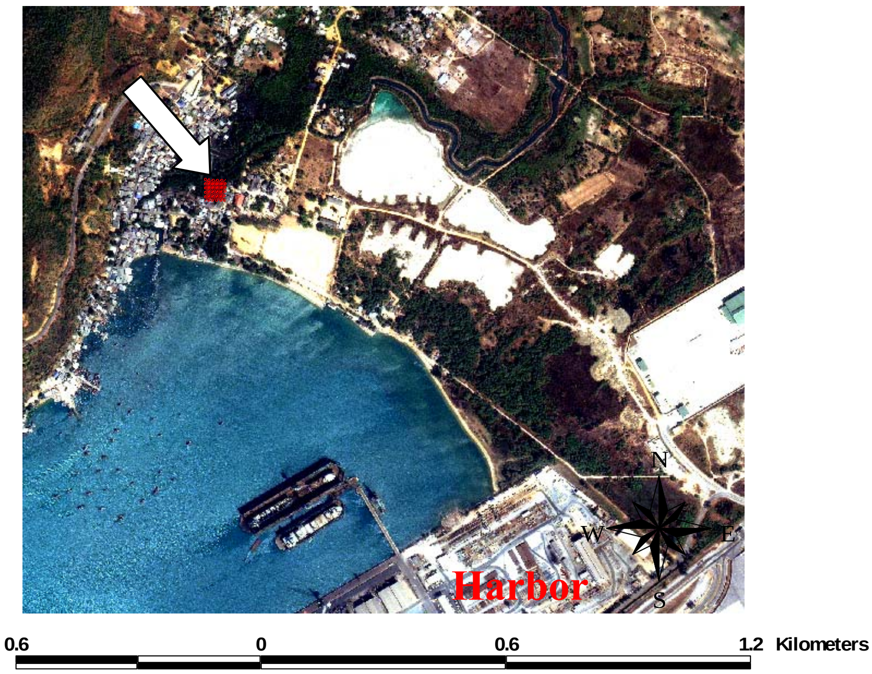


Figure 4-3. Ikonos image of study site at Laemchabung Habor (see the arrow).

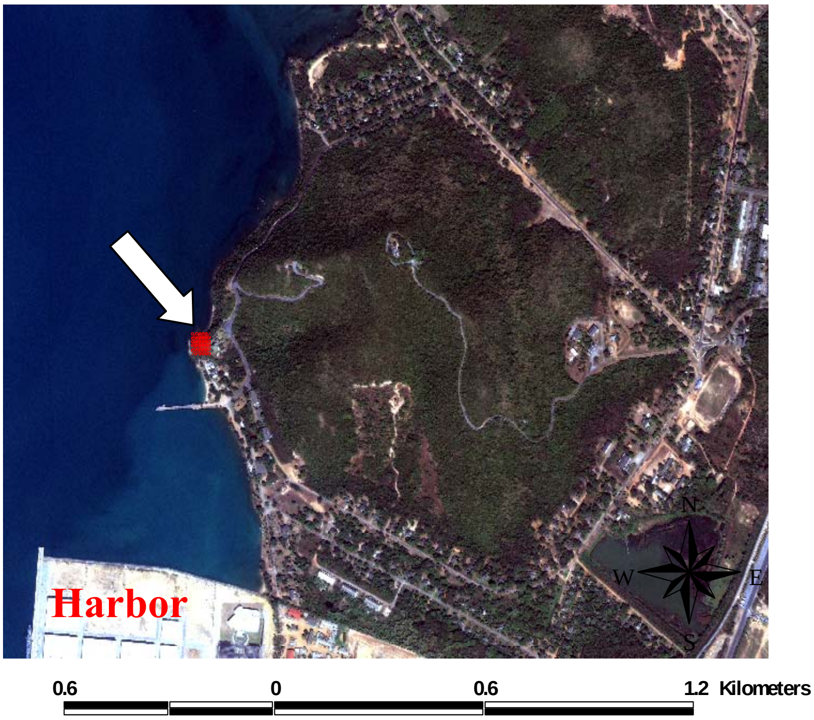


Figure 4-4. Ikonos image of study site at Chuksamet Habor (see the arrow).

4.2 Field study

4.2.1 Soil

In each sampling plot, a square meter of surface soil at five centimeter depth was taken by the aluminum shovel and kept in polyethelene ziplock bags. It was freeze-dried and stored until soil structure and TBT concentration analysis was performed (Figure 4-5).

4.2.2 Gastropods

Gastropods were collected from all sampling sites. The epifauna was randomly hand picked. The shell was classified by the number of species, number of individuals, and their habitats recorded. Shell sizes (shell length, shell width, aperture length, aperture width, and spire angle) were randomly measured. About 20 to 45 individuals of each species at each study area were collected and put into polyethelene ziplock bags, freeze-dried and stored until TBT analysis was performed (Figure 4-5).

The gastropods were identified following Brandt (1974), Nielson *et al*. (1976), Tanarisiwong (1978), Reid (1986), Tan and Chou (2000), and Swennen *et al*. (2001).

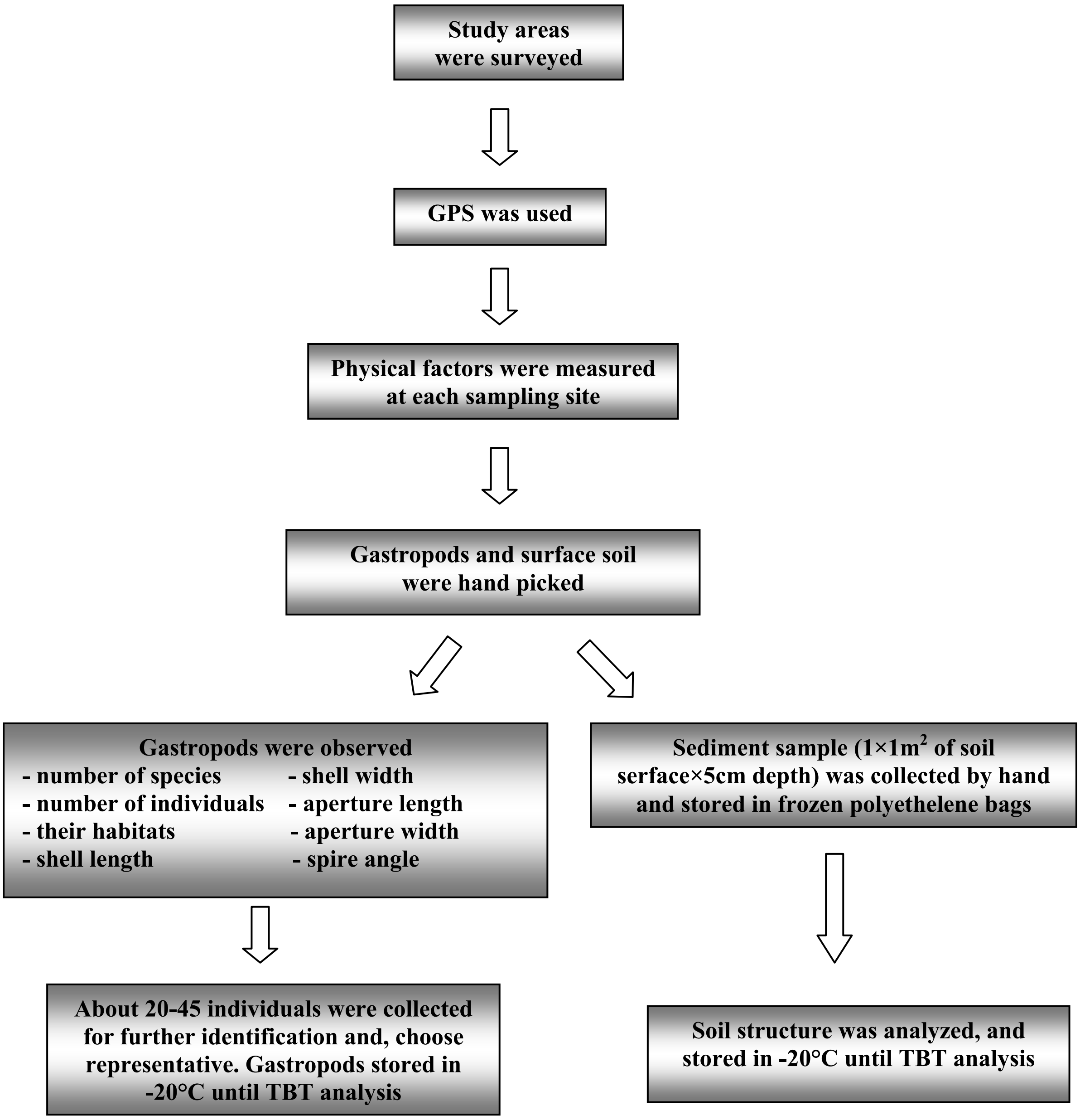


Figure 4-5. Schematic diagram of the methodology for field survey.

4.3 Laboratory study

4.3.1 Soil structure analysis

All three grams of soils from each sampling plot in each zone were analyzed for percentages of sand, silt, and clay by a hydrometer at the Department of Soil Science, Faculty of Agriculture, Kasetsart University (Figures 4-6, 4-7).

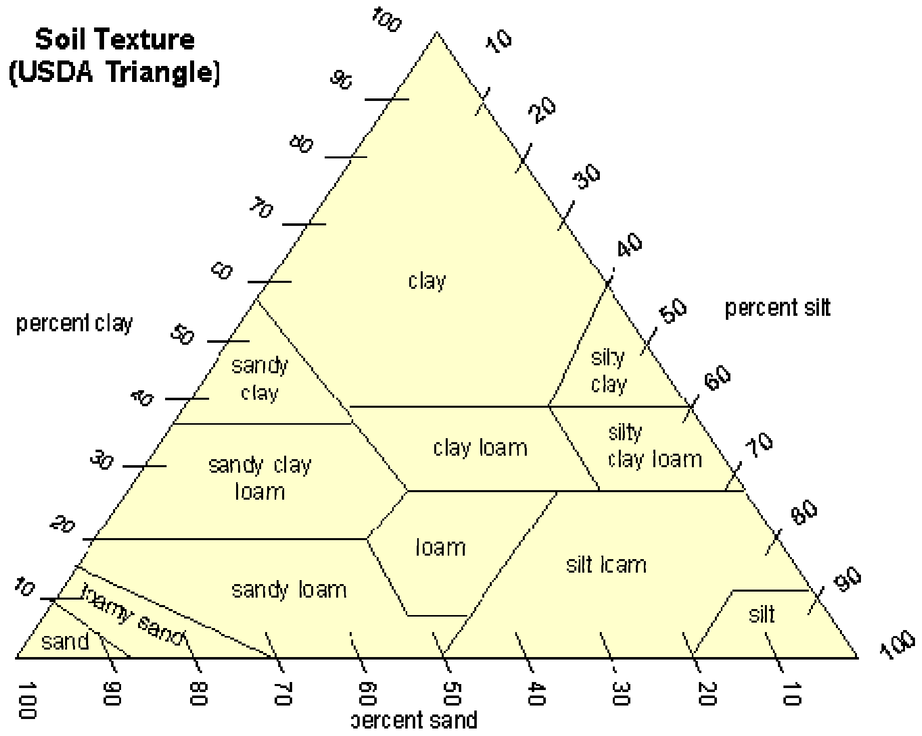


Figure 4-6. Triangular diagram of soil textural classes (USDA triangle).

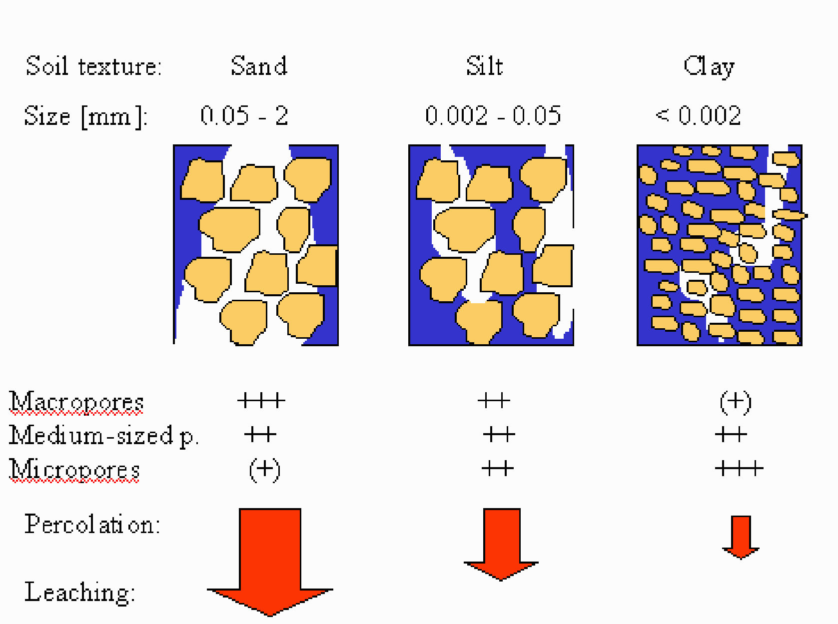


Figure 4-7. Relationship between soil texture and pore size.

4.3.2 Tributyltin (TBT) analysis

Sediment

10 grams of sediments from each zone were put into 100 ml separatory funnel and separated 3 times. Each replicate was added into 10 ml of 2 N HCl. After that, the sample was shaken for 30 minutes by hand and 30 ml of 0.1% tropolone/diethyether was added and, the solution was shaken for 20 minutes. The sample was left for 30 minutes for the layers to separate, after that the organic layer was removed to the 250 ml Erlenmeyer flask. The remaining sample in separatory funnel was added with another 30 ml 0.1% tropolone/diethyether. The solution was shaken once for 20 minutes, and left for 30 minutes to allow the solution to be separated again. After that the organic layer was transferred to the 250 ml Erlenmeyer flask. This extraction process was done 5 times. After that all organic layers were transferred to the separatory funnel, 20 ml 0.5 N NaOH was added to eliminate lipid, shaken for one minute, left for 10 minutes to allow the solution to be separated. The aqueous layer was discarded and the lipid layer was transferred the organic layer of the 250 ml Erlenmeyer flask. After that the organic phase was poured into the activated copper

column to eliminate sulfur. The column was packed by 3 grams of copper that was already soaked with 1:1 HCl:H_2O for 1-3 hours, washed by distilled water until pH 7, then soaked with acetone 3 times, and hexane 3 times. After that the organic phase was transferred to 250 ml Erlenmeyer flask and added with sodium sulfate anhydrous to eliminate water. The organic phase whose sulfur, lipid, and water were eliminated was transferred to the rotary evaporator to reduce the volume to 10-15 ml. The reduced organic phase was transferred to the 40 ml conical flask and capped with septum. Then the organic phase was added with 1.5 ml hexylmagnesium bromide under nitrogen condition, shaken in 40°C water bath by magnetic stirrer for 30 minutes, and cool down for 3 minutes. After that 20 ml saturated NH_4Cl was added to stop the reaction, then transferred the solution to 100 ml separatory funnel and the aqueous layer was discarded. The organic phase was added with 10 ml 0.5 NaOH once to eliminate lipid, shaken for 1 minute, left for 10 minutes, and the aqueous and lipid layers were discarded. The organic layer was added by sodium sulfate anhydrous, and transferred to the rotary evaporator to reduce the volume to 2 ml. The reduced organic phase was loaded into the florisil column. The column was packed by 5 grams of activated florisil (incubated at 120°C for 18 hours) in hexane and eluted by 28 ml hexane. After that the solution was reduced the volume to 1.5 ml by rotary evaporator, and analyzed for TBT by GC-MS (Agilent Technologies 6890 N Network GC System connected with MS 5975 Inert XL Mass Selective Detector) (Table 4-1, and Figure 4-8).

Gastropods

10 grams of gastropod tissues were put into 100 ml separatory funnel, and 10 ml of 2 N HCl were added. After that, the sample was shaken for 30 minutes by hand. 30 ml of 0.1% tropolone/diethyether was added and, the solution was shaken for 20 minutes. The sample was left for 1 hour to separating the layer. After that, the organic layer was removed to the 250 ml Erlenmeyer flask. The remaining sample in separatory funnel was added with another 30 ml 0.1% tropolone/diethyether. The solution was shaken once for 20 minutes, and left for 1 hour to allow the solution to be separated again. After that the organic layer was transferred and combined to the 250 ml Erlenmeyer flask. This extraction process was done 5 times. After that all

organic layers were transferred to the separatory funnel, added with 20 ml 0.5 N NaOH to eliminate lipid, shaken for 1 minute, left for 10 minute to allow the solution to be separated, and the water and lipid layer were discarded. The organic layer was transferred to the 250 ml Erlenmeyer flask, and added with sodium sulfate anhydrous to eliminate water. The organic phase whose lipid and water were eliminated was transferred to the rotary evaporator to reduce the volume to 10-15 ml. The reduced organic phase was transferred to the 40 ml conical flask and capped with septum. Then the organic phase was added with 1.5 ml hexylmagnesium bromide under nitrogen condition, shaken in 40°C water bath by magnetic stirrer for 30 minutes, and cool down for 3 minutes. After that 20 ml saturated NH_4Cl was added to stop the reaction, then transferred to 100 ml separatory funnel and the aqueous layer was discarded. The organic phase was added with 10 ml 0.5 NaOH once to eliminate lipid, shaken for 1 minute, left for 10 minutes, and the water and lipid layer were discarded. The organic layer was added by sodium sulfate anhydrous, and transferred to the rotary evaporator to reduce the volume to 2 ml. The reduced organic phase was loaded into the florisil column. The column was packed by 5 grams of activated florisil (incubated at 120°C for 18 hours) in hexane and eluted by 28 ml hexane. After that the solution was reduced the volume to 1.5 ml by rotary evaporator, and analyzed for TBT by GC-MS (Agilent Technologies 6890 N Network GC System connected with MS 5975 Inert XL Mass Selective Detector) (Table 4-1, and Figure 4-8).

Table 4-1. The condition of GC-MS for TBT analysis.

<table>
<tr><th>PARAMETER</th><th>MODE</th><th>CONDITION</th></tr>
<tr><td>Gas chromatography</td><td>Scan and Sim

- Injector

- Inlets

- Column

- Oven

- Auxilary</td><td>

Injection volume : 1 µl

Mode : Splitless
Gas : Helium
Heater : 260 ºC

DB-5 : 30 m × 0.25 mm × 0.25 µm
Mode : Constant flow
He Flow : 0.8 ml/min
Average velocity : 33 cm/sec

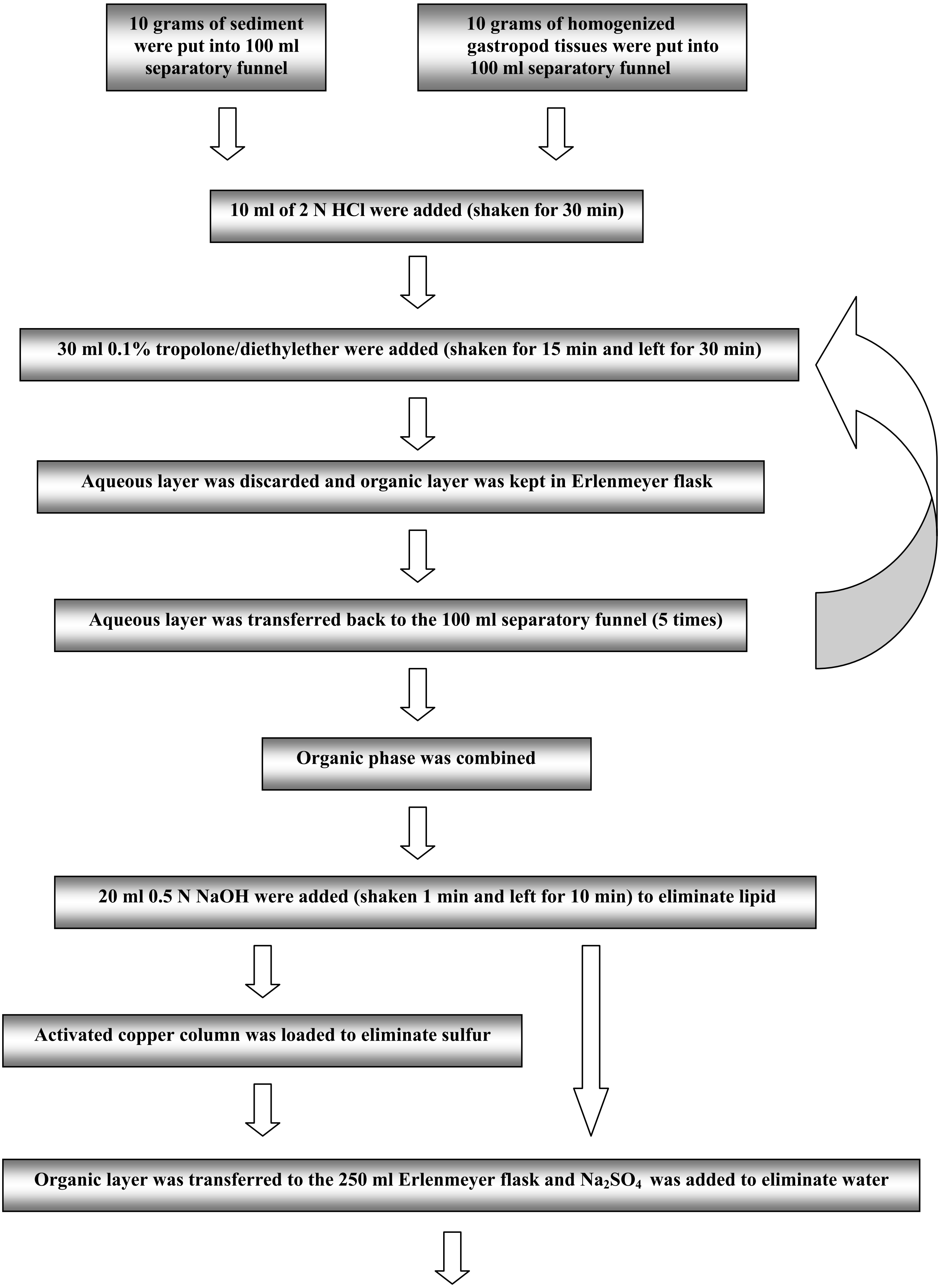
<table>
<tr><th>Oven Ramp</th><th>ºC/min</th><th>Next ºC</th><th>Hold min.</th><th>Run time</th></tr>
<tr><td>Initial</td><td>0</td><td>70</td><td>0</td><td>0</td></tr>
<tr><td>Ramp 1</td><td>30</td><td>190</td><td>0</td><td>4</td></tr>
<tr><td>Ramp 2</td><td>10</td><td>240</td><td>0</td><td>9</td></tr>
<tr><td>Ramp 3</td><td>30</td><td>300</td><td>1</td><td>12</td></tr>
<tr><td>Past Run</td><td></td><td></td><td></td><td>12</td></tr>
</table>

Heater setpoint : 290 ºC</td></tr>
<tr><td>Mass spectrometry</td><td>Scan

Sim

- Ion</td><td>Solvent delay : 3 minutes
Start at mass – End at mass : 50-450 amu

<table>
<tr><th>m/z</th><th>Dwell times (msec)</th></tr>
<tr><td>179</td><td>50</td></tr>
<tr><td>291</td><td>50</td></tr>
<tr><td>319</td><td>50</td></tr>
<tr><td>347</td><td>50</td></tr>
<tr><td>375</td><td>50</td></tr>
</table>
</td></tr>
</table>


10 grams of sediment were put into 100 ml separatory funnel
10 grams of homogenized gastropod tissues were put into 100 ml separatory funnel
10 ml of 2 N HCl were added (shaken for 30 min)
30 ml 0.1% tropolone/diethylether were added (shaken for 15 min and left for 30 min)
Aqueous layer was discarded and organic layer was kept in Erlenmeyer flask
Aqueous layer was transferred back to the 100 ml separatory funnel (5 times)
Organic phase was combined
20 ml 0.5 N NaOH were added (shaken 1 min and left for 10 min) to eliminate lipid
Activated copper column was loaded to eliminate sulfur
Organic layer was transferred to the 250 ml Erlenmeyer flask and Na2SO4 was added to eliminate water

Volume was reduced until 10-15 ml by the rotary evaporator

⇩

Organic layer was transferred to the 40 ml conical flask

⇩

0.5 ml hexylmagnesium bromide was added (under nitrogen condition)

⇩

Organic layer was shaken in 40ºC water bath for 30 min by the magnetic stirrer

⇩

20 ml saturated NH_4Cl was added to stop the reaction

⇩

Organic layer was transferred to the 100 ml separatory funnel

⇩

Aqueous layer was discarded

⇩

10 ml 0.5 N NaOH were added (shaken 1 min and left for 10 min)

⇩

Aqueous layer was discarded

⇩

Na_2SO_4 was added to the organic layer

⇩

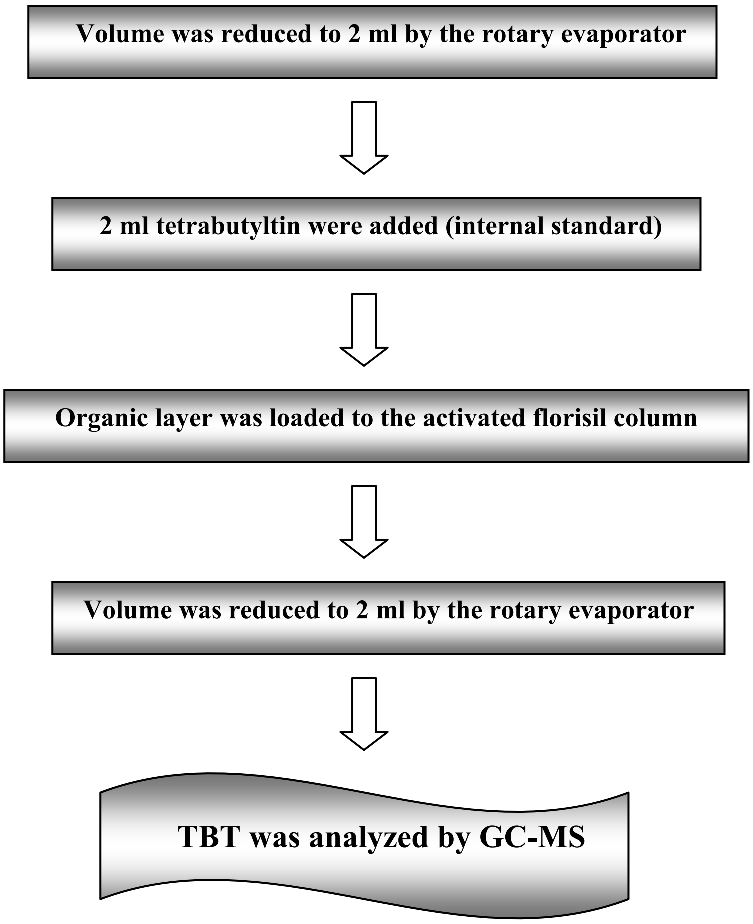


Figure 4-8. Schematic diagram of the methodology for TBT analysis.

4.4 Ecological data analysis

Shannon-Weiner's Diversity index for analyze the species diversity was obtained by the following index:

$$H' = -\sum P_l \ln P_l$$

Where; **H′** = species diversity of Shannon-Weiner

P$_l$ = the proportion of individuals found in the lth species

ln = the natural logarithm

The species richness values (Menkinick) was obtained by the following index:

$$R = \frac{S}{\sqrt{n}}$$

Where; **R** = the richness value.

S = the total number of species.

n = the number of individuals.

The evenness value was obtained by the following index:

$$E = \frac{H'}{\ln S}$$

Where; **E** = the evenness value.

H′ = the species diversity of Shannon-Weiner.

S = the total number of species.

ln = the natural logarithm.

The similarity index (Sorensen index) to analyze the similarity of species in two locations was obtained by the following formula:

$$C_s = \frac{2a}{2a + b + c}$$

Where; **C_s** = the similarity index.

a = the number of species found in both sites.

b = the number of species found in site b, but not a.

c = the number of species found in site a, but not b.

The density value of Mollusks was calculated as follows:

$$Total\ density\ of\ each\ site = \frac{Total\ number\ of\ individuals\ in\ m^2}{Total\ quadrats}$$

$$Density\ of\ each\ zone = \frac{Number\ of\ individuals\ in\ zone}{Number\ of\ quadrats\ in\ each\ transverse\ zone}$$

$$\%\ Density\ of\ each\ species = \frac{Average\ density\ of\ each\ species}{Average\ density\ of\ all\ species} \times 100$$

The distribution pattern (dispersion) of gastropods species in three study areas was calculated by proportion between the variance (s^2), and the mean (x) shown in Table 4-2, and Figure 4-9.

Table 4-2. The distribution pattern (dispersion) of population.

$\frac{s^2}{\bar{x}}$	**Dispersion**
= 1	Random
< 1	Uniform
> 1	Clumped

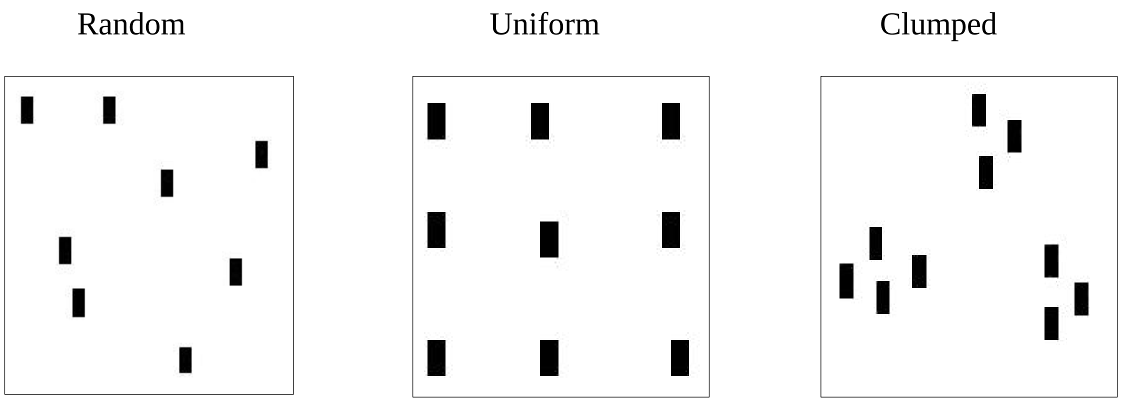


Figure 4-9. Population distribution patterns.

4.5 Statistical analysis

The mean and standard deviation values of shell size and TBT accumulation in gastropod tissue, and TBT concentration in soil and physical factor values in each zone were calculated. All TBT and physical factor data were analyzed by a parametric one-way ANOVA (analysis of variance) after verify normality using Kolmogorov-Smirnov test. The 2 and K-independent samples tests (Non-parametric tests) of the Tukey comparison test were used for TBT analysis for comparison. The pearsons relation coefficient was used to test the relationship between the ecological data and physical factors, ecological data and TBT accumulation, TBT accumulation and soil texture. All statistical tests were performed using the commercial software called Statistical Package for Social Science (SPSS) (version 11.5).

4.6 Geographic Information System (GIS) applications

LandSat-7 ETM from remote sensing and topographic map from GIS were used to perform the image classification of mangrove forest areas. LandSat-7 ETM data were geo-referenced to the UTM projection system based on the topographic map (1:50,000) and thus registered. Cross-section of canals, roads and streams were found to be useful in selecting Ground Control Points (GCP's). Efforts were placed not to select the GCP's at cross-section of the canals and streams which had tidal effects. First order linear transformation was used to convert source coordinate to rectified coordinates. Root mean square (RMS) error which was less than half a pixel (30 m) was accepted for the geometric correction and image registration. Nearest neighbor method of resampling was used, as the value of the closest pixel to assign to the output file. A window size of 3*3 was used during the filtering. Several image enhancement techniques were employed to make the images more interpretable. In order to increase the accuracy of classification, image was stratified into two relatively homogenous mangrove and non-mangrove areas. In other words, in-land, land use, and sea areas were excluded to make the mangrove areas more homogeneous. In each stratum, study areas were selected and signature evaluation was performed. Classification was performed using Maximum Likelihood Classifier (MLC) and aggregation of the outcome of these stratum was done in the post-classification process. All attributed data from the field and laboratory were linked with image classification and digitized (boundary, contour, road, stream) topographic map in order to overlay data layer. A spatial correlation analysis between three study areas were performed to understand the relationship among physical factors (pH, temperature, humidity, and water salinity), species richness, species diversity, species evenness, similarity of gastropods, soil texture, and TBT accumulation. To understand more about the spatial relationship, linear regression analysis was carried out using these data (Figure 4-10).

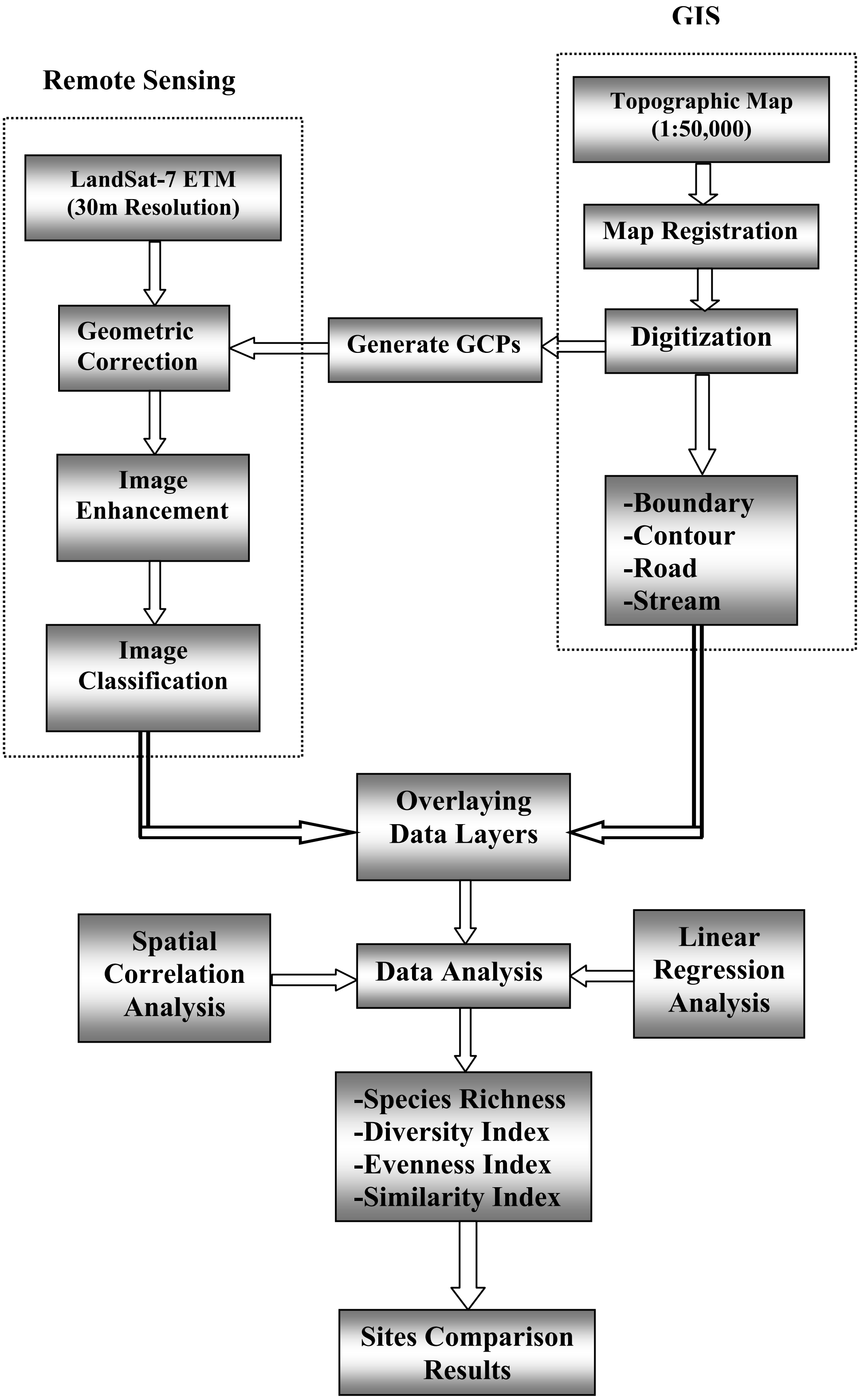


Figure 4-10. Schematic diagram of the methodology for GIS data analysis.

CHAPTER V
RESULTS

5.1 Physical factors

The physical factor values of Samet, Laemchabung, and Chuksamet were shown in Table 5-1, Figures 5-1, and 5-2; Table 5-2, Figures 5-3, and 5-4; and Table 5-3, Figures 5-5, and 5-6, respectively. Besides, the physical factor values of three study areas were shown in Table 5-4, and Figure 5-7.

The soil pH was almost the same in each area. The highest and lowest soil pH at Samet, Laemchabung and Chuksamet were found in zone 1 and 2 (6.38±0.28 and 6.38±0.08) and zone 5 (6.06±0.11) (Table 5-1, and Figure 5-2); zone 5 (6.34±0.09) and zone 3 (5.80±0.52) (Table 5-2, and Figure 5-4); and zone 3 (5.74±0.67) and zone 4 (4.72±0.80) (Table 5-3, and Figure 5-6), respectively ($p>0.05$). The order of total soil pH from the highest to the lowest at three study areas was as follows: Samet (6.26±0.30) > Laemchabung (6.04±0.50) > Chuksamet (5.22±0.74) ($p<0.05$) (Table 5-4, and Figure 5-7).

The water pH values at Samet, Laemchabung and Chuksamet were almost the same in each zone. The highest and lowest water pHs at Samet were found in zone 4 (7.46±0.09) and zone 1 (7.22±0.13) ($p<0.05$) (Table 5-1, and Figure 5-2). While the highest and lowest water pHs at Laemchabung and Chuksamet were found in zone 2 (6.80±0.32) and zone 4 (6.54±0.09) (Table 5-2, and Figure 5-4), and zone 1 (7.50±0.57) and zone 4 (6.75±0.21) (Table 5-3, and Figure 5-6) ($p>0.05$). The order of total water pH from the highest to the lowest at three study areas was as follows: Samet (7.34±0.15) > Chuksamet (7.05±0.50) > Laemchabung (6.68±0.22) ($p<0.05$) (Table 5-4, and Figure 5-7).

At Samet, the highest and lowest soil temperatures were found in zone 5 (28.66±0.39 ºC) and zone 3 (28.10±0.10 ºC) ($p>0.05$). While the highest and lowest water temperature were found in zone 5 (29.82±0.33 ºC) and zone 3 (28.54±0.43 ºC)

($p<0.05$) (Table 5-1, and Figure 5-2). Also, the water temperature at zone 1 (29.50±0.43 ºC) was significantly lower than that at zone 5 ($p<0.05$). At Laemchabung, the highest soil and water temperatures and the lowest ones were found in zone 1 (32.34±1.87 ºC and 32.96±0.86 ºC) and zone 4 (29.74±0.17 ºC and 30.12±0.22 ºC) ($p<0.05$) (Table 5-2, and Figure 5-4). At Chuksamet, the highest and lowest soil and water temperature were found in zone 4 (34.22±2.67 ºC) and zone 1 (31.22±4.08 ºC), and zone 1 (35.15±1.34 ºC) and zone 3 (31.80±0.28 ºC) ($p>0.05$) (Table 5-3, and Figure 5-6). Generally, the total soil and water temperature were the highest at Chuksamet and lowest at Samet ($p<0.05$) (Table 5-4, and Figure 5-7).

The highest and lowest water salinities at Samet were found in zone 1 (25.60±3.78 ppt) and zone 5 (18.20±2.17 ppt) ($p<0.05$) (Table 5-1, and Figure 5-2). At Laemchabung, the highest and lowest water salinity were found in zone 4 (28.00±1.58 ppt) and zone 1 (22.20±2.59 ppt) ($p<0.05$) (Table 5-2, and Figure 5-4). While at Chuksamet, the highest and lowest water salinities were found in zone 1 (14.00±0.10 ppt) and zone 2 (7.00±2.83 ppt) ($p>0.05$) (Table 5-3, and Figure 5-6). Generally, the total water salinity was the highest (26.12±2.91 ppt) at Laemchabung and lowest (11.30±4.00) at Chuksamet ($p<0.05$) (Table 5-4, and Figure 5-7).

The highest and lowest air temperatures at Samet were found in zone 1 (30.60±0.96 ºC) and zone 3 (28.20±0.27 ºC) ($p<0.05$). While the highest humidity was found in zone 3 and 4 (86.60±1.52 %) and the lowest humidity was found in zone 1 (85.40±1.95 %) ($p>0.05$) (Table 5-1, and Figure 5-2). At Laemchabung, the highest and lowest air temperatures were found in zone 1 (33.60±0.96 ºC) and zone 5 (29.40±0.42 ºC) ($p<0.05$). Also, the air temperatures at zone 3 (29.80±0.57 ºC) and zone 4 (29.90±0.42 ºC) were significantly lower that at zone 2 (31.70±1.25 ºC) ($p<0.05$). While, the highest and lowest humidity were found in zone 4 (87.60±0.55 %) and zone 2 (70.40±7.27 %) ($p<0.05$). Also, the humidity at zone 5 (86.60±1.67 %) was higher than that at zone 1 (78.60±5.27 %) ($p<0.05$) (Table 5-2, and Figure 5-4). At Chuksamet, the highest and lowest air temperatures were found in zone 4 (33.90±0.65 ºC) and zone 3 (31.80±0.76 ºC) ($p<0.05$). Whereas the highest and lowest humidity were found in zone 2 (69.90±4.25 %) and zone 1 (65.80±4.82 %) (Table 5-3, and Figure 5-6). Generally, the total air temperature was the highest at Chuksamet (32.87±1.16 ºC) and lowest at Samet (29.36±0.97 ºC) ($p<0.05$). Consequently, the humidity was the highest at Samet (86.04±1.51 %) and lowest at Chuksamet (67.94±3.57 %) ($p<0.05$) (Table 5-4, and Figure 5-7).

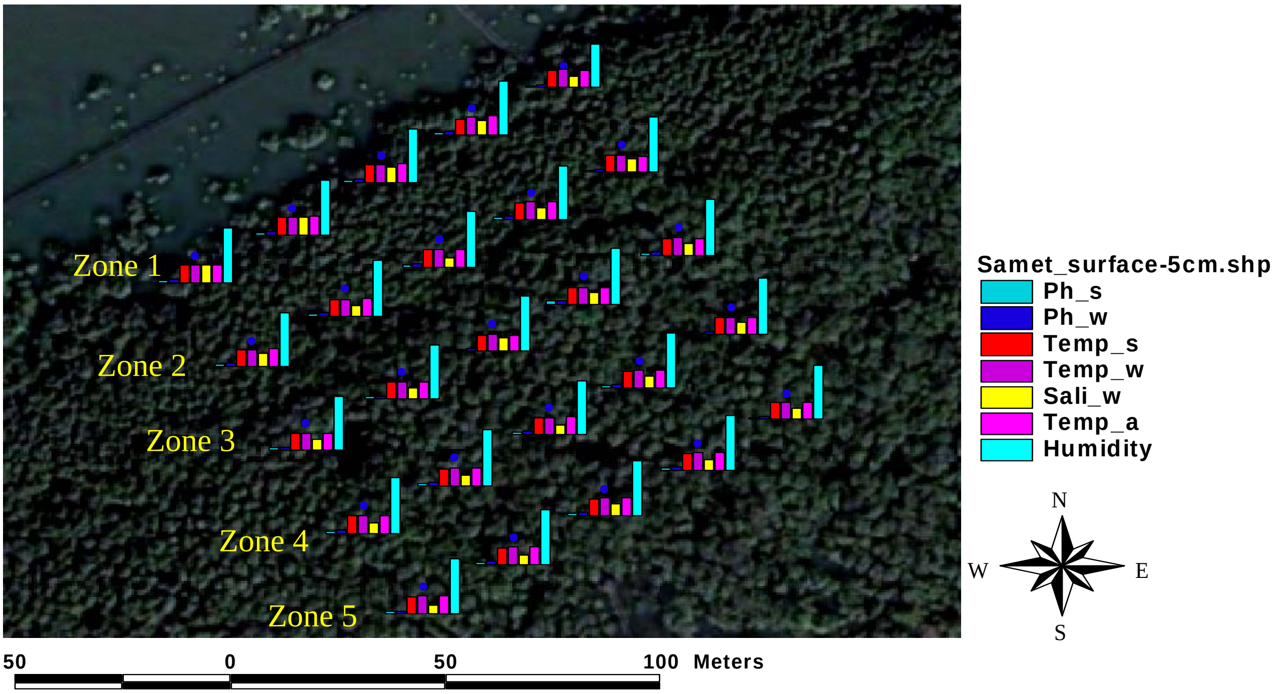


Figure 5-1. Physical factor values in each plot at Samet.

Table 5-1. The average (mean±SD) physical factor values at Samet. The same letters identified the values that were significantly different ($p<0.05$).

Zone	Soil pH	Water pH	Soil temperature (ºC)	Water temperature (ºC)	Water salinity (ppt)	Air temperature (ºC)	Humidity (%)
1	6.38±0.28	7.22±0.13	28.22±1.20	29.50±0.43[a]	25.60±3.78 [a,b,c]	30.60±0.96 [a,b,c]	85.40±1.95
2	6.38±0.08	7.26±0.19	28.36±0.22	28.94±0.46 [b]	20.40±2.97 [a]	29.20±0.76 [a]	86.00±1.87
3	6.36±0.55	7.34±0.11	28.10±0.10	28.54±0.43 [a,c]	20.80±1.92	28.20±0.27 [b,d]	86.60±1.52
4	6.12±0.08	7.46±0.09	28.38±0.29	29.04±0.43	19.20±1.79 [b]	29.10±0.42 [c]	86.60±1.52
5	6.06±0.11	7.42±0.08	28.66±0.39	29.82±0.33 [b,c]	18.20±2.17 [c]	29.70±0.27 [d]	85.60±0.55
Total	6.26±0.30	7.34±0.15	28.34±0.57	29.17±0.60	20.84±3.54	29.36±0.97	86.04±1.51

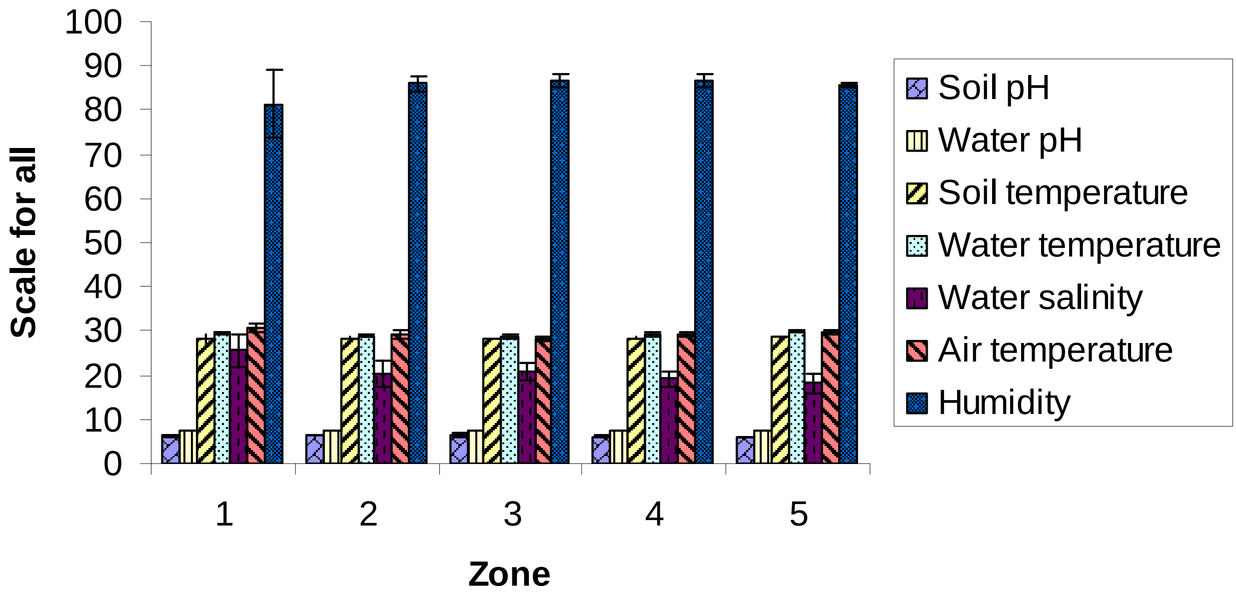


Figure 5-2. Average physical factor values in each zone at Samet.

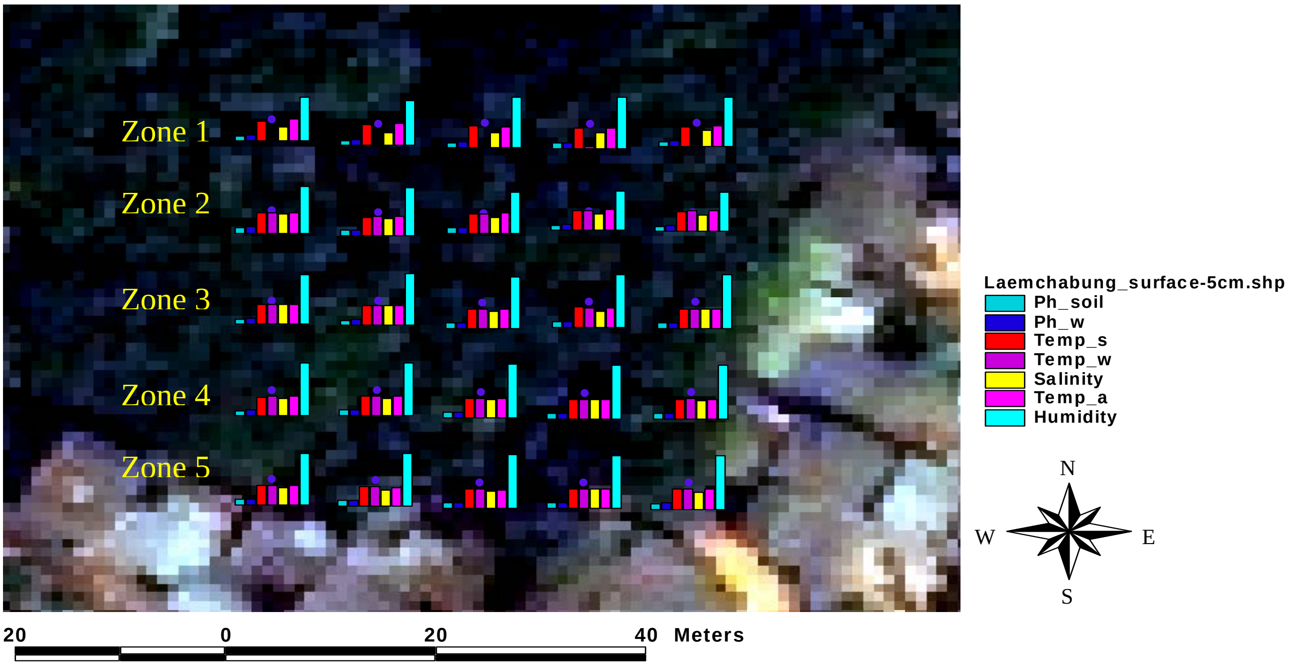


Figure 5-3. Physical factor values in each plot at Laemchabung.

Table 5-2. The average (mean±SD) physical factor values at Laemchabung. The same letters identified the values that were significantly different ($p<0.05$).

Zone	Soil pH	Water pH	Soil temperature (ºC)	Water temperature (ºC)	Water salinity (ppt)	Air temperature (ºC)	Humidity (%)
1	5.84±0.48	6.68±0.24	32.34±1.87 $^{a,b,c, d}$	32.96±0.86 ^{a,b,c,d}	22.20±2.59 ^{a,b,c}	33.60±0.96 ^{a,b,c,d}	78.60±5.27 ^{a,b}
2	5.94±0.69	6.80±0.32	29.82±0.86 ^{a}	30.86±0.65 ^{a}	26.20±2.17	31.70±1.25 ^{a,e,f,g}	70.40±7.27 ^{a,c,d,e}
3	5.80±0.52	6.66±0.25	30.26±0.93 ^{b}	30.24±0.36 ^{b}	27.80±2.17 ^{a}	29.80±0.57 ^{b,e}	84.20±2.68 ^{c}
4	6.30±0.07	6.54±0.09	29.74±0.17 ^{c}	30.12±0.22 ^{c}	28.00±1.58 ^{b}	29.90±0.42 ^{c,f}	87.60±0.55 ^{b,d}
5	6.34±0.09	6.72±0.13	30.28±0.66 ^{d}	30.38±0.48 ^{d}	26.40±2.19 ^{c}	29.40±0.42 ^{d,g}	86.60±1.67 ^{e}
Total	6.04±0.50	6.68±0.22	30.49±1.37	30.91±1.19	26.12±2.91	30.88±1.76	81.48±7.57

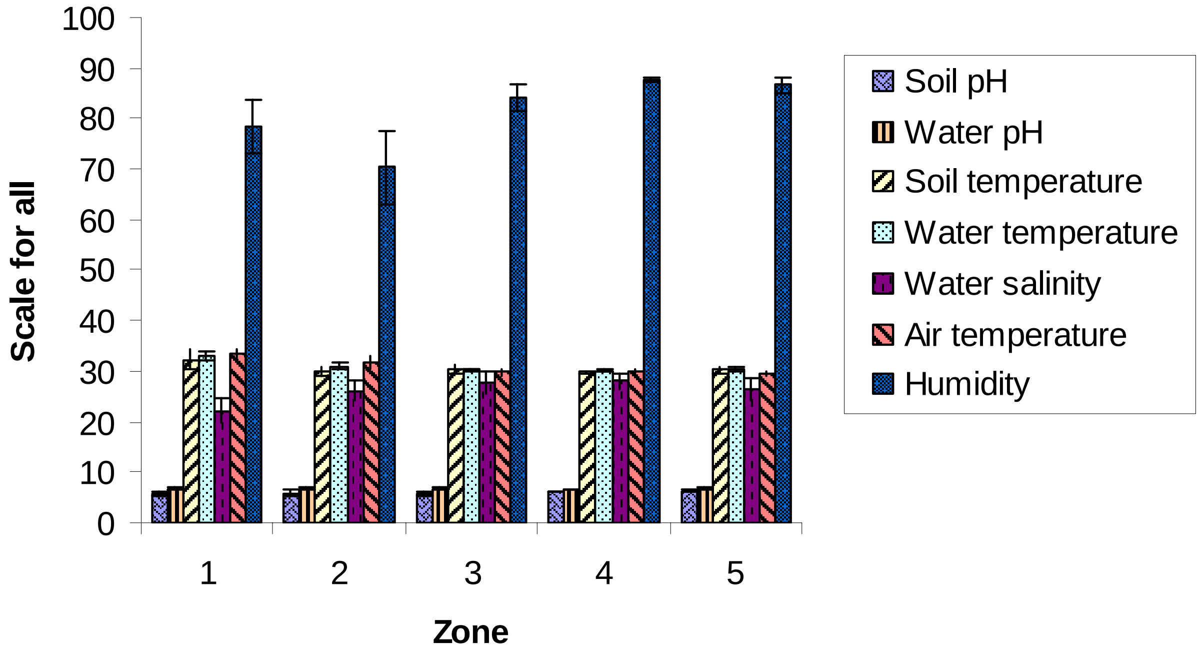


Figure 5-4. Average physical factor values in each zone at Laemchabung.

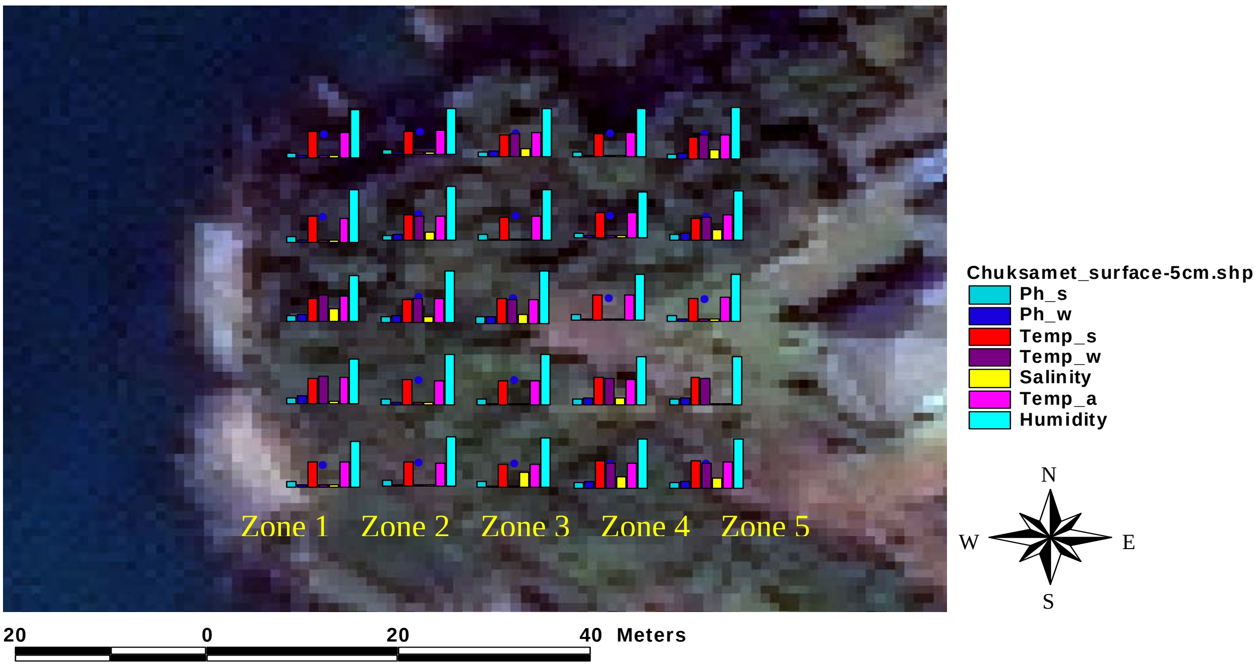


Figure 5-5. Physical factor values in each plot at Chuksamet.

Table 5-3. The average (mean±SD) physical factor values at Chuksamet. The same letters identified the values that were significantly different ($p<0.05$).

Zone	Soil pH	Water pH	Soil temperature (°C)	Water temperature (°C)	Water salinity (ppt)	Air temperature (°C)	Humidity (%)
1	5.08±0.70	7.50±0.57	31.22±4.08	35.15±1.34	14.00±0.10	33.30±1.20	65.80±4.82
2	5.34±0.52	7.10±0.71	32.20±1.60	32.65±0.78	7.00±2.83	32.10±0.42 [a]	69.90±4.25
3	5.74±0.67	6.80±0.14	31.42±1.61	31.80±0.28	13.33±5.77	31.80±0.76 [b]	69.80±1.92
4	4.72±0.80	6.75±0.21	34.22±2.67	34.25±1.34	10.50±4.95	33.90±0.65 [a,b]	66.20±2.49
5	5.24±0.87	7.08±0.62	32.44±3.64	33.10±2.23	11.67±1.15	33.25±1.26	68.00±2.55
Total	5.22±0.74	7.05±0.50	32.3±2.87	33.39±1.74	11.3±4.00	32.87±1.16	67.94±3.57

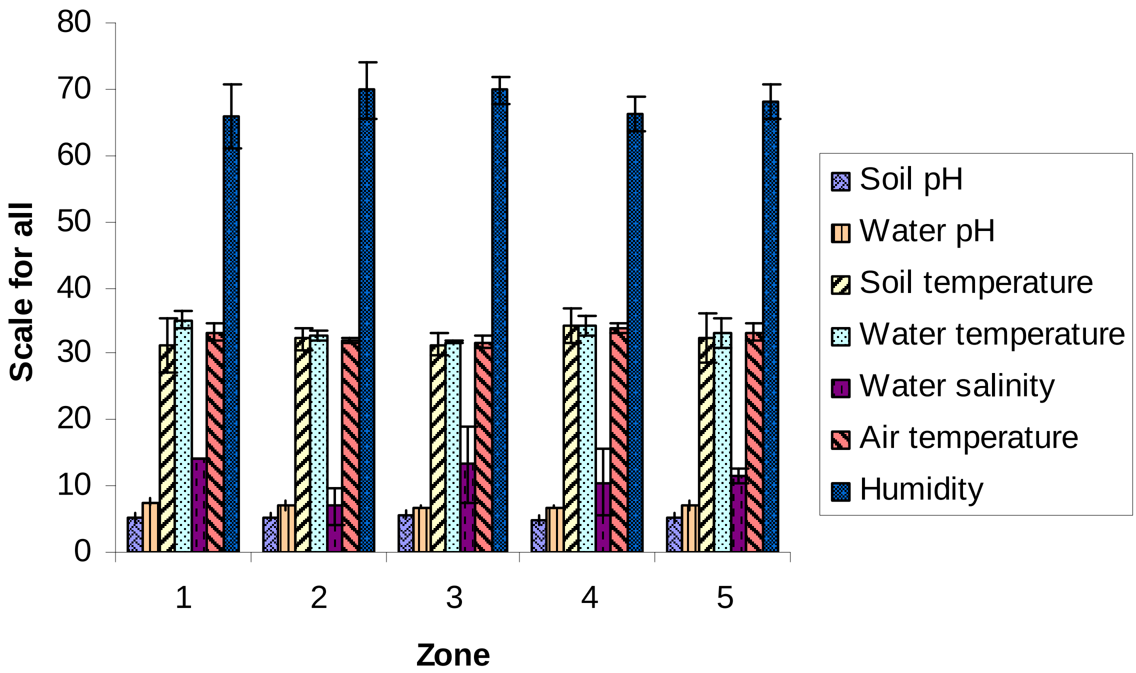


Figure 5-6. Average physical factor values in each zone at Chuksamet.

Table 5-4. The total average (mean±SD) of physical factor values at three study areas. The same letters identified the values that were significantly different ($p<0.05$).

Study area	Soil pH	Water pH	Soil temperature (°C)	Water temperature (°C)	Water salinity (ppt)	Air temperature (°C)	Humidity (%)
Samet	6.26±0.16 a	7.34±0.10 a,b	28.34±0.21 a,b	29.17±0.50 a,b	20.84±2.85 a,b	29.36±0.88 a,b	85.24±2.19 a,b
Laemchabung	6.04±0.26 b	6.68±0.09 a,c	30.49±1.06 a,c	30.91±1.78 a,c	26.12±2.33 a,c	30.88±1.76 a,c	81.48±7.11 a,c
Chuksamet	5.22±0.37 a,b	7.05±0.30 b,c	32.30±1.19 b,c	33.39±1.32 b,c	11.3±2.77 b,c	32.87±0.88 b,c	67.94±1.93 b,c

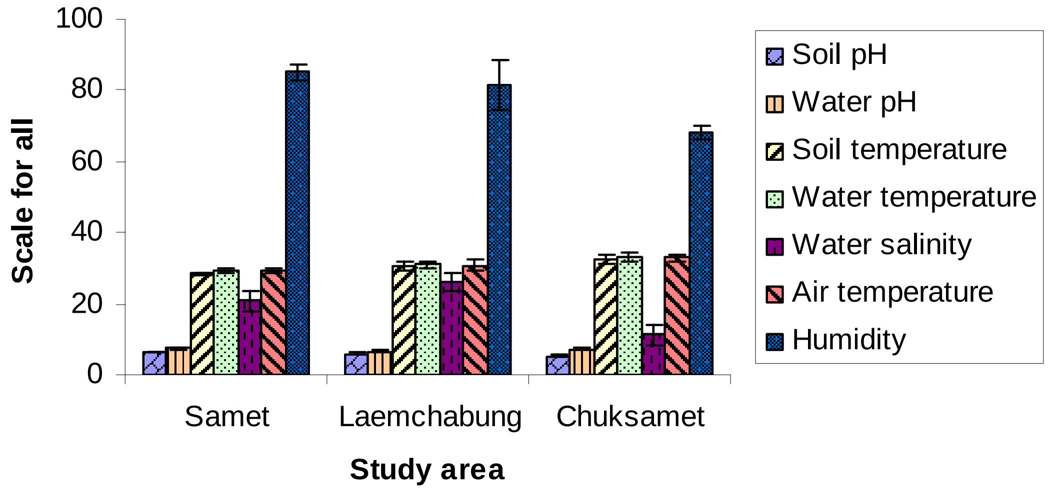


Figure 5-7. Comparing physical factor values at Samet, Laemchabung, and Chuksamet.

5.2 Soil texture

Soils were sampled on the 1 m^2 surface to 5 centimeters depth in all study areas. At Samet, four types of soil textures, sandy loams (48% from 12 plots), loam (40% from 10 plots), sandy clay loams (8% from 2 plots), and clay loams (4% from 1 plot) were found. At Laemchabung, three types of soil textures, sandy loams (84% from 21 plots), loam (12% from 3 plots), and loamy sands (4% from 1 plot) were found. At Chuksamet, five types of soil textures, sandy loams (76% from 19 plots), loam (8% from 2 plots), loamy sands (8% from 2 plots), sandy clay loams (4% from 1 plot), and clay loams (4% from 1 plot) were found (Table 5-5, and Figures 5-8 to 5-14).

Table 5-5. Soil textures in each study area (* = usually).

Studied area	Zone				
	1	2	3	4	5
Samet	Loam* Sandy loams	Loam* Sandy loams	Loam Sandy loams* Clay loams Sandy clay loams	Sandy loams*	Loam* Sandy loams* Sandy clay loams
Laemchabung	Sandy loams*	Loam* Sandy loams* Loamy sands	Sandy loams*	Sandy loams*	Loam Sandy loams*
Chuksamet	Loam Sandy loams* Clay loams	Loam Sandy loams* Sandy clay loams	Sandy loams* Loamy sands	Sandy loams*	Sandy loams* Loamy sands

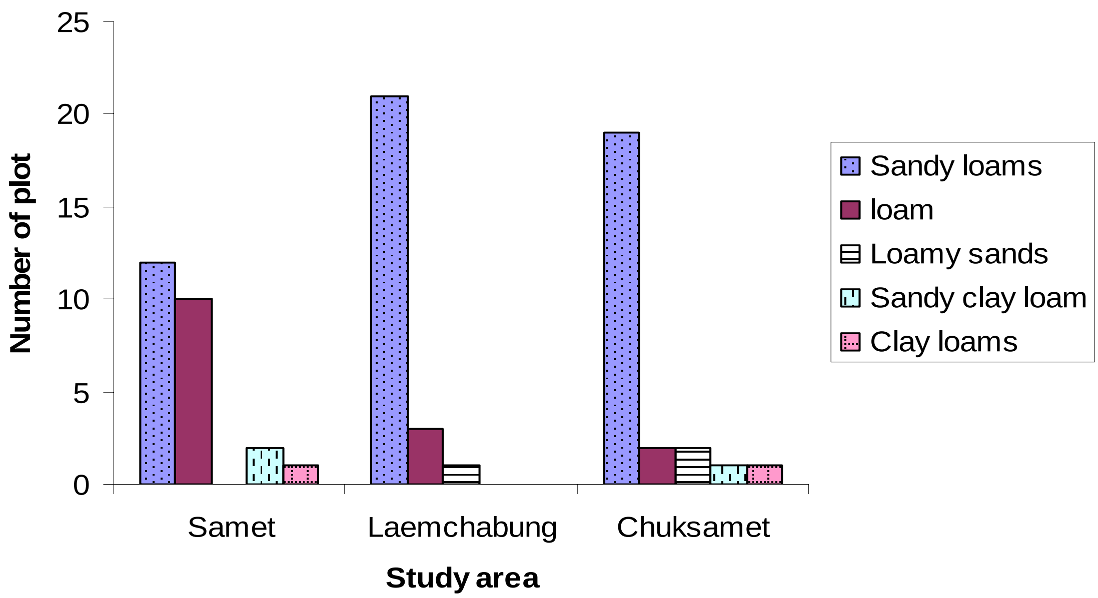


Figure 5-8. Soil textures at Samet, Laemchabung, and Chuksamet.

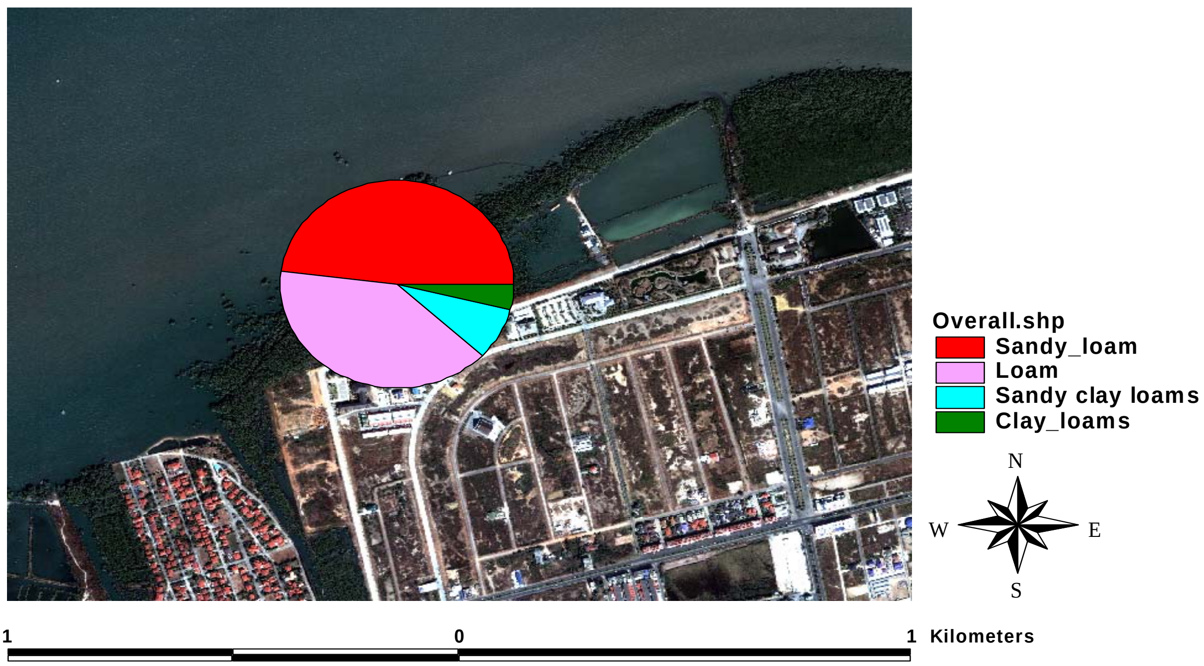


Figure 5-9. The percentage of soil textures at Samet.

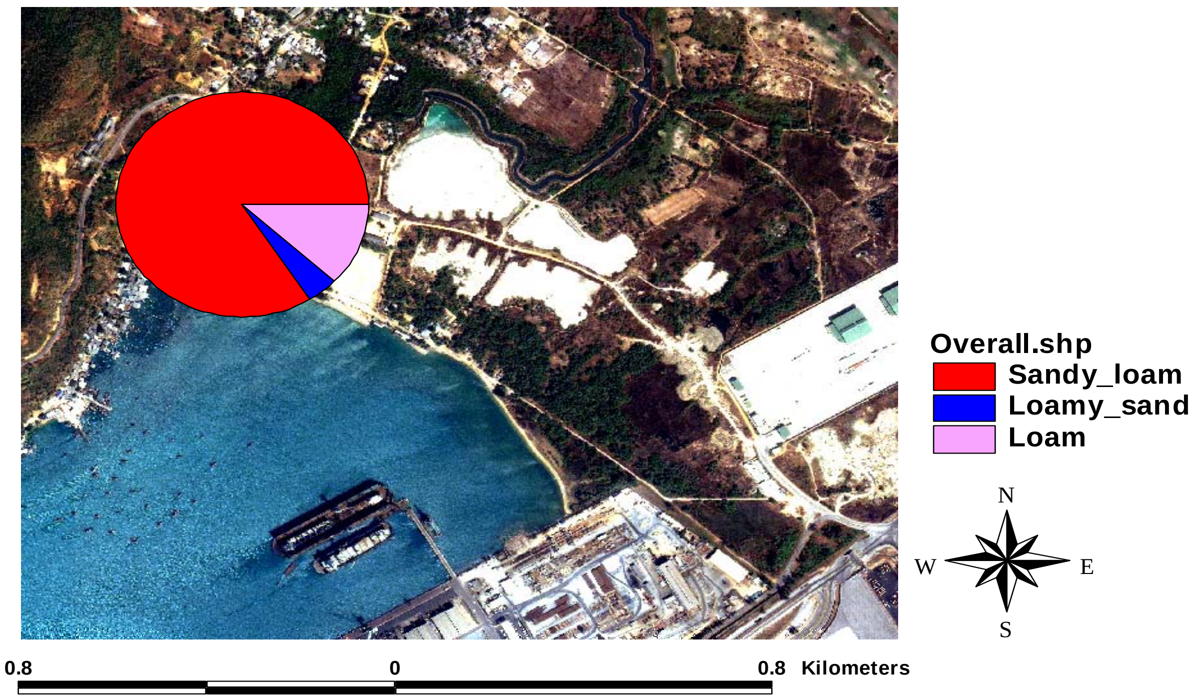


Figure 5-10. The percentage of soil textures at Laemchabung.

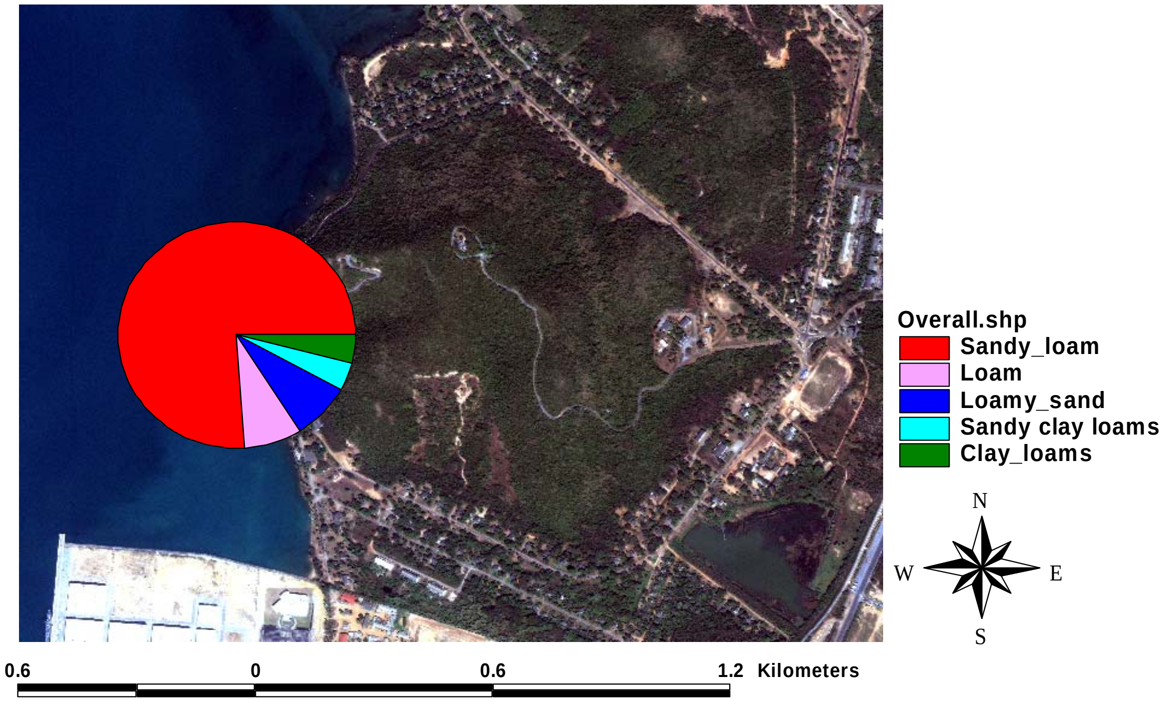


Figure 5-11. The percentage of soil texture at Chuksamet.

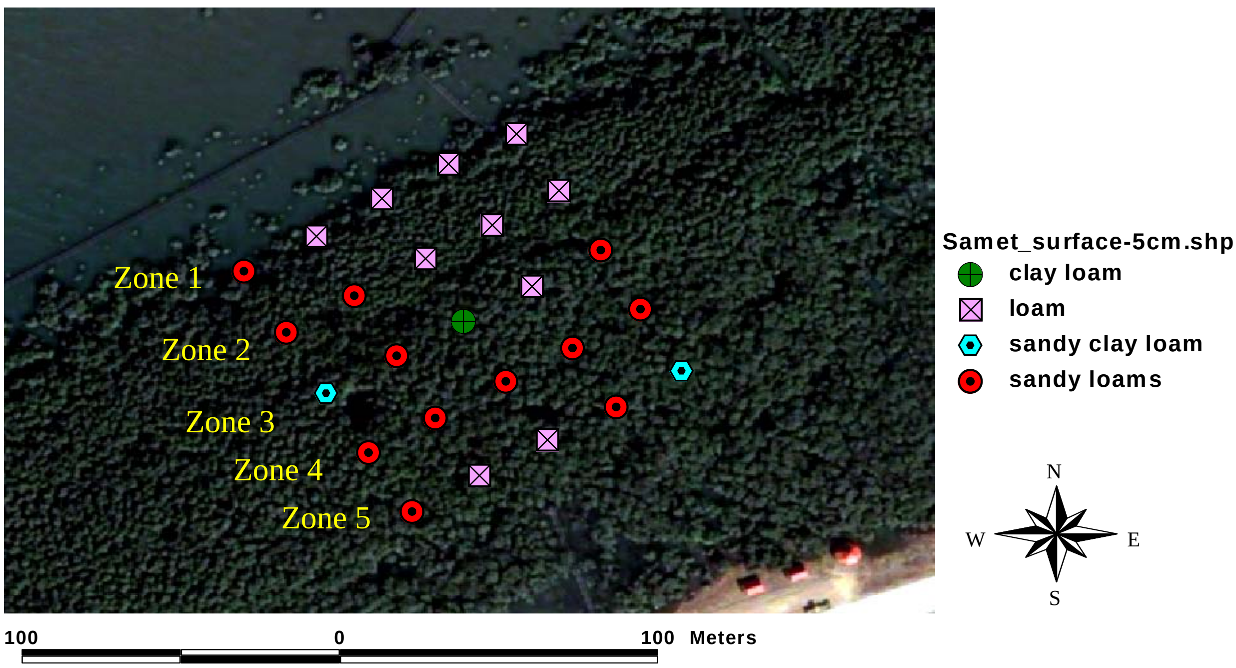


Figure 5-12. The soil textures at the surface to five centimeter depth at Samet.

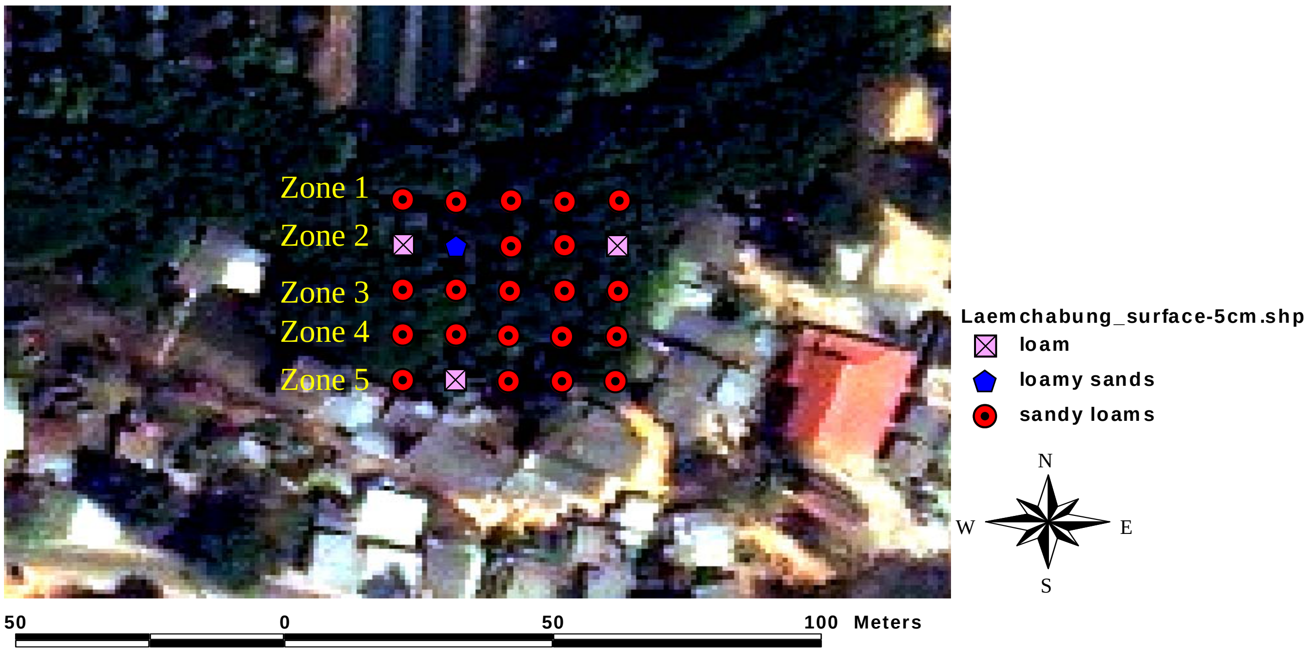


Figure 5-13. The soil textures at the surface to five centimeter depth at Laemchabung.

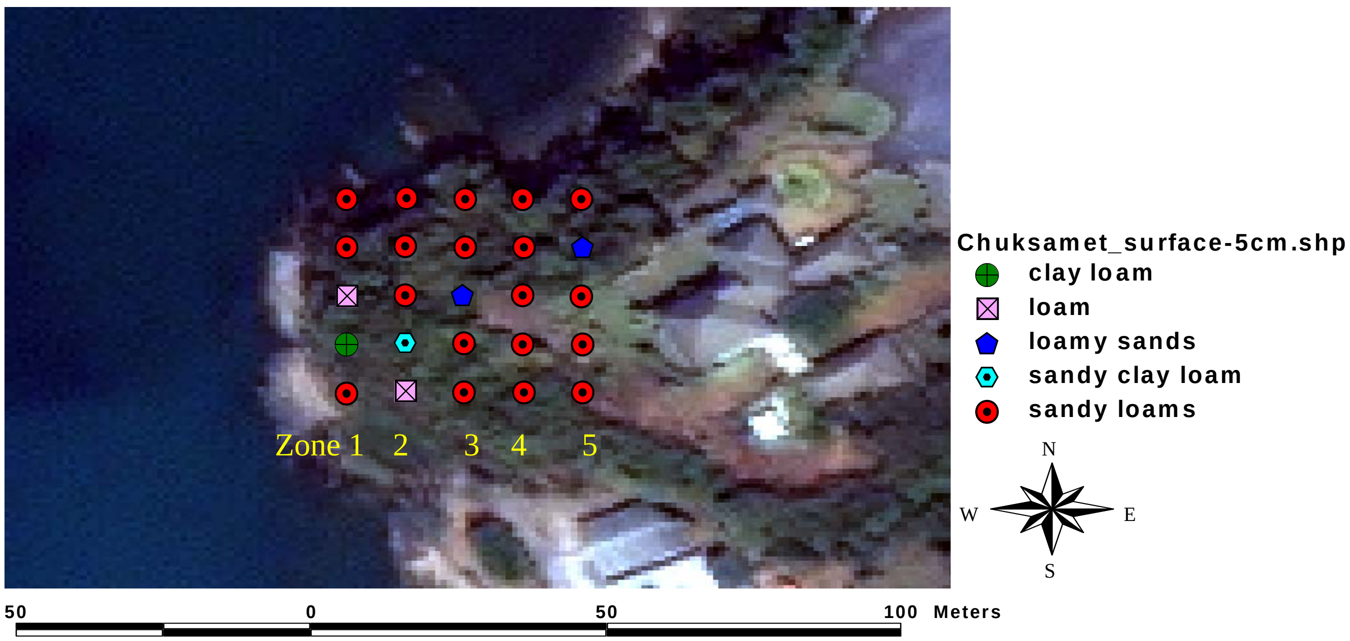


Figure 5-14. The soil textures at the surface to five centimeter depth at Chuksamet.

5.3 Ecological data and shell characteristics

5.3.1 Number of species and species diversity

A total of 3,418 individuals of gastropods were found in all three study areas belonging to 21 species from 12 families, 6 orders, 3 subclasses, and only one class of Gastropoda. 16 gastropod species (10 families) were found at Samet district while 13 gastropod species were found at Laemchabung, and Chuksamet. At Samet, Littorinidae was the most diversed family with four species, *Littoraria calinifera*, *Littoraria palescene*, *Littoraria strigata,* and *Littoraria melanostoma*. There were two species of family Potamididae, Neritidae, and Ellobiidae whereas only one species each was found in Thiaridae, Assimineidae, Onchidiidae, Atyidae, Amphibolidae, and Stenothyridae. Thirteen gastropod species (9 families) were found at Laemchabung. Littorinidae was the most diversed family with three species, *Littoraria calinifera*, *Littoraria palescene,* and *Littoraria melanostoma*. Two species, *Cerithidea cingulata*, and *Cerithidea obtusa* of Potamididae, and two species, *Cassidula aurisfelis*, and *Cassidula multiplicata* of Ellobiidae whereas only one species in families Neritidae, Thiaridae, Assimineidae, Onchidiidae, Muricidae, and Iravadiidae were found. There were 13 gastropod species (6 families) at Chuksamet. Ellobiidae was the most diversed family with four species, *Cassidula aurisfelis*, *Cassidula multiplicata*, *Ellobium aurismidae*, and *Laemodonta siamensis*. Three species, *Cerithidea cingulata*, *Cerithidea quadrata*, and *Cerithidea obtusa* of family Potamididae were found. There were two species each of Neritidae, and Littorinidae while one species each was found in Thiaridae, and Iravadiidae (Tables 5-6, and 5-7).

Eight generalized gastropod species, *Cassidula aurisfelis*, *Cassidula multiplicata*, *Cerithidea cingulata*, *Cerithidea obtusa*, *Melanoides tuberculata*, *Littoraria calinifera*, *Littoraria palescene*, and *Clithon oualaniensis*, were found at all three sites. Moreover, *Assiminea brevicula*, *Platevindex* sp., *Littoraria melanostoma* were found at Samet, and Laemchabung while *Neritina violacea* was found at Samet and Chuksamet. Gastropods found at Laemchabung, and Chuksamet were *Fairbankia* sp. Also, the specialized gastropod species, *Salinator burmana*, *Stenothyra* sp., *Haminoea succinea*, and *Littoraria strigata* were found only at Samet which had the mixed soil texture between the sandy loams and loam, a weak alkaline and rather high humidity while *Chicoreus capucinus* was found only at Laemchabung which had highest water salinity, and *Laemodonta siamensis*, *Cerithidea quadrata*, and *Ellobium aurismidae* were found only at Chuksamet which was high water, soil, and air temperature and low salinity and humidity. Also, these two substrate usually contained sandy loams soil texture. Gastropods were generally found at the epifauna of all three sites. Due to soil texture type at Samet, *Melanoides tuberculata* was found only at zone 1 (usually loam) while *Littoraria palescene* was found at zone 2,3,4 (usually loam and sandy loam) and *Cassidula aurisfelis*, *Haemonea succinea*, *Stenothyra* sp., *Clithon oualaniensis*, and *Platevindex* sp. were found only at zone 5 (usually sandy loams). *Assiminea brevicula*, *Littoraria melanostoma*, and *Littoraria calinifera* were found at all zones and *Neritina violacea* was found at all zones except zone 1. At Laemchabung, *Cerithidea cingulata* and *Clithon oualaniensis* were found only at zone 1 while *Assiminea brevicula*, *Platevindex* sp., *Littoraria calinifera* were found at all zones. Also, *Littoraria palescene*, *Cassidula aurisfelis*, *Cassidula mutiplicata* were found at all zones except zone 1. At Chuksamet, *Neritina violacea*, *Melanoides tuberculata* were found at zone 1 while *Cassidula aurisfelis*, *Cassidula mutiplicata*, *Cerithidea quadrata*, *Littoraria calinifera*, and *Littoraria palescene* were found at all zones. The significance of finding various species in various zones may be because of mangrove vegetation; physical factors e.g. salinity, temperature and humidity; food source, predators, and other pollutants (Table 5-6).

The total number of individuals at Samet, Laemchabung and Chuksamet were 1554, 897, and 967, respectively. The total value of richness was highest at Laemchabung (0.434) and lowest at Samet (0.406) ($p<0.05$). The total diversity index of gastropods was highest at Chuksamet (1.712), and lowest at Samet (0.832) ($p<0.05$). Furthermore, the total value of evenness was highest at Chuksamet (0.667), and lowest at Samet (0.300) ($p<0.05$) (Figure 5-27). The similarity index of gastropods species at both Laemchabung and Chuksamet was 69.23%, 75.86% at Laemchabung and Samet, and 62.07% at Chuksamet and Samet (Figure 5-28).

At Samet, the total value of evenness was highest at zone 5 (0.653) and lowest at zone 2 (0.142) ($p<0.05$). The total value of richness was highest at zone 5 (0.674) and lowest at zone 2 (0.356) ($p<0.05$). Also, the total diversity index was highest at zone 5 (1.623) and lowest at zone 2 (0.277) ($p<0.05$) (Table 5-8, and Figures 5-15 to 5-18). At Laemchabung, the total value of evenness was highest at zone 5 (0.723) and lowest at zone 1 (0.388) (p>0.05). The total value of richness was highest at zone 2 (1.076) and lowest at zone 1 (0.334) (p>0.05). Also, the total diversity index was highest at zone 5 (1.504) and lowest at zone 1 (0.808) (p>0.05) (Table 5-9, and Figures 5-19 to 5-22). At Chuksamet, the total value of evenness was highest at zone 4 (0.867) and lowest at zone 1 (0.409) (p>0.05). The total value of richness was highest at zone 4 (0.839) and lowest at zone 1 (0.402) (p>0.05). Also, the total diversity index was highest at zone 4 (1.802) and lowest at zone 1 (0.898) (p>0.05) (Table 5-10, and Figures 5-23 to 5-26).

Table 5-6. Gastropod species in three sampling areas (+ = found).

Species	Study area		
	Samet District	**Laemchabung Habor**	**Chuksamet Habor**
Cassidula aurisfelis	+	+	+
Cassidula multiplicata	+	+	+
Cerithidea cingulata	+	+	+
Cerithidea obtusa	+	+	+
Melanoides tuberculata	+	+	+
Littoraria calinifera	+	+	+
Littoraria palescene	+	+	+
Clithon oualaniensis	+	+	+
Assiminea brevicula	+	+	
Platevindex sp.	+	+	
Littoraria melanostoma	+	+	
Neritina violacea	+		+
Fairbankia sp.		+	+
Salinator burmana	+		
Stenothyra sp.	+		
Haminoea succinea	+		
Littoraria strigata	+		
Chicoreus capucinus		+	
Laemodonta siamensis			+
Cerithidea quadrata			+
Ellobium aurismidae			+

Table 5-7. Classification of gastropods in three study areas.

Class	Subclass	Order	Family	Genus	Species
Gastropoda	Prosobranchia	Archaeogastropoda	Neritidae	Neritina Clithon	*N. violacea* *C. oualaniensis*
		Mesogastropoda	Littorinidae	Littoraria	*L. melanostoma* *L. palescene* *L. calinifera* *L. strigata*
			Stenothyridae	Stenothyra	*Stenothyra* sp.
			Iravadiidae	Fairbankia	*Fairbankia* sp.
			Assimineidae	Assiminea	*A. brevicula*
			Potamididae	Cerithidea	*C. cingulata* *C. obtusa* *C. quadrata*
			Thiaridae	Melanoides	*M. tuberculata*
		Neogastropoda	Muricidae	Chicoreus	*C. capucinus*
	Opisthobranchia	Cephalaspidea	Atyidae	Haminoea	*H. succinea*
	Pulmonata	Basommatophora	Ellobiidae	Cassidula	*C. aurisfelis* *C. multiplicata*
				Laemodonta	*L. siamensis*
				Ellobium	*E. aurismidae*
			Amphibolidae	Salinator	*S. burmana*
		Systellommatophora	Onchidiidae	Platevindex	*Platevindex* sp.

Table 5-8. The ecological data at Samet. The same letters identified the values that were significantly different ($p<0.05$).

Zone	Number of species	Number of individuals	Density / m^2	Richness	Evenness	Shannon index
1	5	148	29.6 [a]	0.410997	0.50581	0.81407 [a]
2	7	387	77.4 [a]	0.35583 [a]	0.142247 [a]	0.2768 [b]
3	7	332	66.4	0.384175	0.183986 [b]	0.35802 [c]
4	7	370	74	0.363913	0.186864	0.36362 [d]
5	12	317	63.4	0.673987 [a]	0.6533 [a,b]	1.62339 [a,b,c,d]
Total	16	1554	62.16	0.405877	0.29998	0.83172

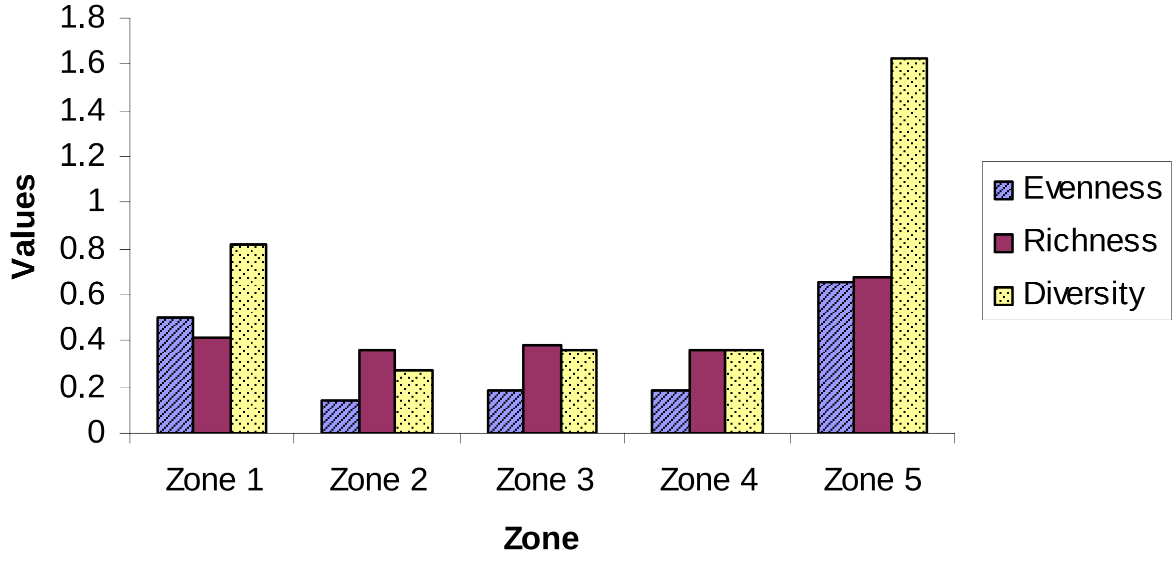


Figure 5-15. The diversity index, evenness, and richness in each zone at Samet.

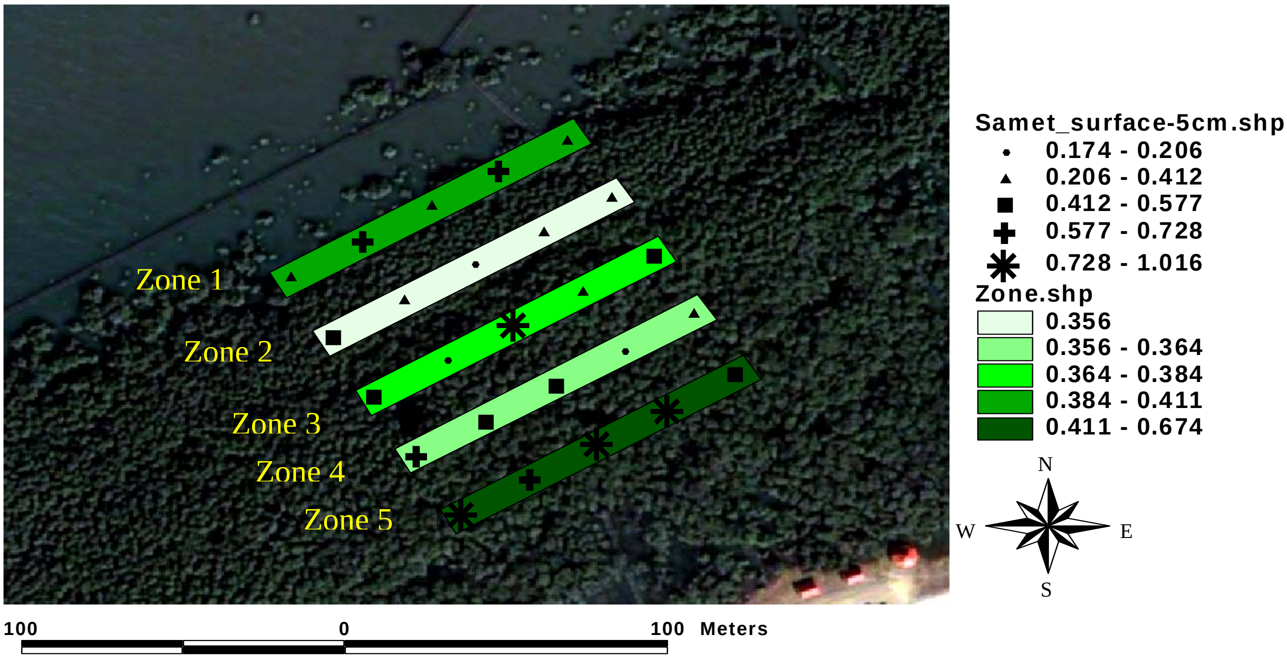


Figure 5-16. Comparing the richness in each plot of each zone at Samet.

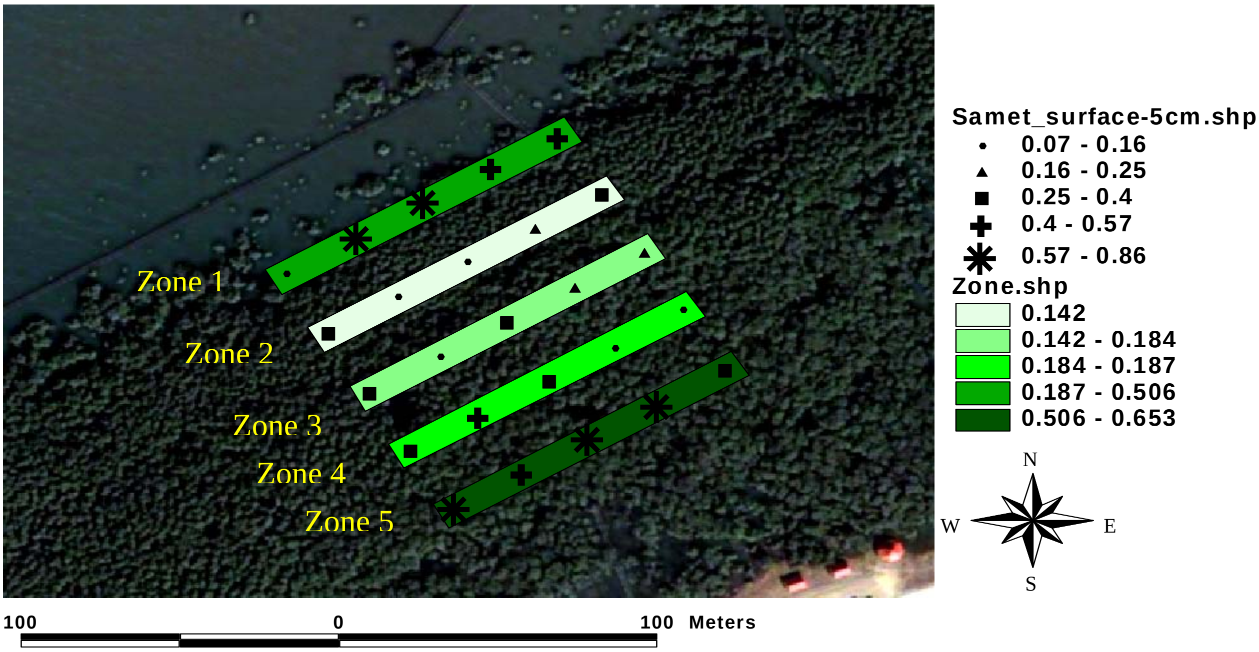


Figure 5-17. Comparing the evenness in each plot of each zone at Samet.

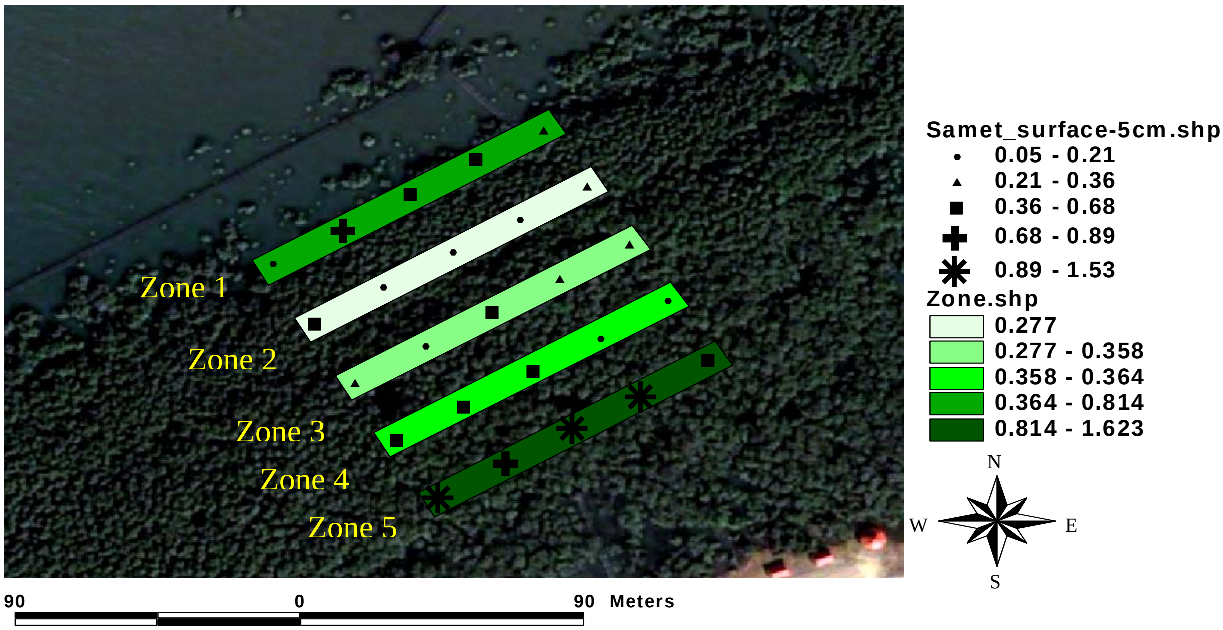


Figure 5-18. Comparing the diversity index in each plot of each zone at Samet.

Table 5-9. The ecological data at Laemchabung. The same letters identified the values that were significantly different ($p<0.05$).

Zone	Number of species	Number of individuals	Density / m^2	Richness	Evenness	Shannon index
1	8	572	114.4	0.334497	0.388503	0.80787
2	9	70	14	1.075706	0.583327	1.2817
3	8	94	18.8	0.825137	0.582161	1.21057
4	8	90	18	0.843274	0.687454	1.42952
5	8	71	14.2	0.949425	0.723377	1.50422
Total	13	897	35.88	0.434057	0.615392	1.57845

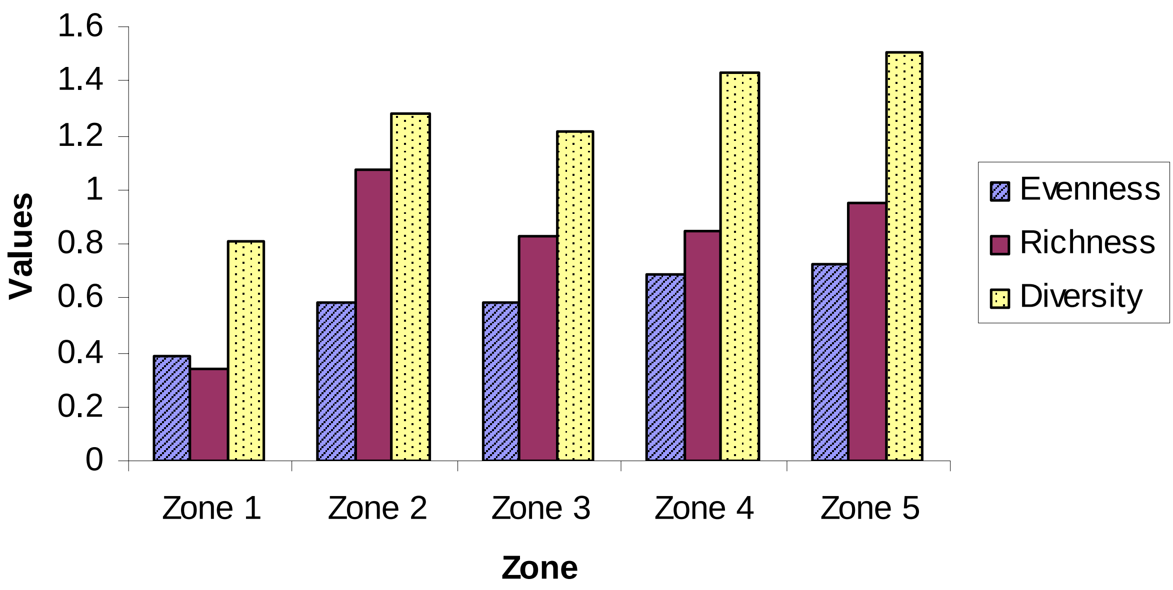


Figure 5-19. The diversity index, evenness, and richness in each zone at Laemchabung.

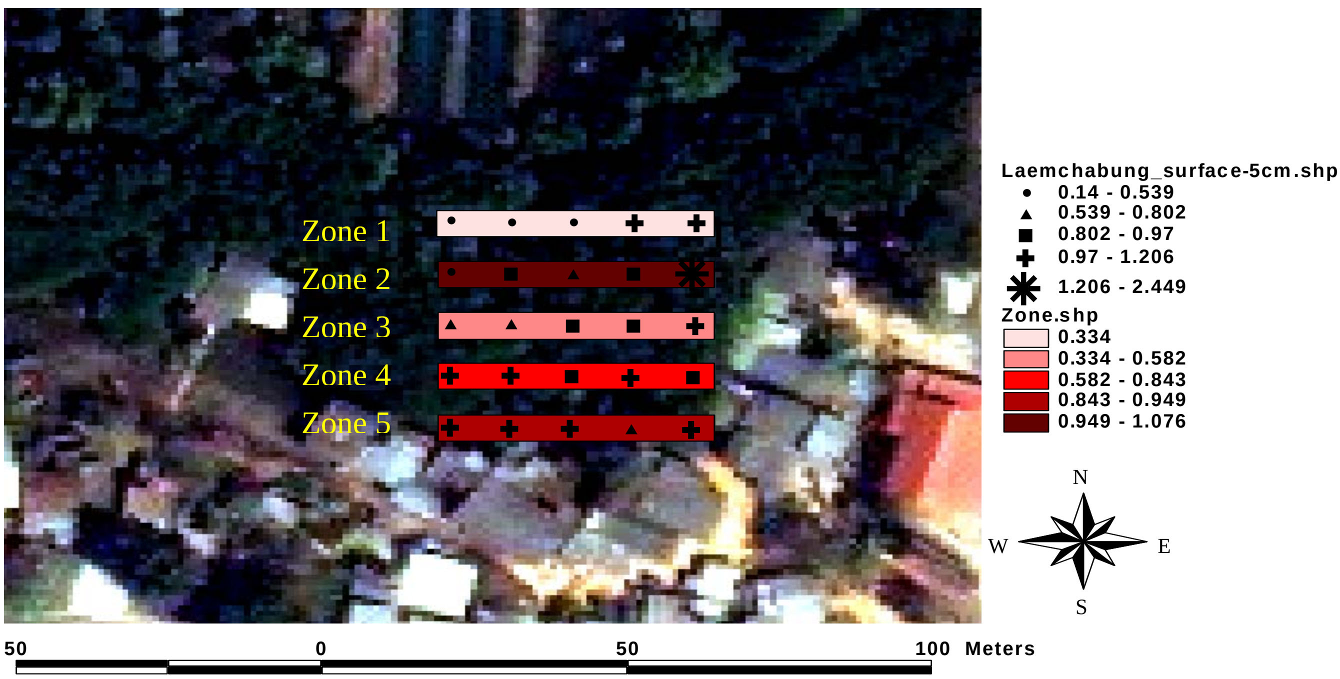


Figure 5-20. Comparing the richness in each plot of each zone at Laemchabung.

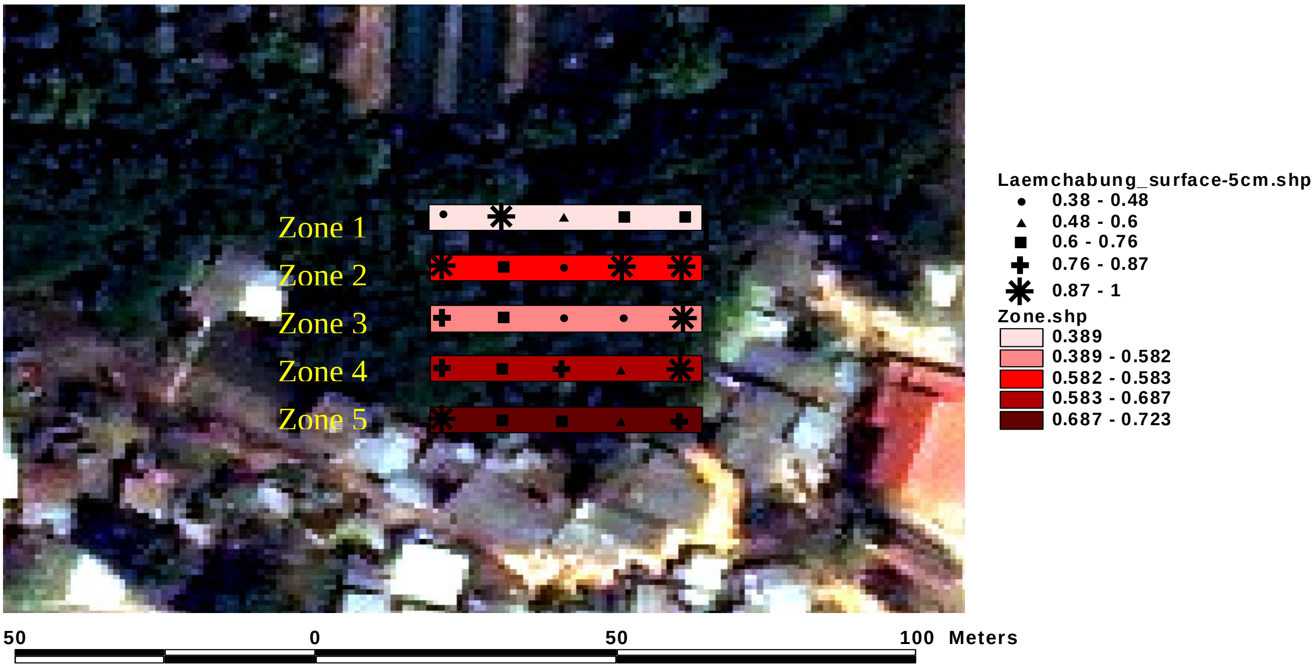


Figure 5-21. Comparing the evenness in each plot of each zone at Laemchabung.

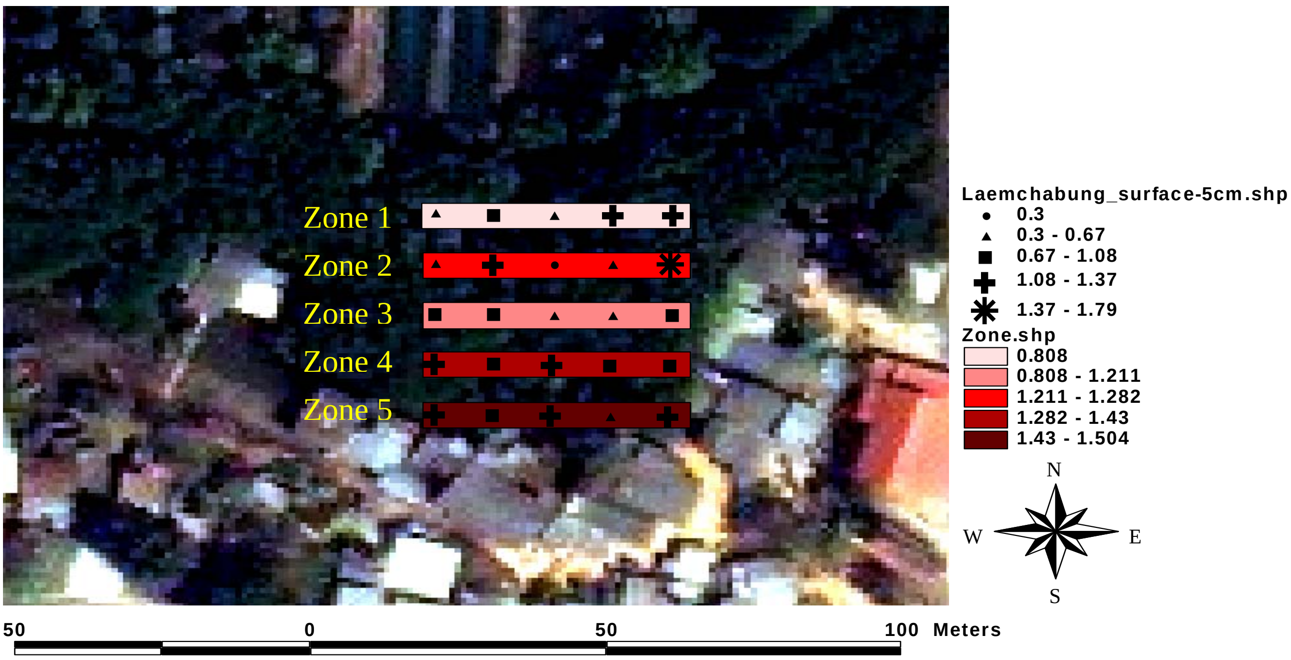


Figure 5-22. Comparing the diversity index in each plot of each zone at Laemchabung.

Table 5-10. The ecological data at Chuksamet. The same letters identified the values that were significantly different (P<0.05).

Zone	Number of species	Number of individuals	Density / m^2	Richness	Evenness	Shannon index
1	9	500	100	0.402492	0.408757	0.89813
2	6	121	24.2	0.545455	0.758338	1.35876
3	10	156	31.2	0.800641	0.772275	1.77823
4	8	91	18.2	0.838628	0.866776	1.80241
5	8	99	19.8	0.80403	0.845237	1.75762
Total	13	967	38.64	0.418052	0.667444	1.71196

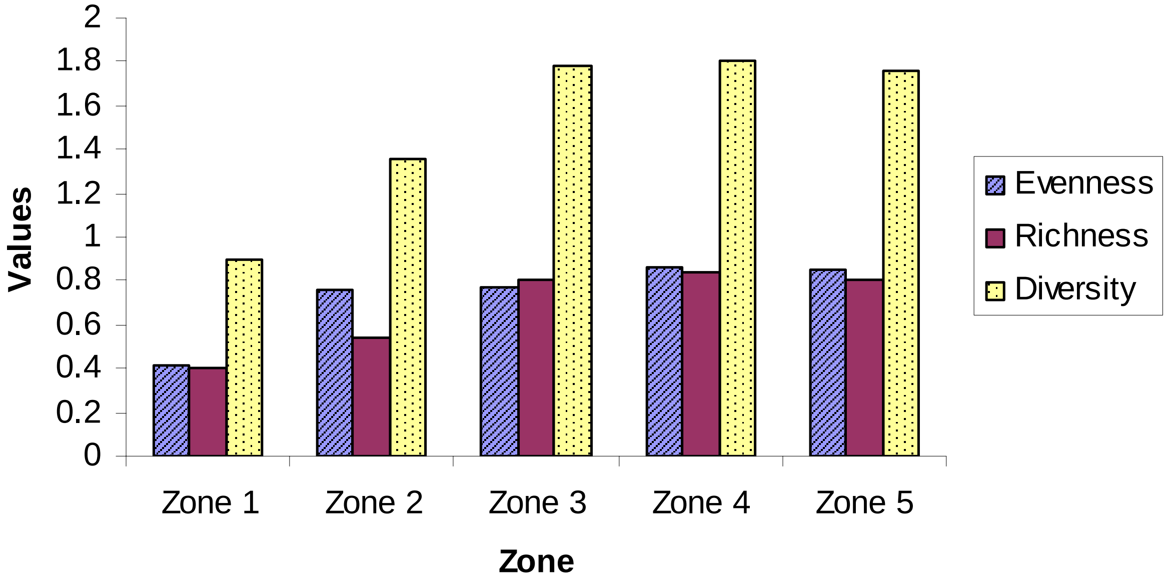


Figure 5-23. The diversity index, evenness, and richness in each zone at Chuksamet.

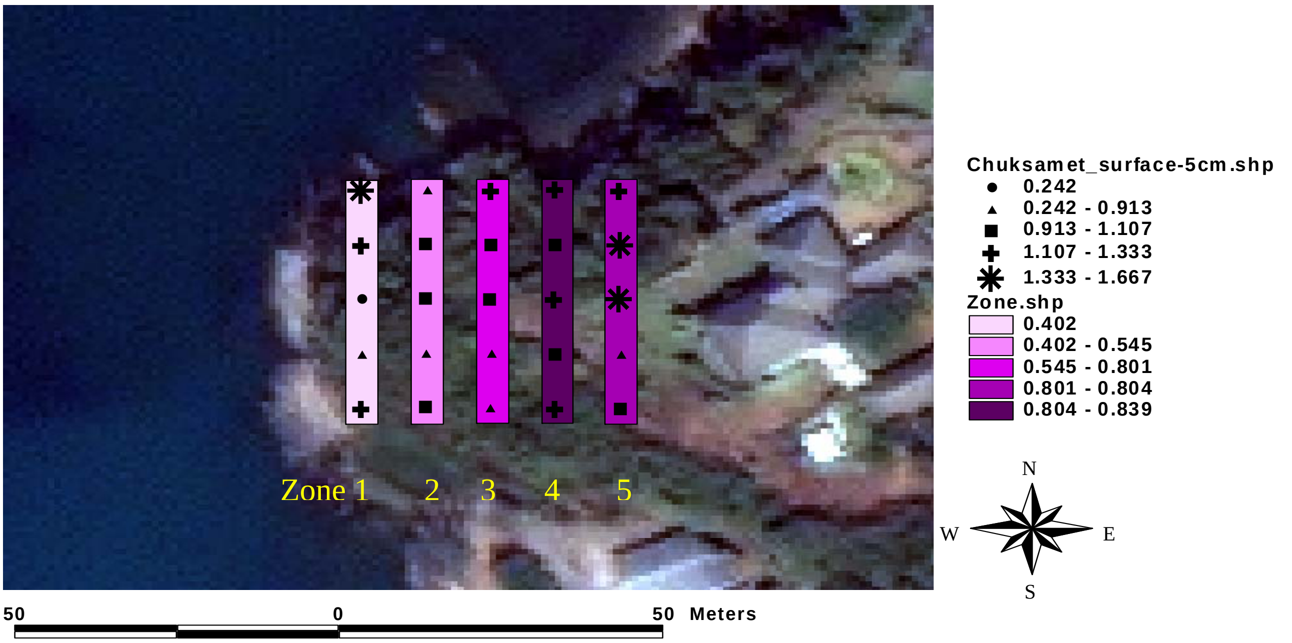


Figure 5-24. Comparing the richness in each plot of each zone at Chuksamet.

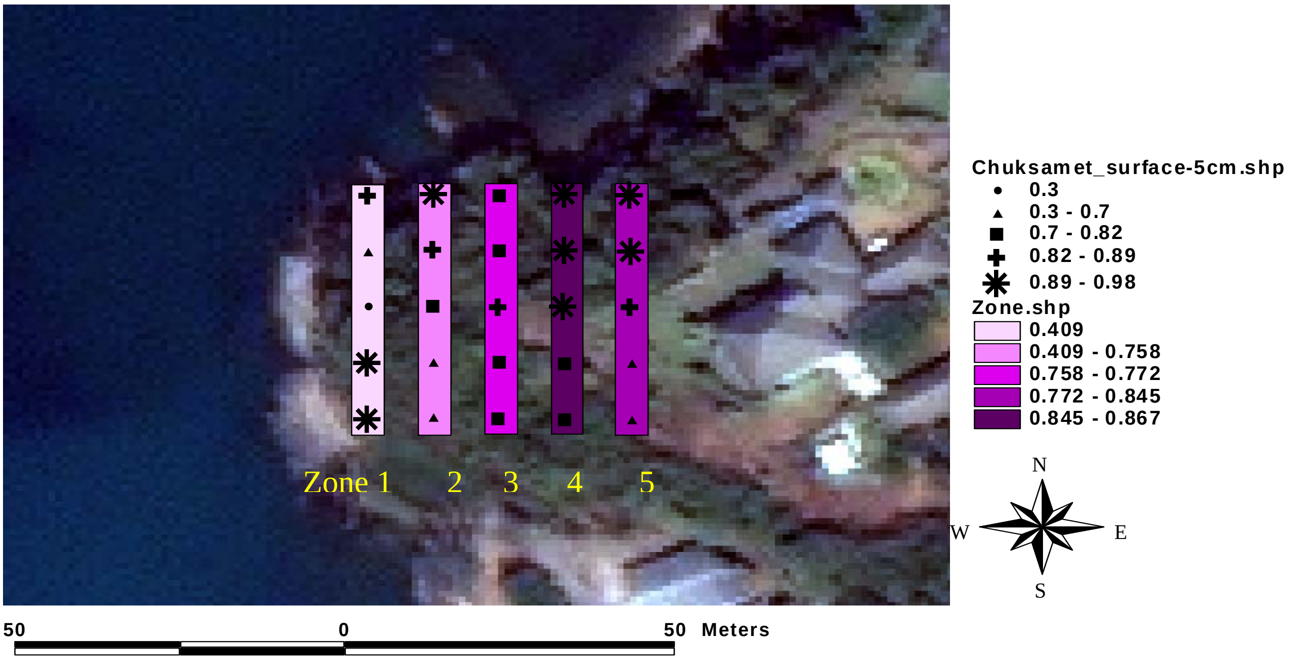


Figure 5-25. Comparing the evenness in each plot of each zone at Chuksamet.

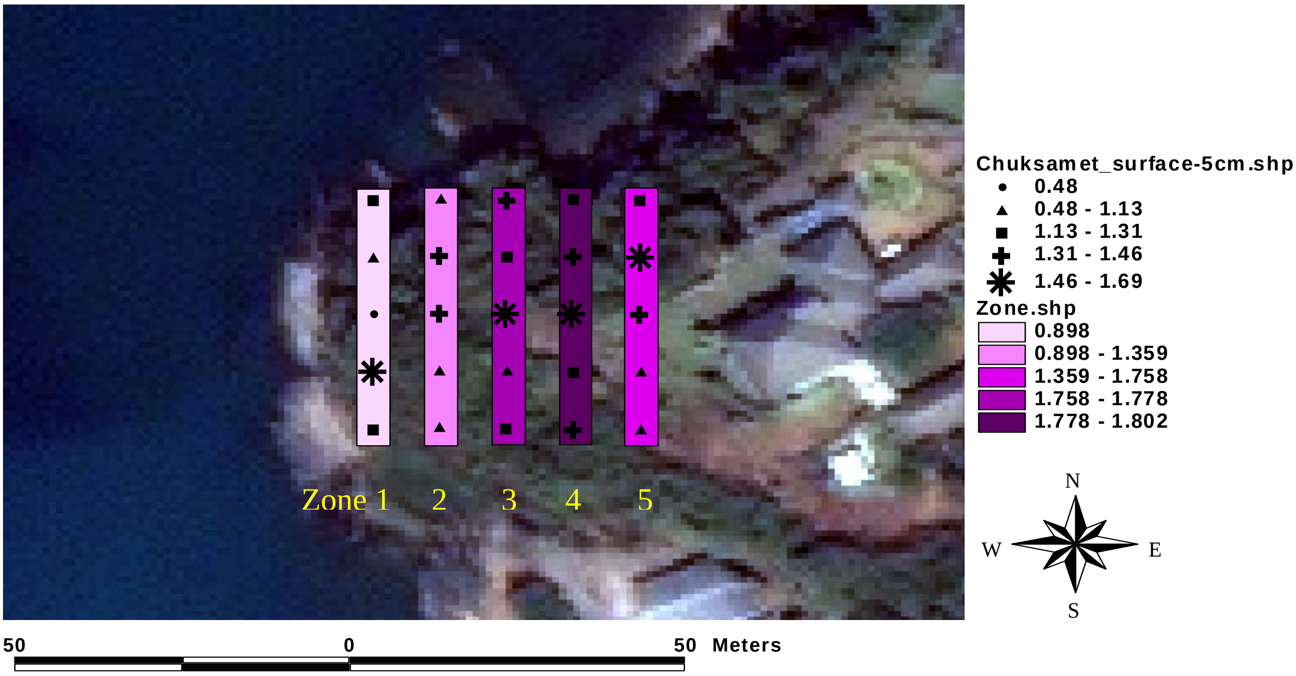


Figure 5-26. Comparing the diversity index in each plot of each zone at Chuksamet.

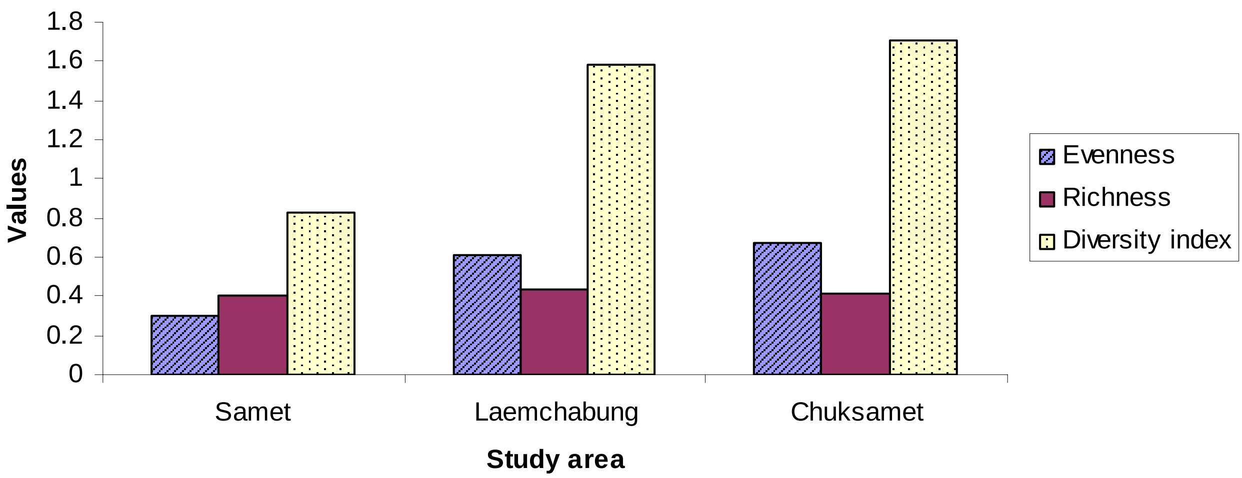


Figure 5-27. Comparing of Shannon diversity index, evenness, and richness of gastropods at Samet, Laemchabung, and Chuksamet.

Bray-Curtis Cluster Analysis (Complete Link)

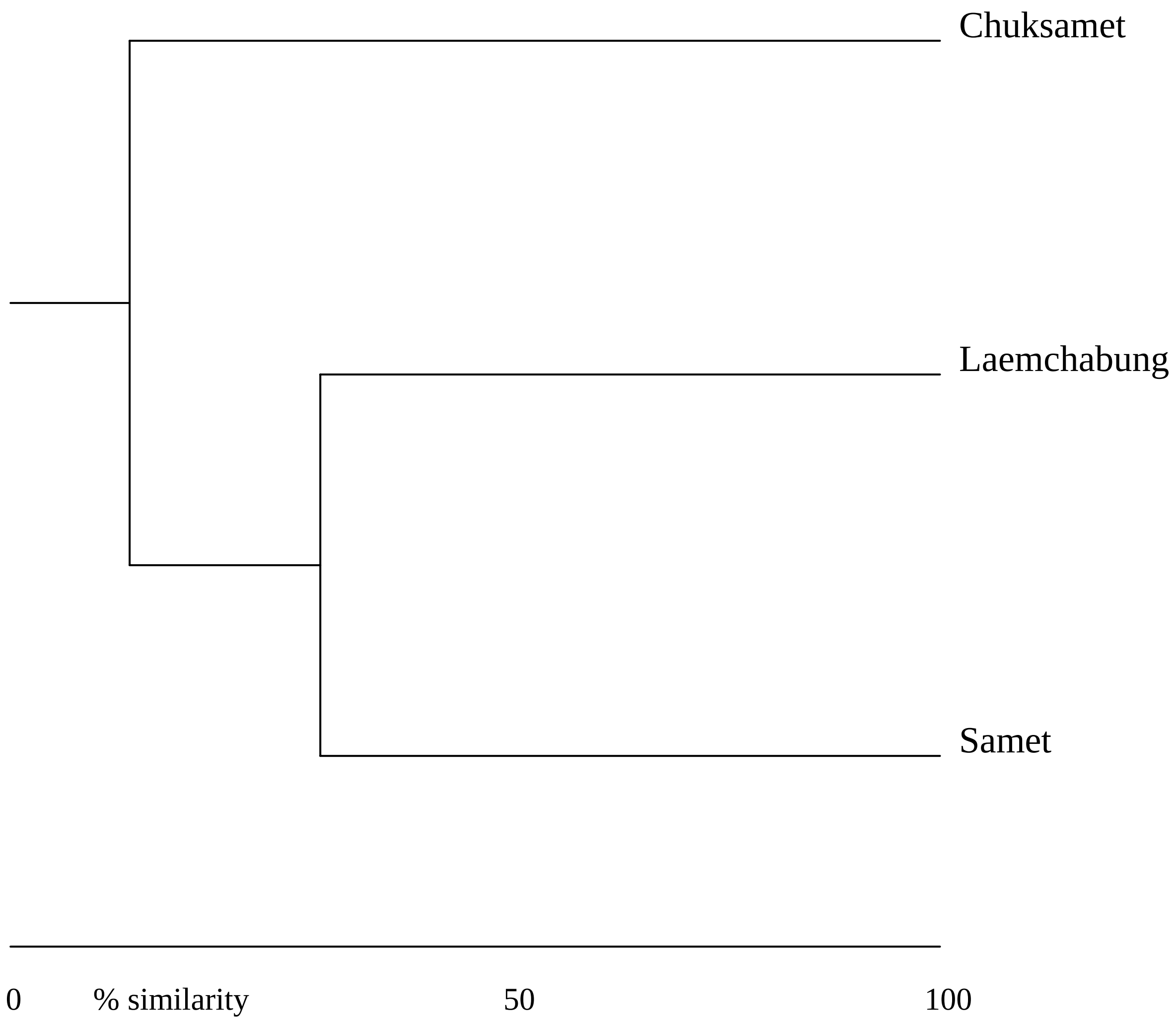


Figure 5-28. Bray-Curtis Cluster Analysis in three study areas.

5.3.2 Density value and distribution pattern

The total value of density of gastropods was highest at Samet (62.16/m^2), and lowest at Laemchabung (35.88/m^2) ($p>0.05$). At Samet, the total value of density was highest at zone 2 (77.4/m^2), and lowest at zone 1 (29.6/m^2) ($p<0.05$). At Laemchabung, the total value of density was highest at zone 1 (114.4/m^2) and lowest at zone 2 (14/m^2) ($p>0.05$). At Chuksamet, the total value density was highest at zone 1 (100/m^2), and lowest at zone 4 (18.2/m^2) ($p>0.05$). Among gastropod species at Samet, *Assiminea brevicula* was most dense in zone 2 (73.6/m^2) and showed the highest total density/m^2 value in all zones. At Laemchabung, *Melanoides tuberculata* showed the highest total density/m^2 value (83.4/m^2) in zone 1 that is the quantitative data whereas *Assiminea brevicula* showed the highest total density/m^2 value in all zones except zone 1 that is the qualitative data. At Chuksamet, *Clithon oualaniensis* found the most dense in zone 1 (74.2/m^2) and less dense in zone 5 (6/m^2) that is the quantitative data whereas *Cassidula aurisfelis* showed the highest total desity/m^2 value in zone 2,3,4 that is qualitative data (Tables 5-8 to 5-10, and Figures 5-29 to 5-31).

At Samet, *Assiminea brevicula*, *Neritina violacea*, *Cerithidea cingulata*, *Stenothyra* sp., and *Salinator burmana* were the first five that showed the highest percentage density of 82, 4, 3, 2, and 2%, respectively. At Laemchabung, *Melanoides tuberculata*, *Assiminea brevicula*, *Clithon oualaniensis*, *Platevindex* sp., and *Cassidula aurisfelis* were the first five that showed the highest percentage density of 47, 23, 13, 7, and 3%, respectively. At Chuksamet, *Clithon oualaniensis*, *Cassidula aurisfelis*, *Cerithidea cingulata*, *Littoraria palescene*, and *Cassidula mutiplicata* were the first five that showed the highest percentage density of 43, 21, 9, 9, and 8%, respectively (Tables 5-11 to 5-13, and Figures 5-32 to 5-34).

The comparisons of density values at three study areas were determined. It is found that *Assiminea brevicula*, *Melanoides tuberculata*, and *Clithon oualaniensis* were the dominant species (most common species ++++) at Samet, Laemchabung, and Chuksamet, respectively. At Samet, , *Cerithidea cingulata*, *Neritina violacea* were the common species (+++), *Cassidula aurisfelis*, *Cassidula mutiplicata*, *Littoraria melanostoma*, *Salinator burmana*, *Stenothyra* sp. were the moderate species (++), and *Cerithidea obtusa*, *Clithon oualaniensis*, *Haminoea succinea*, *Littoraria calinifera*, *Littoraria palescene*, *Littoraria strigata*, *Melanoides tuberculata*, *Platevindex* sp. were the rare species (+). At Laemchabung, *Assiminea brevicula, Cassidula aurisfelis, Clithon oualaniensis, Platevindex* sp. were the common species (+++), *Cassidula mutiplicata, Cerithidea cingulata, Chicoreus capucinus, Littoraria palescene* were the moderate species (++), and *Cerithidea obtusa, Fairbankia* sp., *Littoraria calinifera, Littoraria melanostoma* were the rare species. At Chuksamet, *Cassidula aurisfelis, Cassidula mutiplicata, Cerithidea cingulata, Cerithidea quadrata, Littoraria calinifera, Littoraria palescene* were the common species (+++), *Laemodonta siamensis* was the moderate species (++), and *Cerithidea obtusa, Ellobium aurismidae, Fairbankia* sp., *Melanoides tuberculata, Neritina violacea* were the rare species (+) (Table 5-14).

The distribution pattern of gastropods species at three study areas was mostly clumped or cluster pattern except for *Cerithidea obtusa, Haminoea succinea, Littoraria melanostoma, Littoraria strigata, Littoraria calinifera* at Samet; *Cerithidea obtusa, Chicoreus capucinus, Fairbankia* sp., *Littoraria calinifera, Littoraria melanostoma* at Laemchabung; *Cerithidea obtusa, Ellobium aurismidae, Neritina violacea* at Chuksamet, that showed random pattern (Table 5-15).

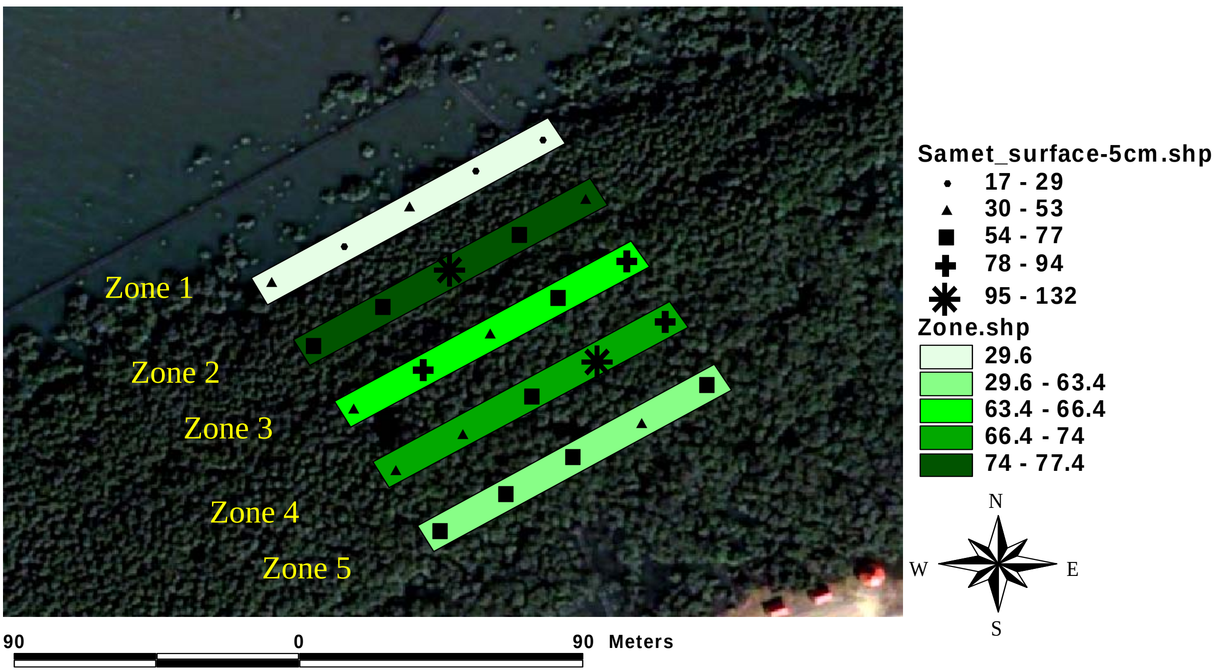


Figure 5-29. The density value in each plot and each zone at Samet.

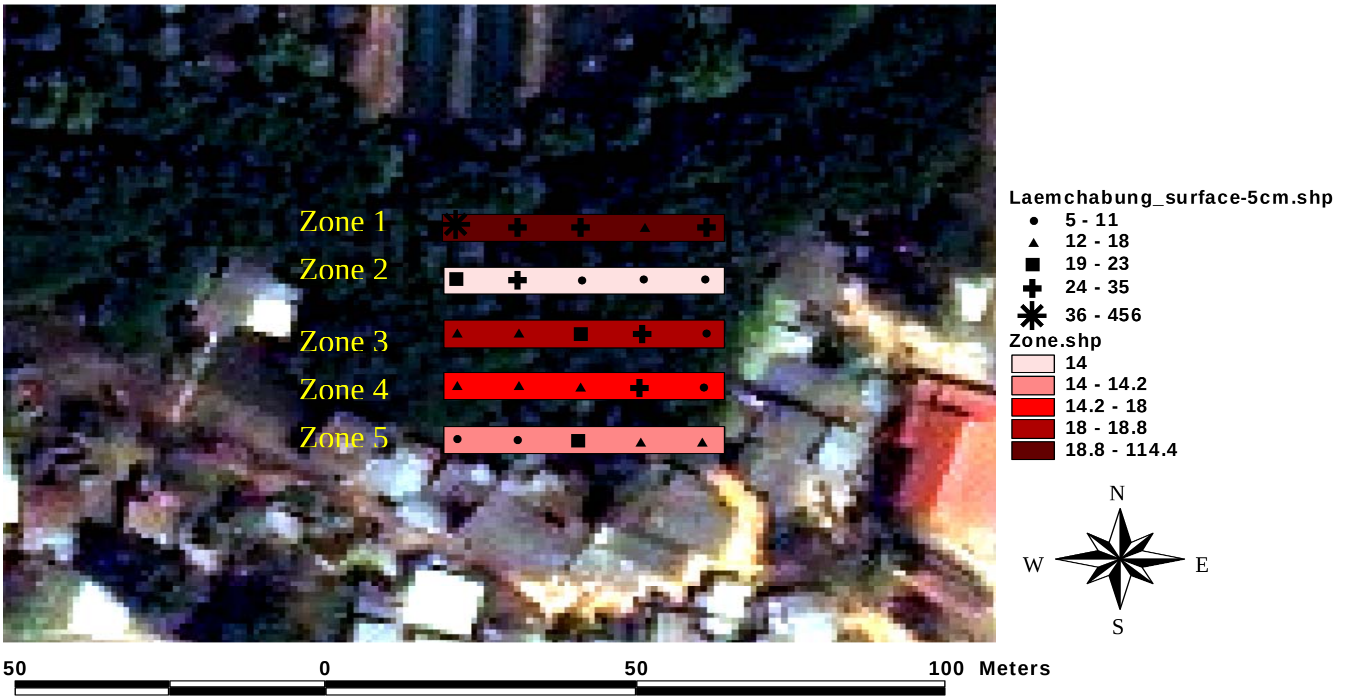


Figure 5-30. The density value in each plot and each zone at Laemchabung.

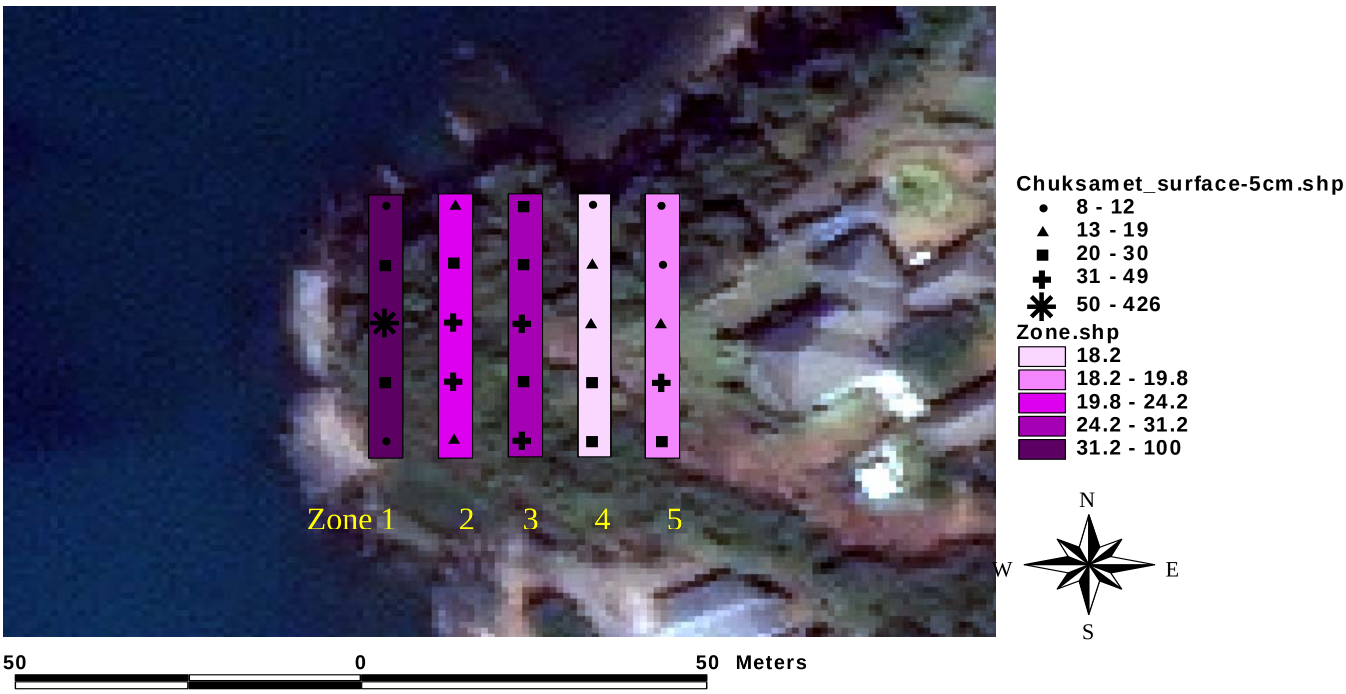


Figure 5-31. The density value in each plot and each zone at Chuksamet.

Table 5-11. Percentage density of gastropods at Samet.

Species	% density.
Assiminea brevicula	82
Neritina violacea	4
Cerithidea cingulata	3
Stenothyra sp.	2
Salinator burmana	2
Littoraria melanostoma	2
Cassidula mutiplicata	1
Cassidula aurisfelis	1
Littoraria palescene	1
Littoraria calinifera	1
Other	1

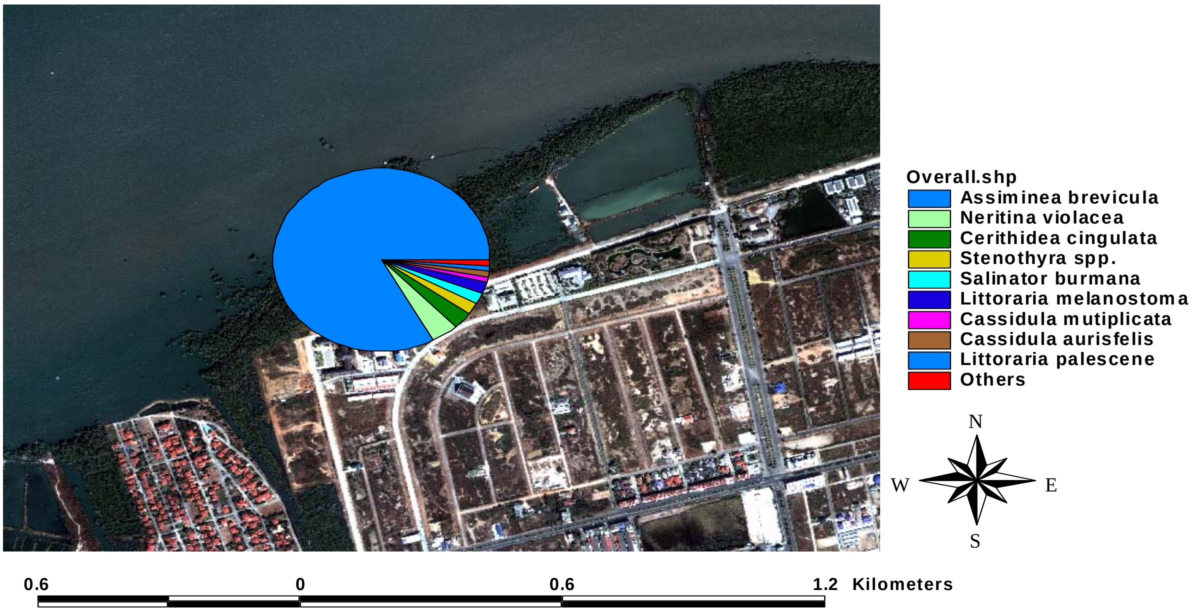


Figure 5-32. Percentage density of gastropods at Samet.

Table 5-12. Percentage density of gastropods at Laemchabung.

Species	% density.
Melanoides tuberculata	47
Assiminea brevicula	23
Clithon oualaniensis	13
Platevindex sp.	7
Cassidula aurisfelis	3
Chicoreus capucinus	2
Littoraria palescene	2
Cassidula mutiplicata	1
Cerithidea cingulata	1
Other	1

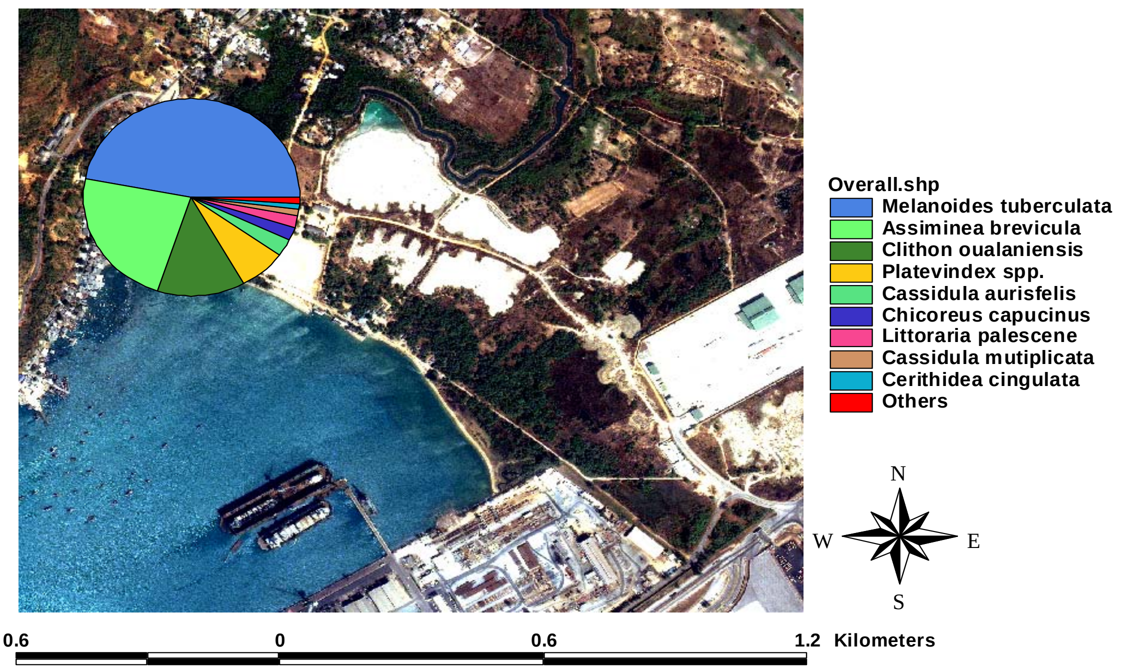


Figure 5-33. Percentage density of gastropods at Laemchabung.

Table 5-13. Percentage density of gastropods at Chuksamet.

Species	% density.
Clithon oualaniensis	43
Cassidula aurisfelis	21
Cerithidea cingulata	9
Littoraria palescene	9
Cassidula mutiplicata	8
Cerithidea quadrata	5
Littoraria calinifera	3
Laemodonta siamensis	1
Other	1

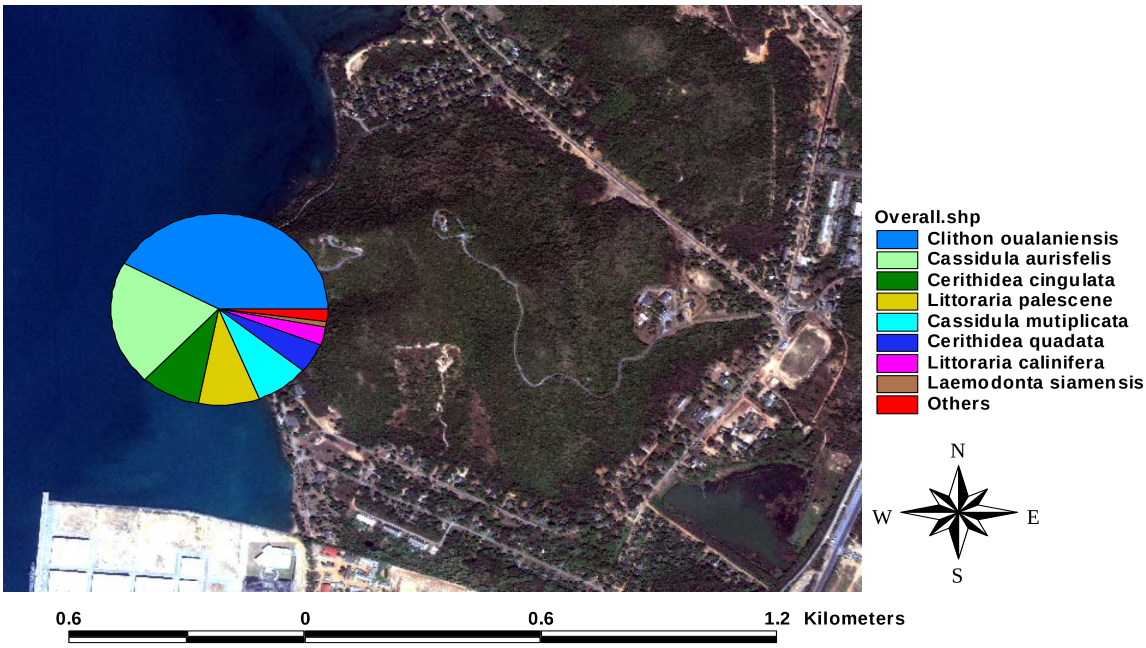


Figure 5-34. Percentage density of gastropods at Chuksamet.

Table 5-14. Comparison with density values in three study areas.

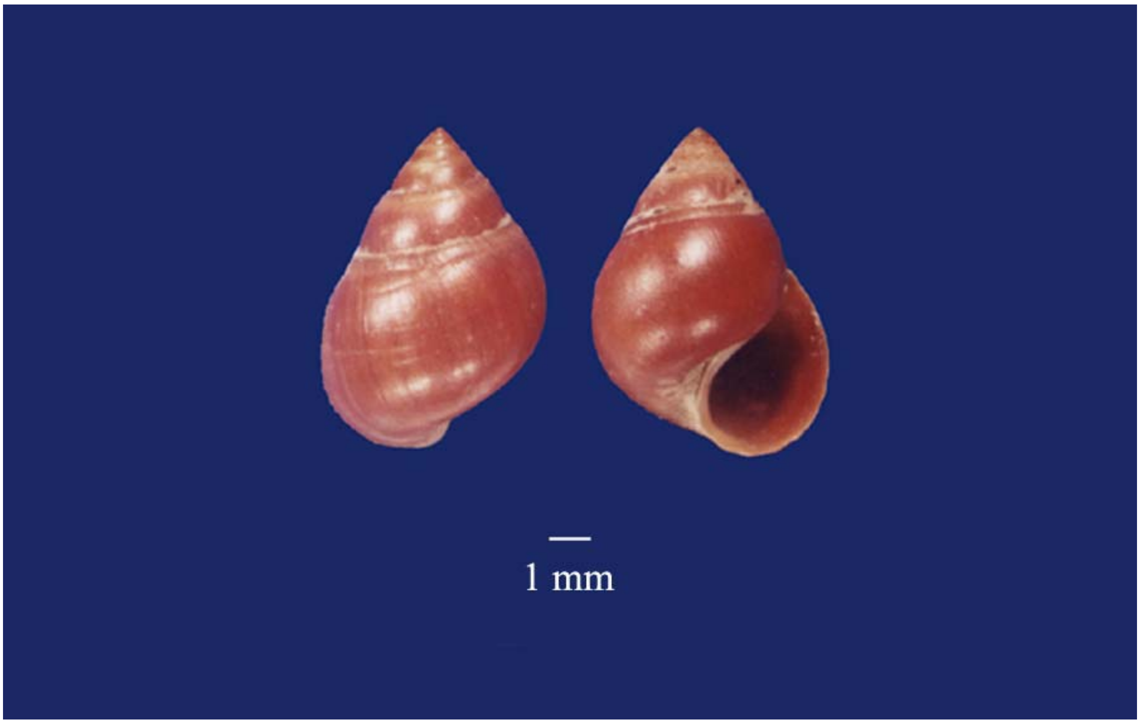
Species	Samet	Laemchabung	Chuksamet
Assiminea brevicula	++++	+++	-
Cassidula aurisfelis	++	+++	+++
Cassidula mutiplicata	++	++	+++
Cerithidea cingulata	+++	++	+++
Cerithidea obtusa	+	+	+
Cerithidea quadrata	-	-	+++
Chicoreus capucinus	-	++	-
Clithon oualaniensis	+	+++	++++
Ellobium aurismidae	-	-	+
Fairbankia sp.	-	+	+
Haminoea succinea	+	-	-
Laemodonta sp.	-	-	++
Littoraria calinifera	+	+	+++
Littoraria melanostoma	++	+	-
Littoraria palescene	+	++	+++
Littoraria strigata	+	-	-
Melanoides tuberculata	+	++++	+
Neritina violacea	+++	-	+
Platevindex sp.	+	+++	-
Salinator burmana	++	-	-
Stenothyra sp.	++	-	-

Where ; - not found
+ rare species
++ moderate species
+++ common species
++++ most common species

Table 5-15. Types of species distribution.

Species	Samet	Laemchabung	Chuksamet
Assiminea brevicula	Clumped	Clumped	-
Cassidula aurisfelis	Clumped	Clumped	Clumped
Cassidula mutiplicata	Clumped	Clumped	Clumped
Cerithidea cingulata	Clumped	Clumped	Clumped
Cerithidea obtusa	Random	Random	Random
Cerithidea quadrata	-	-	Clumped
Chicoreus capucinus	-	Random	-
Clithon oualaniensis	Clumped	Clumped	Clumped
Ellobium aurismidae	-	-	Random
Fairbankia sp.	-	Random	Clumped
Haminoea succinea	Random	-	-
Laemodonta siamensis	-	-	Clumped
Littoraria calinifera	Random	Random	Clumped
Littoraria melanostoma	Random	Random	-
Littoraria palescene	Clumped	Clumped	Clumped
Littoraria strigata	Random	-	-
Melanoides tuberculata	Clumped	Clumped	Clumped
Neritina violacea	Clumped	-	Random
Platevindex sp.	Clumped	Clumped	-
Salinator burmana	Clumped	-	-
Stenothyra sp.	Clumped	-	-

5.3.3 Shell characteristics



Scientific name: *Assiminea brevicula*

Common name: Red Berry

Shell: rather large, broadly conic, not transparent, dull, brick-red, brownish, yellowish. The 6 whorls are moderately convex and separated by a well incised suture. The sculpture consists generally of one spiral cord below the suture and one to four incised spiral lines, the uppermost of that was the deepest. No umbilicus or chink umbilicus.

Aperture: large, oval, angled above and well round below.

Operculum: thin, and paucispiral nucleus.

Size: SL: 0.65±0.11 cm, SW: 0.45±0.07 cm, AL: 0.41±0.05 cm, AW: 0.32±0.04 cm, SA: 54.12±4.71°.

Habitat: predominantly brackish, the species was mostly amphibious, spending most of the time outside the water on wet mud-flats under stones, on decaying wood. Common in mangrove.

Location: Samet and Laemchabung.

Scientific name: *Cassidula aurisfelis*

Common name: -

Shell: medium size for the family, conic spire, thick, solid, not translucent, covered with a thick and brownish periostracum. No umbilicus. The body whorl was truncate. Its length was about 5/6 of the length of the shell.

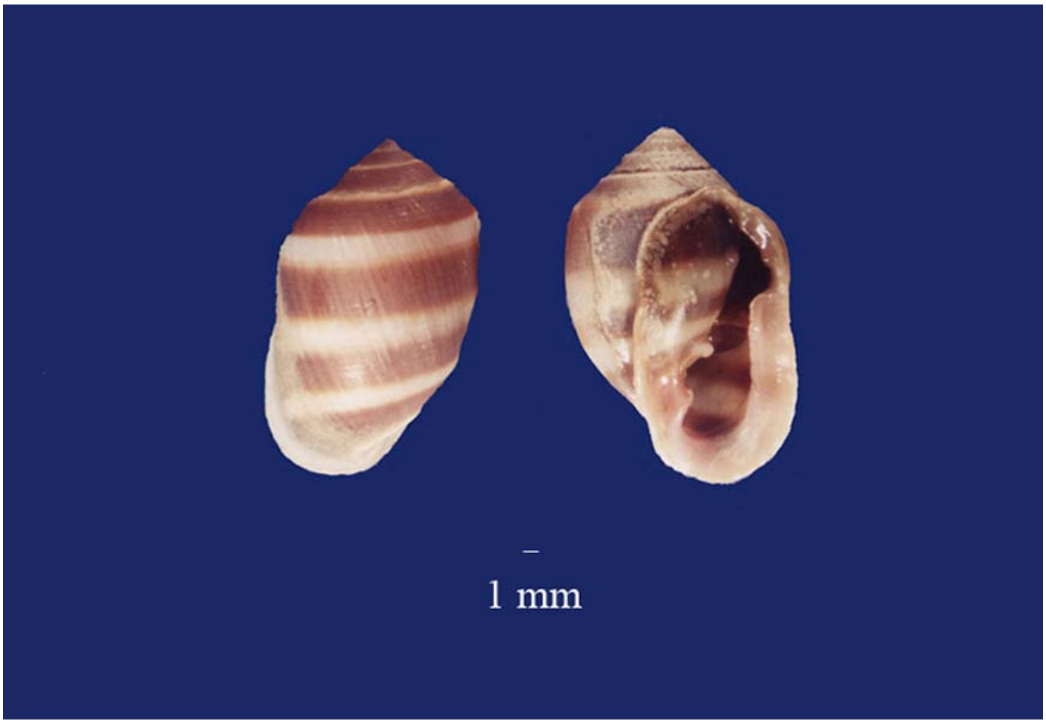
Aperture: narrow, ear-shaped, thick lip, the inner lip with carina, the inner left aperture consisted of one obviously tooth. The length of the aperture was about ¾ of the shell length.

Operculum: none.

Size: SL: 1.88±0.23 cm, SW: 1.23±0.14 cm, AL: 1.54±0.19 cm, AW: 0.87±0.13 cm, SA: 93.13±5.04º.

Habitat: common in mangrove together with the other species of the family and with *Cerithidea* sp.

Location: Samet, Laemchabung, and Chuksamet.



Scientific name: *Cassidula multiplicata*

Common name: -

Shell: smaller size than *Cassidula aurisfelis*, more slender shape, the periostracum was brown with white spiral bands, twisted columellar, the tuberculated middle part of the peristome ridge.

Aperture: narrow, ear-shaped, the inner surface of the left aperture was tuberculate of the middle part.

Operculum: none.

Size: SL: 1.88±0.24 cm, SW: 1.23±0.17 cm, AL: 1.55±0.21 cm, AW: 0.87±0.16 cm, SA: 92.92±5.82°.

Habitat: common in mangrove together with the other species of the family and with *Cerithidea* sp.

Location: Samet, Laemchabung, and Chuksamet.

Scientific name: *Cerithidea cingulata*

Common name: -

Shell: elongately conoidal or turreted, not translucent, and dark or violet-brown mixed with white. The shell had three spiral tubercle rows in each whorl. The spiral groove between spiral tubercle was darker brown. The whorls were numerous and almost flat. They are almost flat; the body whorl was delicately angled at the end before becoming the aperture.

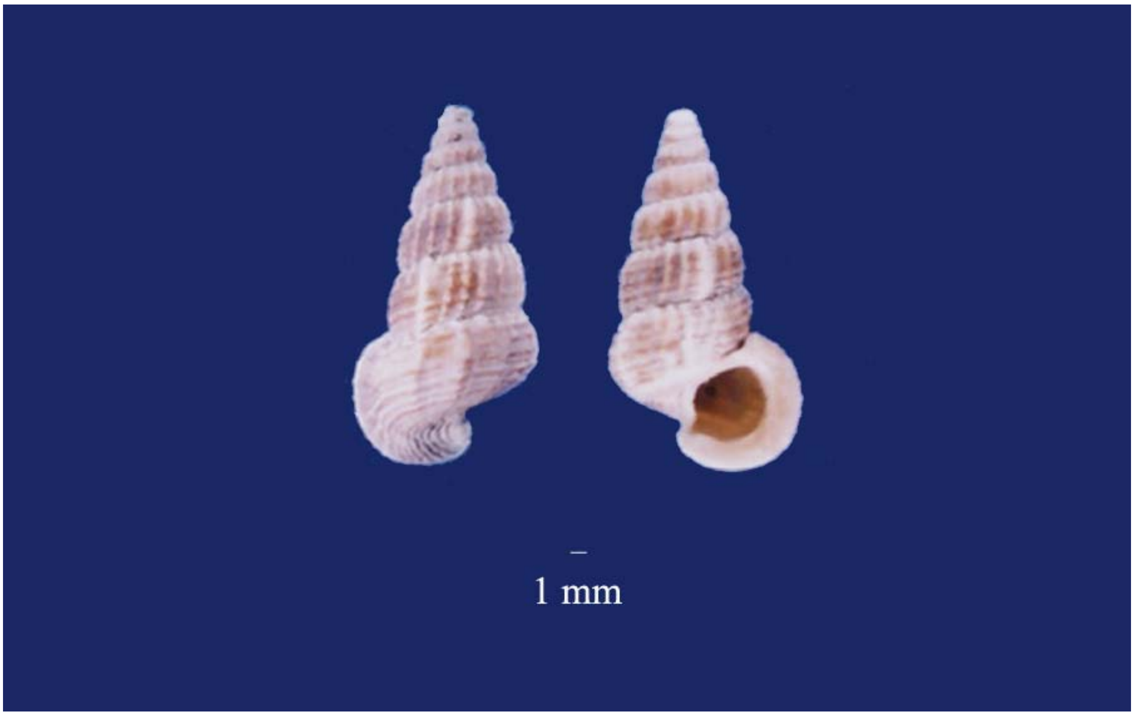
Aperture: oval, angled above and below, with short siphonal canal at the base.

Operculum: multispiral with subcentral nucleus, and large.

Size: SL: 2.19±0.52 cm, SW: 0.86±0.18 cm, AL: 0.62±0.12 cm, AW: 0.57±0.18 cm, SA: 21.26±2.40º.

Habitat: common on mud-flats in the mangrove forest.

Location: Samet, Laemchabung, and Chuksamet.



Scientific name: *Cerithidea obtusa*

Common name: -

Shell: large, elongate conic, rather thick and broad at the base, not translucent, with brown or purplish spire and a brighter zone below the suture; sculptured with axial ribs and spiral ridges. The apex was generally eroded. The shell had deep sutures. A varix occured on the last whorl before becoming the aperture. The peristome was cream color.

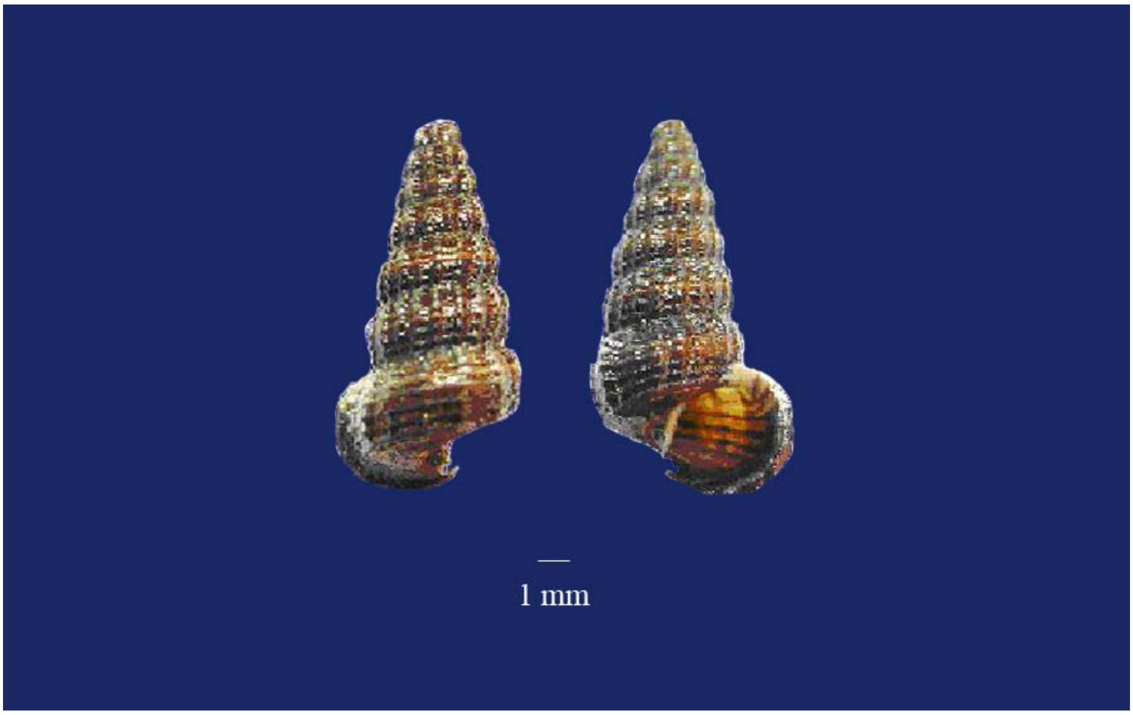
Aperture: oval, and angled above and below with short siphonal canal at the base.

Operculum: multispiral with subcentral nucleus, and large.

Size: SL: 4.24±1.08 cm, SW: 1.89±0.87 cm, AL: 1.47±0.47 cm, AW: 1.43±0.25 cm, SA: 24.50±4.95º.

Habitat: common in the mangrove forests. The animals liked to climb up at the roots and stems of trees.

Location: Samet, Laemchabung, and Chuksamet.



Scientific name: *Cerithidea quadrata*

Common name: -

Shell: The shell was smaller, elongate conic, thinner and darker color than *Cerithidea obtusa*. It had dense transverse ribs and strong spiral ridges at the spire whorls and weaker at the body whorl. The body whorl was varix at the end before becoming the aperture.

Aperture: brownish and glossy inside, oval, angled above and below, with short siphonal knob.

Operculum: multispiral with subcentral nucleus and large.

Size: SL: 3.53±0.18 cm, SW: 1.55±0.10 cm, AL: 1.11±0.08 cm, AW: 1.09±0.08 cm, SA: 21.35±1.63º.

Habitat: common on mud-flats in the mangrove forest. The animals climbed up the trees and feed on algae growing at the roots and stems. It was often found together with *Cerithidea obtusa*.

Location: Chuksamet.

Scientific name: *Chicoreus capucinus*

Common name: -

Shell: medium size, broadly conic, thick, not translucent, grayish, with strong, irregular spiral ridges and a lateral and a dorsal row of scaly spines. Siphonal canal very long and narrow.

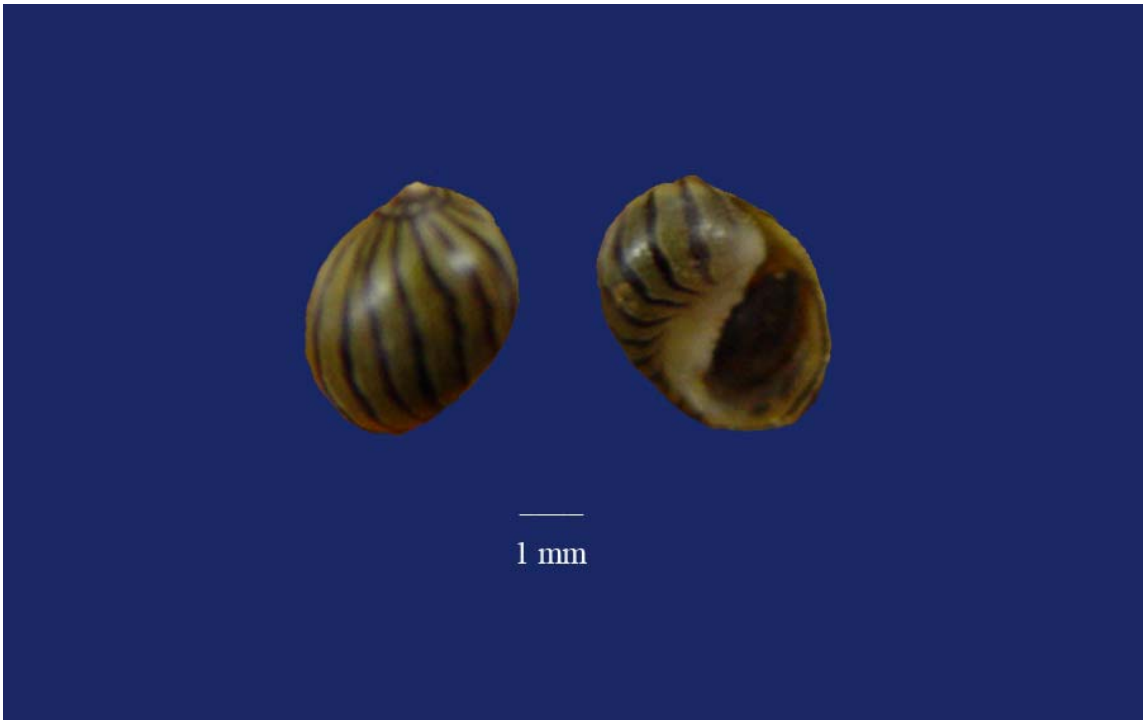
Aperture: brownish-violet inside, outer lip had a thick varix outside and serrate inside.

Operculum: ovate, thin, concentric with basal nucleus.

Size: SL: 3.88±0.54 cm, SW: 2.09±0.23 cm, AL: 1.70±0.45 cm, AW: 1.10±0.22 cm, SA: 52.40±2.12º.

Habitat: mangrove forests. They were amphibious on mud flats or climb up the truck and fed on oysters and other gastropods.

Location: Laemchabung.



Scientific name: *Clithon oualaniensis*

Common name: -

Shell: small, subglobose, with low, somewhat conical, but mostly eroded apex, glossy, with various patterns of colored ornamentation. The color of the periostracum was generally grayish or olive-green, rarely blackish or yellow with black transverse zigzag lines.

Aperture: oblique, semicircular, bluish inside, serrate inner lip.

Operculum: semicircular, grayish outer surface, inner surface with a more or less distinctly curved ridge and short knob-like peg.

Size: SL: 0.79±0.20 cm, SW: 0.62±0.14 cm, AL: 0.67±0.16 cm, AW: 0.57±0.15 cm, SA: 105.25±16.68º.

Habitat: mangrove forests. The species lived on sand or silt ground and was never found in the mud flats.

Location: Samet, Laemchabung, and Chuksamet.

Scientific name: *Ellobium aurismidae*

Common name: -

Shell: very large for the family, thick and solid, of white ground color, but covered with brown periderm. Spire short, conic, with obtuse apex, body whorl large, ovate, measuring about 6/7 of the height of the shell; it is obtusely shouldered. The granulation of the surface is particularly coarse above this shoulder and stronger around the umbilical area than on the middle part.

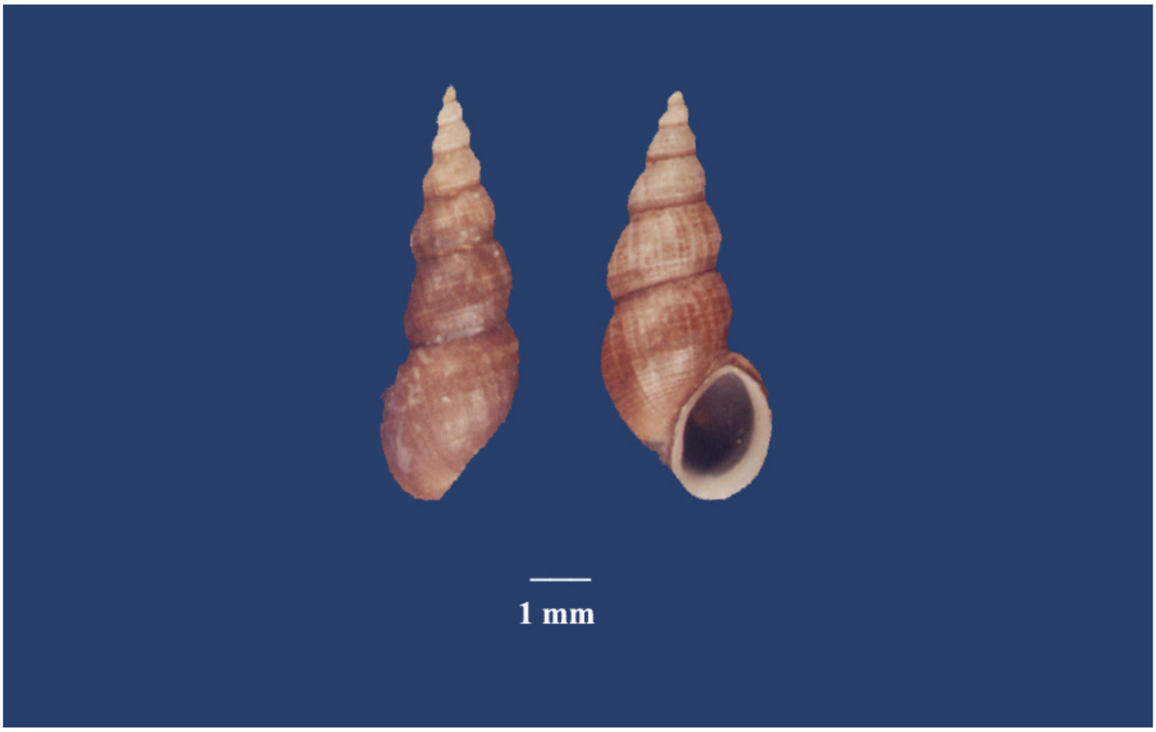
Aperture: ear-shaped, it thick lip especially at the base, a vertical ridge on the parietal wall.

Operculum: none.

Size: SL: 6.51 cm, SW: 3.95 cm, AL: 5.22 cm, AW: 3.29 cm, SA: 65º.

Habitat: amphibious on mud flats with vegetation, and mangrove swamps.

Location: Chuksamet.



Scientific name: *Fairbankia sp.*

Common name: -

Shell: elongately conic, usually had eroded shell. Thin and brown periostracum covered with numerous fine hair. Sculptured with fine spiral lines.

Aperture: bluish-white inside, thick lip especially at the basal and outer parts.

Operculum: corneous, and concentric.

Size: SL: 0.75±0.10 cm, SW: 0.33±0.03 cm, AL: 0.29±0.04 cm, AW: 0.23±0.02 cm, SA: 22.50±4.95°.

Habitat: found in brackish water and mangrove forest with muddy ground and feed on decaying organic substance.

Location: Laemchabung, and Chuksamet.

Scientific name: *Haminoea succinea*

Common name: Bubble Shell

Shell: ovoid, thin and translucent, smooth, apex is sunken or enclosed and no longer visible, large body whorl with fine spiral growth lines. Smooth columella. The thin outer lip of the aperture extended beyond the apex of the shell and was thus longer than the body whorl.

Aperture: The aperture was narrow above and wider below.

Operculum: none.

Size: SL: 1.20±0.01 cm, SW: 0.75±0.07 cm, AL: 1.19±0.02 cm, AW: 0.53±0.03 cm.

Habitat: amphibious on the mud flats.

Location: Samet.

Scientific name: *Laemodonta* sp.

Common name: -

Shell: rather small, abruptly broadly conic with taper aperture. The shell was brown with dark brown spiral bands. Strong spiral lines. The closed umbilicus or a chick umbilicus.

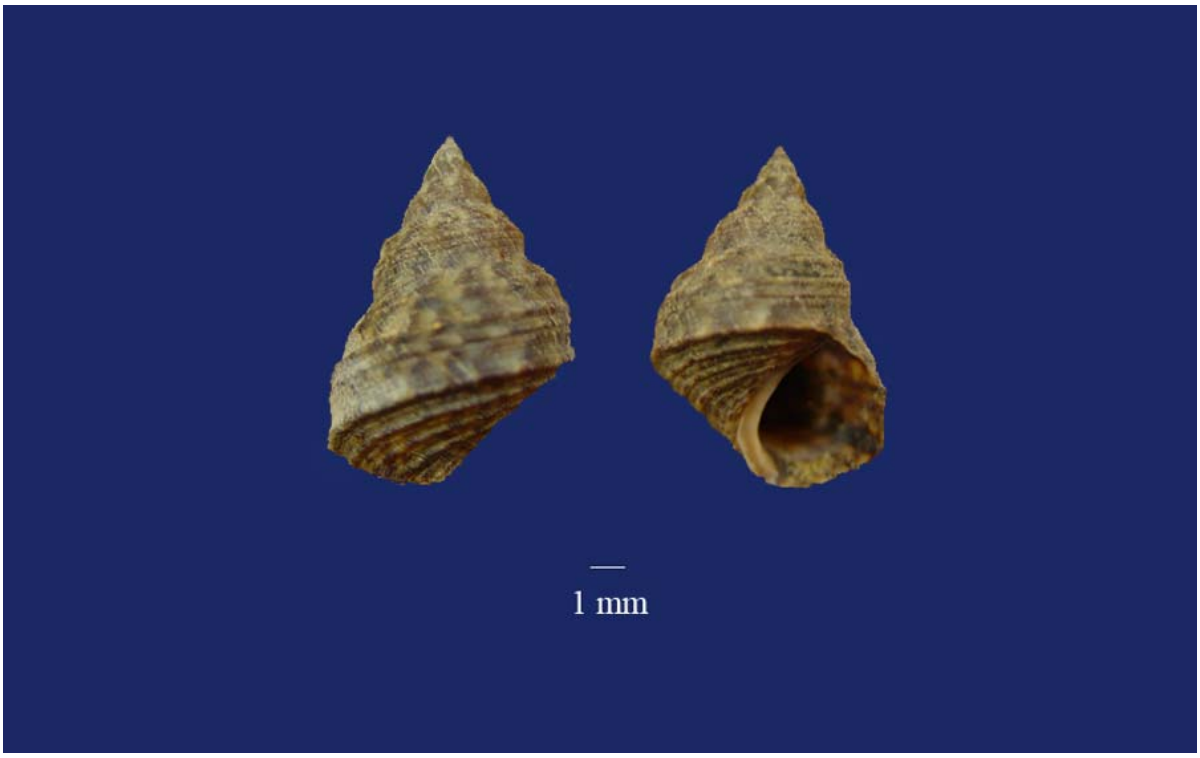
Aperture: long narrow, typical 3 folds and with 3 usually palatal teeth.

Operculum: none.

Size: SL: 0.98±0.32 cm, SW: 0.59±0.17 cm, AL: 0.74±0.28 cm, AW: 0.32±0.05 cm, SA: 61.67±13.34º.

Habitat: common in all mud-flats and mangrove.

Location: Chuksamet.



Scientific name: *Littoraria carinifera*

Common name: -

Shell: rather thin, broadly conic, high conical with pointed apex and almost flat whorls. This species differs from all other species of this genus by its few strong spiral ridges. Its color was grayish, dotted with reddisd-brown.

Aperture: nearly round, and thin.

Operculum: A thin, paucispiral operculum with half-oval shape. The color of operculum was yellow, light-brown and dark brown from the outer to the inner part, respectively.

Size: SL: 1.78±0.34 cm, SW: 1.16±0.19 cm, AL: 1.01±0.18 cm, AW: 0.80±0.15 cm, SA: 49.31±4.44º.

Habitat: mangrove forests and liked to climb up the trunk and root of the mangrove trees.

Location: Samet, Laemchabung, and Chuksamet.

Scientific name: *Littoraria melanostoma*

Common name: -

Shell: rather thin, broadly conic, and middle sized for the family, high conical with pointed apex and almost flat whorls, dark brown parietal callus. The surface was rather smooth with weak spiral lines. The body whorl was flat. The color pattern was brown wavy transverse line.

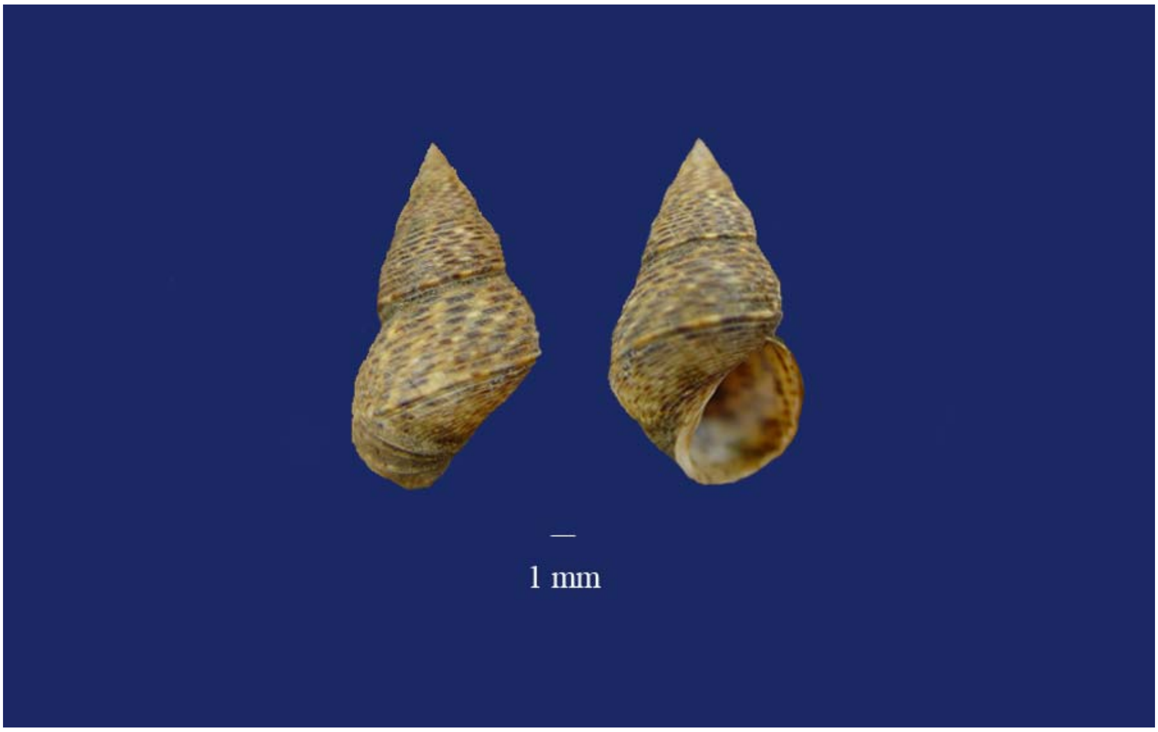
Aperture: nearly round, and thin.

Operculum: A thin, paucispiral operculum with half-oval shape. The color of operculum was yellow, light-brown and dark brown from the outer to the inner part, respectively.

Size: SL: 2.37±0.22 cm, SW: 1.28±0.12 cm, AL: 1.33±0.19 cm, AW: 0.92±0.09 cm, SA: 40.33±3.46º.

Habitat: mangrove forests and liked to climb up the trunk and root of the mangrove trees.

Location: Samet and Laemchabung.



Scientific name: *Littoraria palescene*

Common name: -

Shell: They were broadly conic, moderate thickness, fairly low spine and weak carina at the lower body whorl. They had about 5-6 whorls. They were cream-yellow color and had many dark-brown to black dashes on the spiral ribs which sometimes form the axial stripes on the shell.

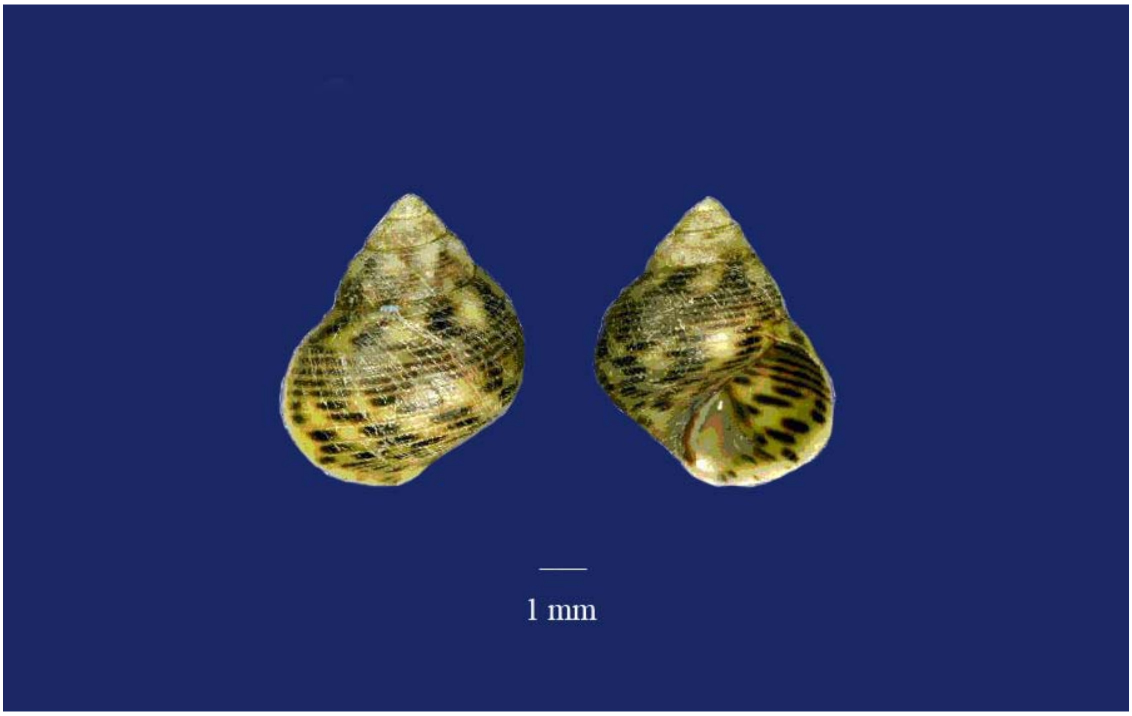
Aperture: oval shape with a thin outer lip.

Operculum: A thin, paucispiral operculum with half-oval shape. The color of operculum was yellow to light-brown which darker at the middle and lighter at the edge.

Size: SL: 1.21±0.67 cm, SW: 0.77±0.39 cm, AL: 0.68±0.33 cm, AW: 0.54±0.27 cm, SA: 47.09±3.77º.

Habitat: mangrove forests and liked to climb up the trunk and root of the mangrove trees.

Location: Samet, Laemchabung, and Chuksamet.



Scientific name: *Littoraria strigata*

Common name: -

Shell: small size, broadly conic, moderate thickness, eroded (usually), weak spiral ribs and weak transverse lines, shoulder body whorl, cream-yellow or white color, many dark-brown to black dashes on the weak spiral ribs which sometimes form the axial stripes on the shell, these features could be seen clearly at the body whorl.

Aperture: oval shape with a thin outer lip.

Operculum: A thin, paucispiral operculum with half-oval shape. The color of operculum was yellow to light-brown which darker at the middle and lighter at the edge.

Size: SL: 0.84±0.36 cm, SW: 0.57±0.22 cm, AL: 0.53±0.21 cm, AW: 0.43±0.18 cm, SA: 52.50±1.97º.

Habitat: mangrove forests and liked to climb up the trunk and root of the mangrove trees.

Location: Samet.

Scientific name: *Melanoides tuberculata*

Common name: -

Shell: moderately thick, elongate conic, turreted, numerous whorls, usually eroded apex. The whorls were either somewhat convex or nearly flat. The periostracum was brownish, yellowish or olive with 2-3 chestnut-brown bands at lower body whorl. The sculpture consisted of many strong narrow spiral and especially transverse ridges.

Aperture: ovate, with protrude and sharp peristome.

Operculum: paucispiral.

Size: SL: 0.93±0.34 cm, SW: 0.39±0.12 cm, AL: 0.43±0.15 cm, AW: 0.28±0.07 cm, SA: 25.35±3.68º.

Habitat: The species was found in slightly brackish water and was abundant in the tidal areas of mangrove forests.

Location: Samet, Laemchabung, and Chuksamet.

Scientific name: *Neritina violacea*

Common name: -

Shell: medium size for the family neritiform. The shell was from brown to dark brown in color. The color pattern with yellowish brown dots on the upper whorls and the edge of the body whorl and yellowish brown broken line on the body whorl. The sculpture consisted of strong growth lines.

Aperture: very large but the entrance half closed by the septum, formed by the parietal and columellar part. The septum and the inner aperture were either brownish-orange, or brick-colored. The opening of the aperture is semicircular.

Operculum: generally semilunar, calcareous, with an apophysis (with peg and ridge) at the inner part.

Size: SL: 1.86±0.19 cm, SW: 1.33±0.14 cm, AL: 1.59±0.16 cm, AW: 1.33±0.14 cm, SA: 67.17±9.07º.

Habitat: mangrove forests. They lived on the mud flats, declaying wood or on the trunk of mangrove trees.

Location: Samet, and Chuksamet

Scientific name: *Platevindex sp.*

Common name: -

Shell: no shell, sea-slug like. They were usually oval in shapes with a hard leathery mantles.

Aperture: none.

Operculum: none.

Size: SL: 3.63±0.32 cm, SW: 1.93±0.51 cm.

Habitat: amphibious on mud in the landward mangrove forest.

Location: Samet, and Laemchabung.

Scientific name: *Salinator* sp.

Common name: -

Shell: rather thin, depressed conic, brown ground color, conspicuous umbilicus, very inflated, body whorl large.

Aperture: round with thin lip.

Operculum: thin paucispiral.

Size: SL: 1.02±0.14 cm, SW: 0.84±0.11 cm, AL: 0.77±0.12 cm, AW: 0.67±0.10 cm, SA: 93.08±11.24º.

Habitat: amphibious on the mud flats.

Location: Chuksamet.

Scientific name: *Stenothyra sp.*

Common name: -

Shell: very small, broadly conic, thin corneous, tanslucent, large elongate and flat body whorl. Often with a sculpture of weak spiral lines. The periostracum covered with few hair.

Aperture: small, and round; peristome with a thin lip.

Operculum: ovate with three inner ridges, two short and straight, and one semicircular ridges.

Size: SL: 0.53±0.03 cm, SW: 0.31±0.02 cm, AL: 0.24±0.03 cm, AW: 0.22±0.01 cm, SA: 45.86±2.73º.

Habitat: brackish water, mangrove forest, and tidal area.

Location: Samet.

5.4 TBT accumulation

Standard solution of hexylated tributyltin compounds in hexane were prepared in the concentration ranges as follows: 15 ppb; 30 ppb; 60 ppb; 120 ppb; and 240 ppb in the retention time of 7.58 minutes. The calibration curve of standard solution of TBT was shown in Figure 5-35. The comparison of the TBT concentrations between the samples and standard solutions on DB-5 capillary column was evaluated. Figure 5-36 illustrates showing the separation and identification of TeBT, TBT, DBT, and MBT at the retention times of 6.38, 7.58, 8.91, and 9.53 minutes, respectively.

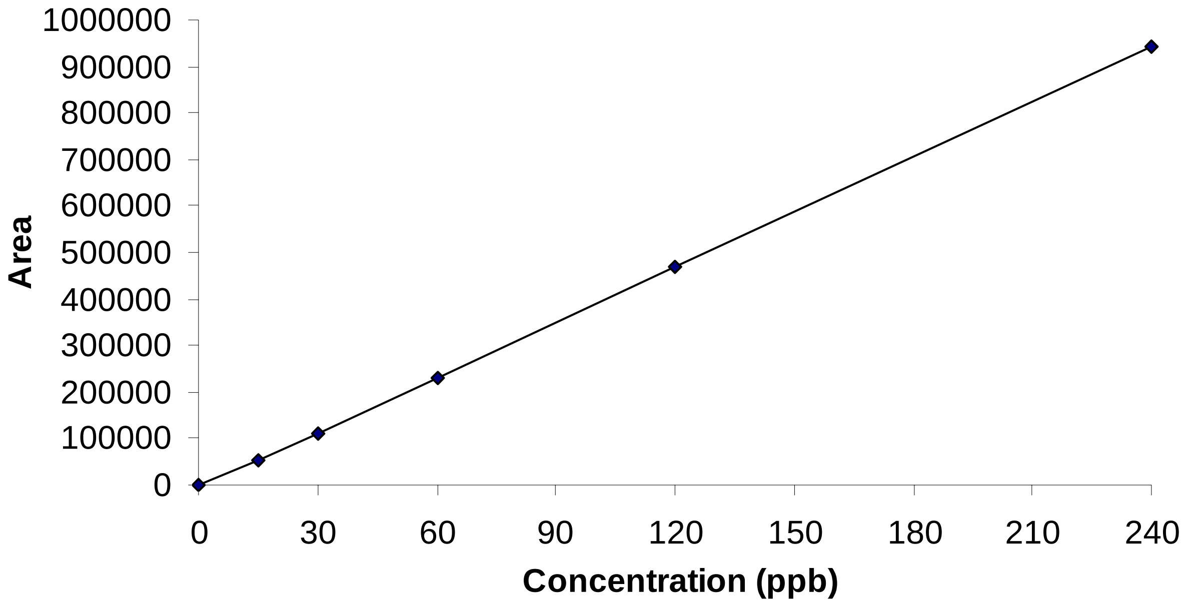


Figure 5-35. The calibration curve of TBT.

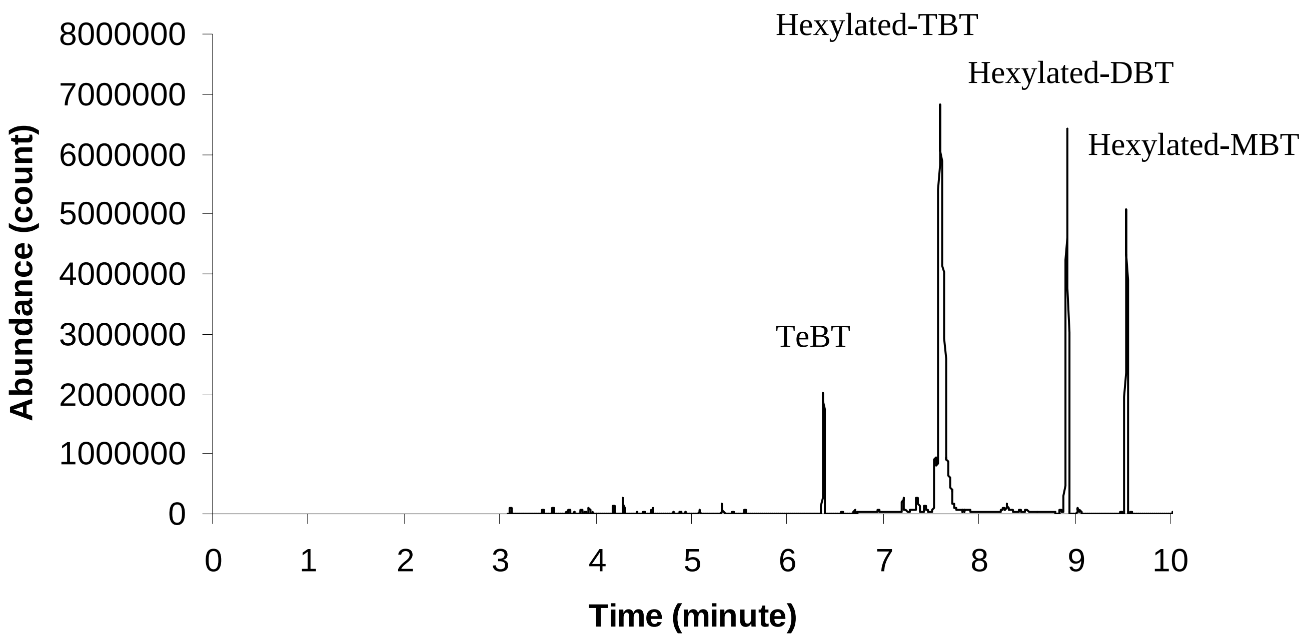


Figure 5-36. The chromatogram of the separation and identification of TBT, DBT, MBT, and TeBT in Scan mode.

5.4.1 Soil samples

Each 10 grams of soil samples at three study areas were analyzed for TBT accumulations. TBT was found in all samples and DBT, MBT, and TeBT were not obviously found in some samples. At Samet, TBT was found in soil samples in the range of 1.42-6.48 ng/g. At Laemchabung, TBT was found in soil samples in the range of 5.76-16.48 ng/g. At Chuksamet, TBT was found in soil samples in the range of 1.30-1.93 ng/g. Moreover, the TBT accumulation at Laemchabung (10.52±2.82 ng/g) was significantly higher than that at Samet (2.46±1.32 ng/g) and Chuksamet (1.56±0.24 ng/g) ($p<0.05$) (Table 5-16, and Figures 5-36 to 5-41).

Table 5-16. Average (mean±SD) of TBT concentrations in soil samples of each zone of three sampling areas. The same letters identified the values that were significantly different ($p<0.05$).

Study area	Zone					Total average (mean±SD)
	1	2	3	4	5	
Samet	2.94±1.19	1.57±1.16	1.88±0.11	3.85±2.35	2.07±0.27	2.46±1.32[a]
Laemchabung	13.17±1.12	8.40±2.67	9.11±0.61	8.46±0.26	13.36±2.83	10.5±2.82 [a,b]
Chuksamet	1.42±0.15	1.57±0.32	1.82±0.01	1.56±0.30	1.41±0.17	1.56±0.24 [b]

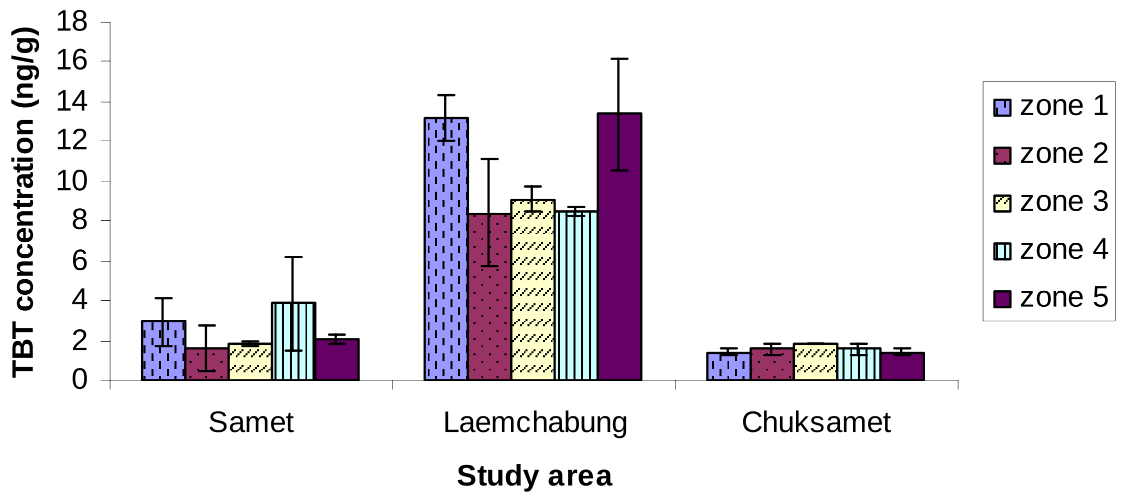


Figure 5-37. Comparing TBT accumulations in soil sample of each zone at Samet, Laemchabung, and Chuksamet.

There was no significant difference in the TBT accumulation among the zones at Samet and Chuksamet. The highest and lowest TBT accumulations at Samet were at zone 4 (3.85±2.35 ng/g) and zone 2 (1.57±1.16 ng/g), and at Chuksamet, zone 3 (1.82±0.01 ng/g), and zone 5 (1.41±0.17 ng/g). While at Laemchabung, the TBT accumulation was highest at zone 5 (13.36±2.83 ng/g) and lowest at zone 2 (8.40±2.67 ng/g) ($p<0.05$) (Table 5-16, and Figures 5-37 to 5-40).

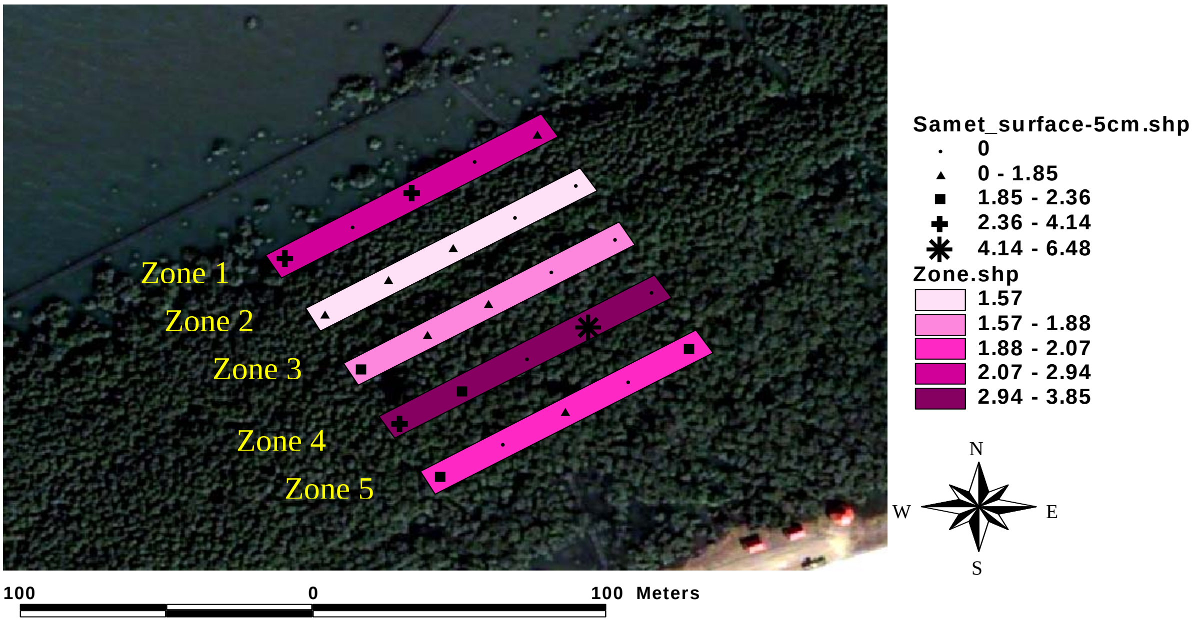


Figure 5-38. TBT accumulation in each plot of each zone of soil samples at Samet.

Figure 5-39. TBT accumulation in each plot of each zone of soil samples at Laemchabung.

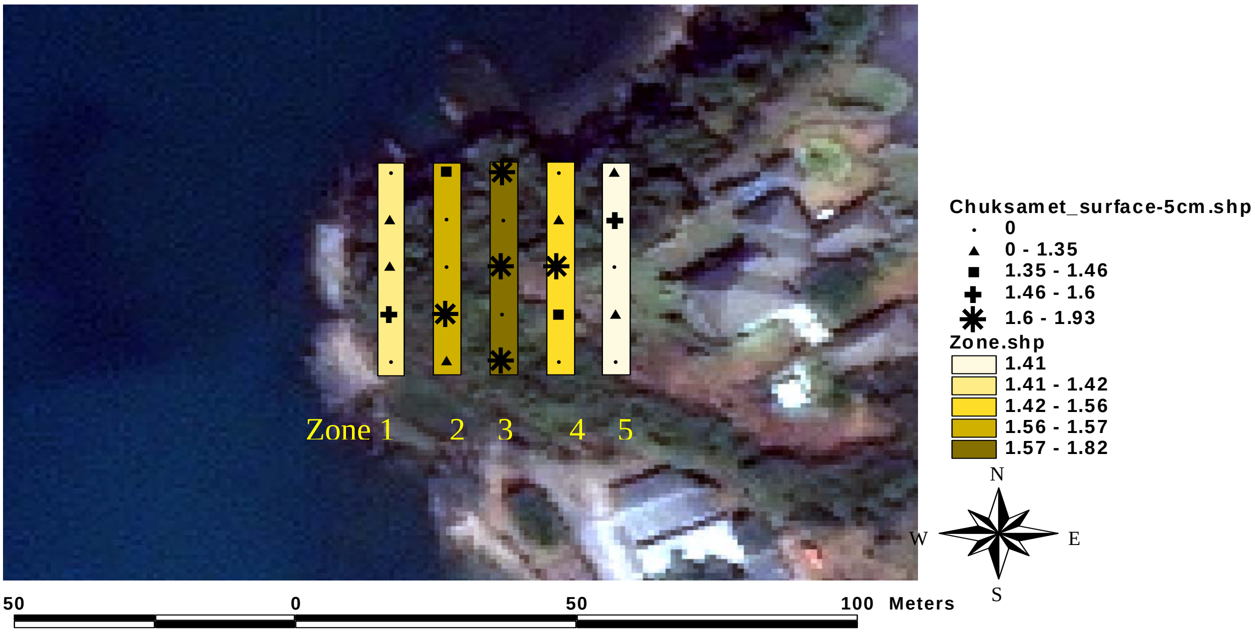


Figure 5-40. TBT accumulation in each plot of each zone of soil samples at Chuksamet.

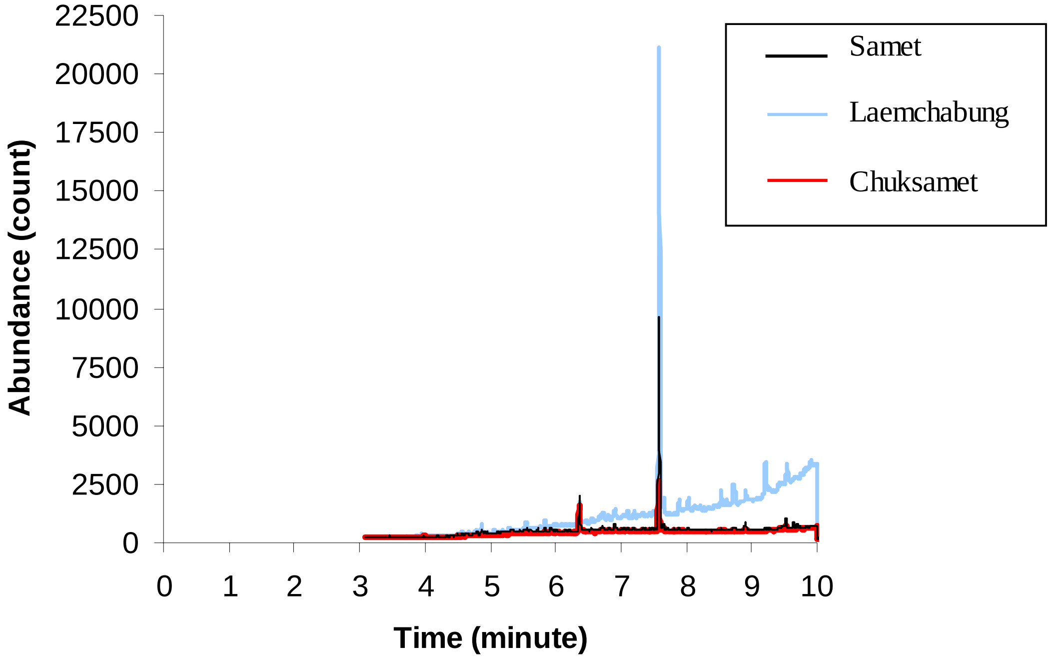


Figure 5-41. Chromatogram of TBT accumulations in soil samples at Samet, Laemchabung, and Chuksamet.

5.4.2 Tissue samples

The TBT accumulations, in range, in *Cerithidea cingulata* and *Cassidula aurisfelis* at Samet, Laemchabung and Chuksamet were 1.06 to 1.57 and 1.06 to 2.22 ng/g ($p>0.05$), 1.30 to 2.56 and 2.78 to 3.85 ng/g ($p<0.05$), and 1.22 to 1.83 and 1.59 to 3.74 ng/g ($p>0.05$), respectively. There was no significant difference in the TBT accumulation in *Cerithidea cingulata* in each study area ($p>0.05$). The TBT accumulation was highest at Laemchabung (1.99 ± 0.64 ng/g) and lowest at Samet (1.35 ± 0.21 ng/g). Similarly, in *Cassidula aurisfelis*, there was no significant difference in the TBT accumulation in each study area ($p>0.05$) which TBT accumulation was highest at Laemchabung (3.39 ± 0.55 ng/g) and lowest at Samet (1.51 ± 0.51 ng/g) (Table 5-17, and Figures 5-42 to 5-45).

Table 5-17. The TBT accumulations (mean±SD) between *Cerithidea cingulata* and *Cassidula aurisfelis* in three study areas with three replicates. (n=3).

Study area	TBT concentration (ng/g)		p-value
	Cerithidea cingulata	*Cassidula aurisfelis*	
Samet	1.35 ± 0.21	1.51 ± 0.51	1.000
Laemchabung	1.99 ± 0.64	3.39 ± 0.55	0.045
Chuksamet	1.59 ± 0.33	2.35 ± 1.21	0.827

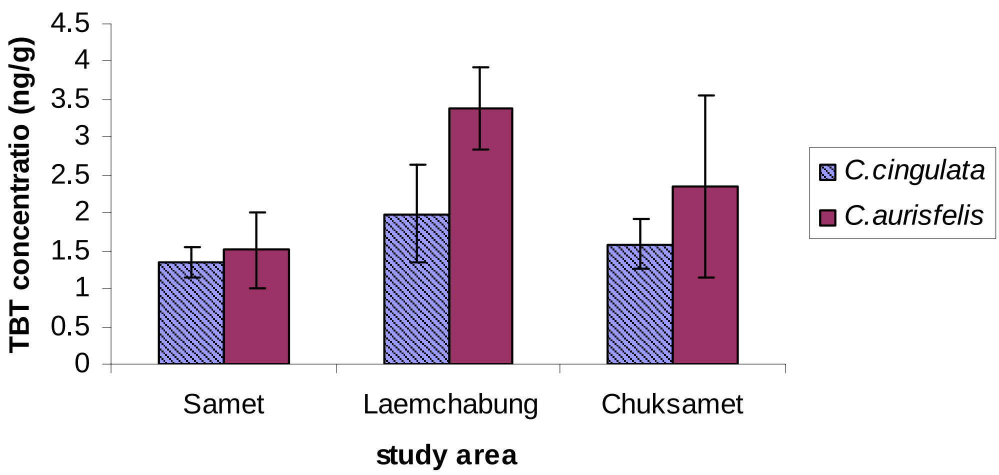


Figure 5-42. TBT accumulation in two gastropod species in three study areas.

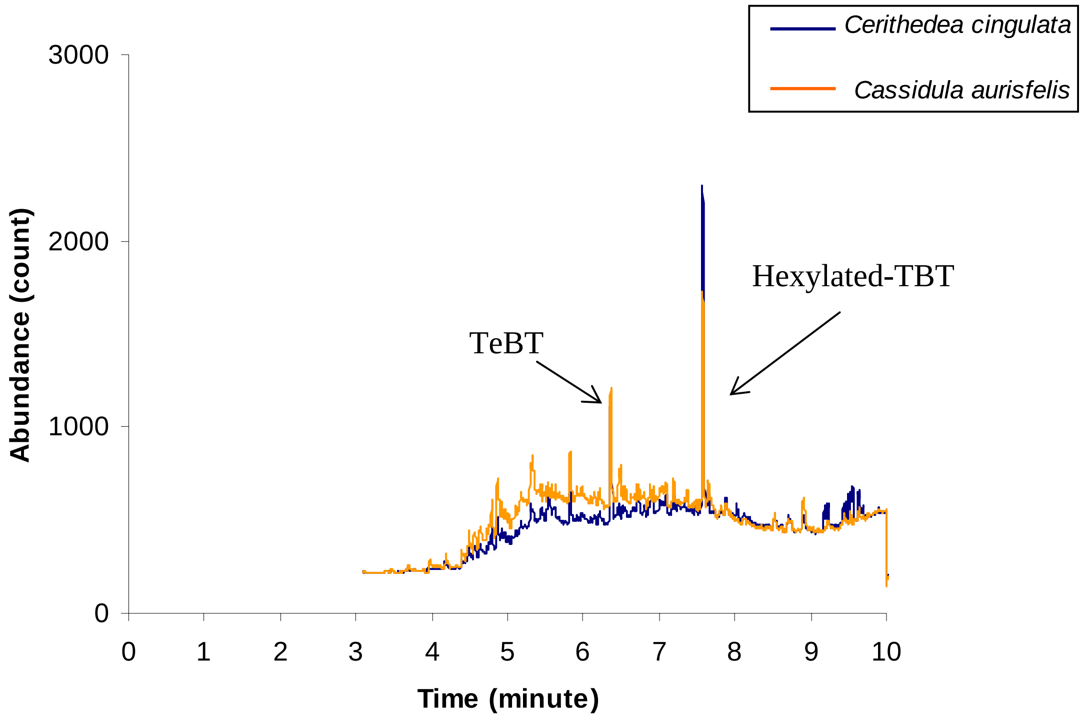


Figure 5-43. Chromatogram of TBT in *Cerithidea cingulata* and *Cassidula aurisfelis* at Samet.

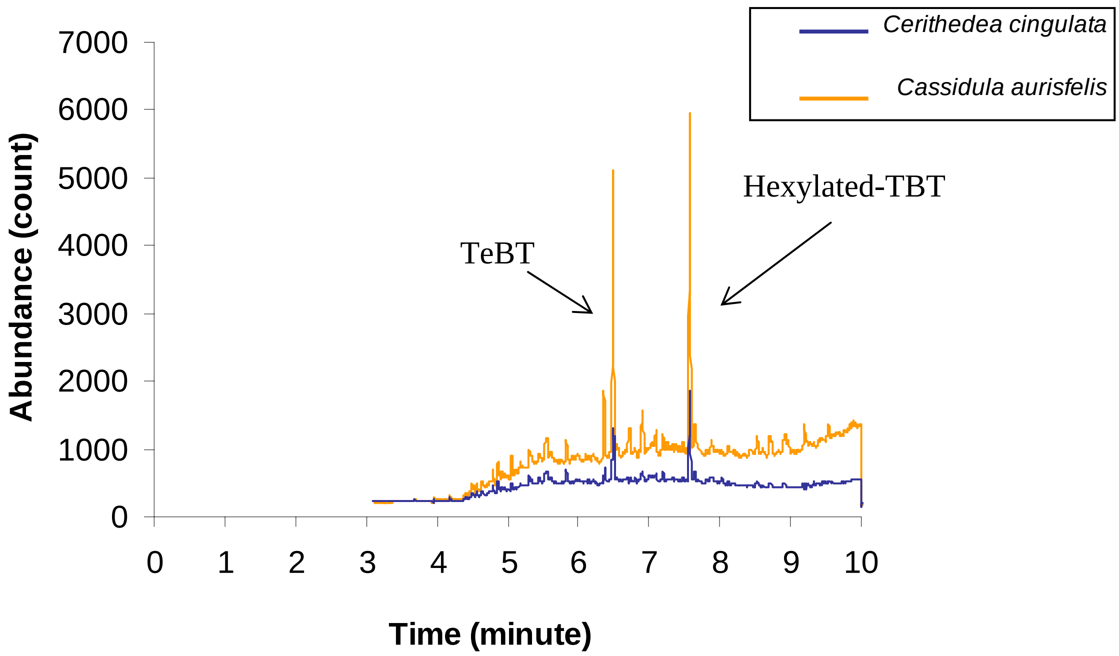


Figure 5-44. Chromatogram of TBT in *Cerithidea cingulata* and *Cassidula aurisfelis* at Laemchabung.

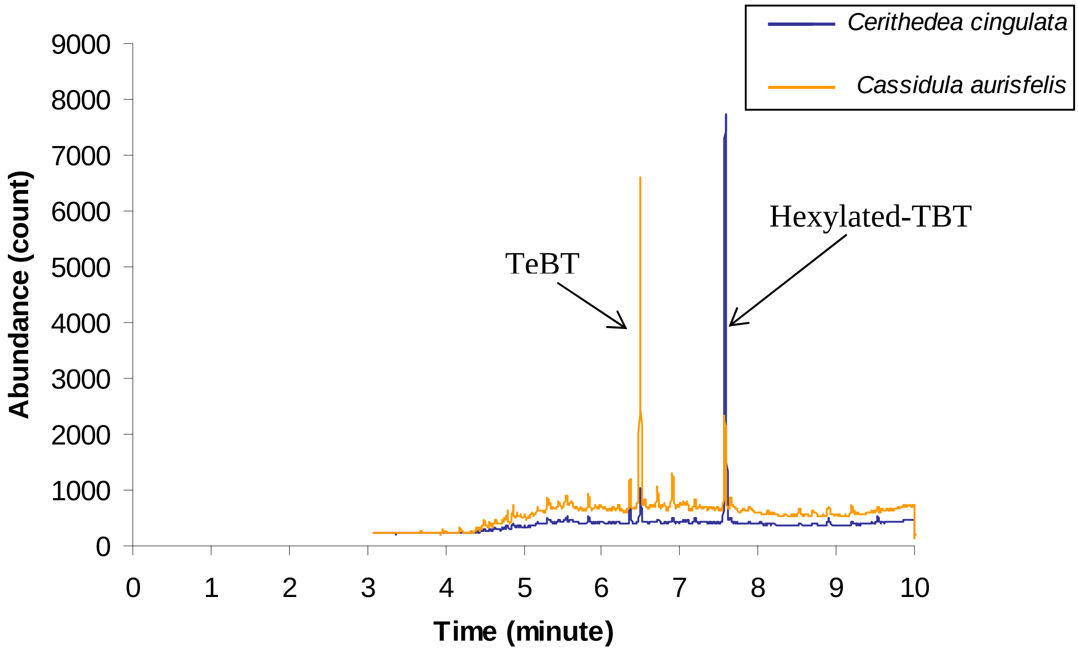


Figure 5-45. Chromatogram of TBT in *Cerithidea cingulata* and *Cassidula aurisfelis* at Chuksamet.

5.5 Relationships

5.5.1 TBT accumulation and physical factors

The Pearson Correlation showed the relationship between TBT accumulation in soil and all physical factor values. At Samet, the TBT accumulation showed no relationship with all physical factors ($p>0.05$). At Laemchabung, the TBT accumulation showed the positive linear relationship with the water temperature ($r^2=0.536$, $p<0.05$), and negative linear relationship with the water salinity ($r^2=-0.560$, $p<0.05$) while the other factors showed the random relationship ($p>0.05$). At Chuksamet, the TBT accumulation showed the positive linear relationship with the soil pH ($r^2=0.514$, $p=0.050$) while the other factors showed the random relationship ($P>0.05$) (Table 5-18).

Table 5-18. The correlation between TBT accumulation and all physical factor values in each study area. P-value was indicated in the brackets.

TBT concentration / Study area	Physical factor						
	Soil pH	Water pH	Soil temperature (ºC)	Water temperature (ºC)	Water salinity (ppt)	Air temperature (ºC)	Humidity (%)
Samet	0.068 (0.809)	0.135 (0.631)	-0.266 (0.338)	-0.139 (0.623)	0.355 (0.194)	0.067 (0.814)	-0.263 (0.344)
Laemchabung	-0.368 (0.177)	0.400 (0.140)	0.272 (0.326)	0.536 (0.039*)	-0.560 (0.030*)	0.348 (0.204)	-0.105 (0.711)
Chuksamet	0.514 (0.050*)	0.135 (0.631)	-0.266 (0.338)	-0.139 (0.623)	0.355 (0.194)	-0.123 (0.676)	0.042 (0.882)

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

5.5.2 TBT accumulation and soil texture

Pearson Correlation showed no relationship between TBT accumulation in soil and soil texture in all study areas ($p>0.05$) (Table 5-19, and Figures 5-46 to 5-48).

Table 5-19. The correlation between TBT accumulation and soil texture in each study areas. P-value was indicated in the brackets.

Soil texture / Study area	TBT accumulation
Samet	
Pearson correlation	-0.256
P-value	(0.356)
Laemchabung	
Pearson correlation	-0.360
P-value	(0.188)
Chuksamet	
Pearson correlation	0.327
P-value	(0.234)

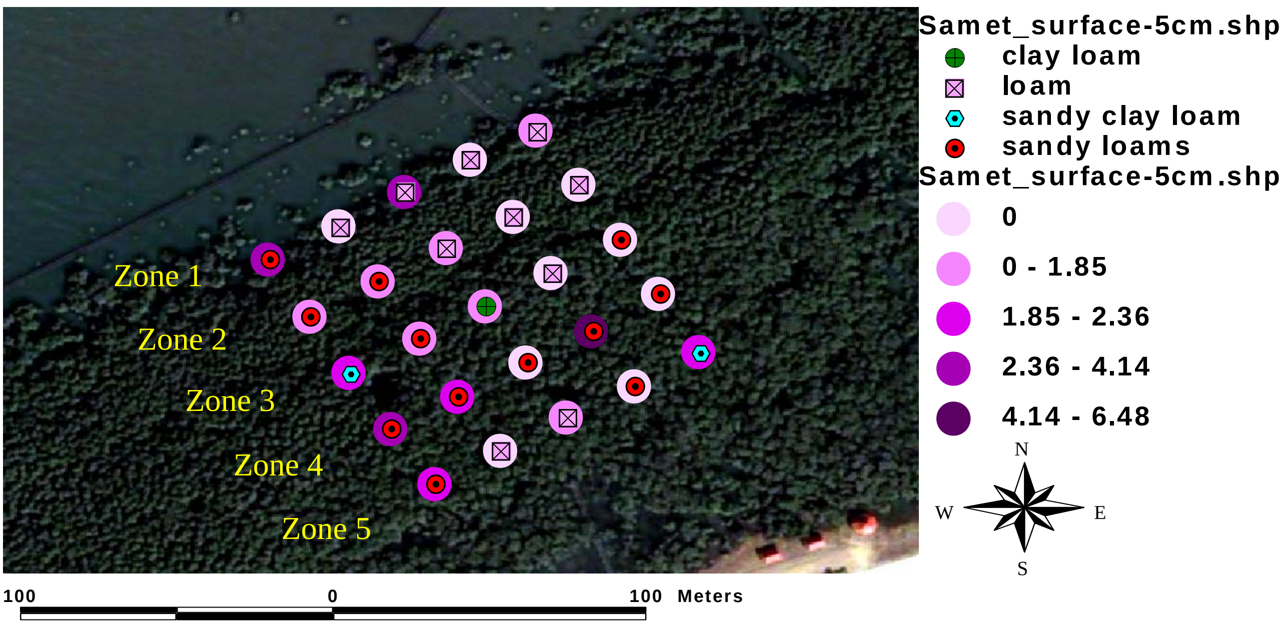


Figure 5-46. The relationship between TBT accumulation and soil texture at Samet.

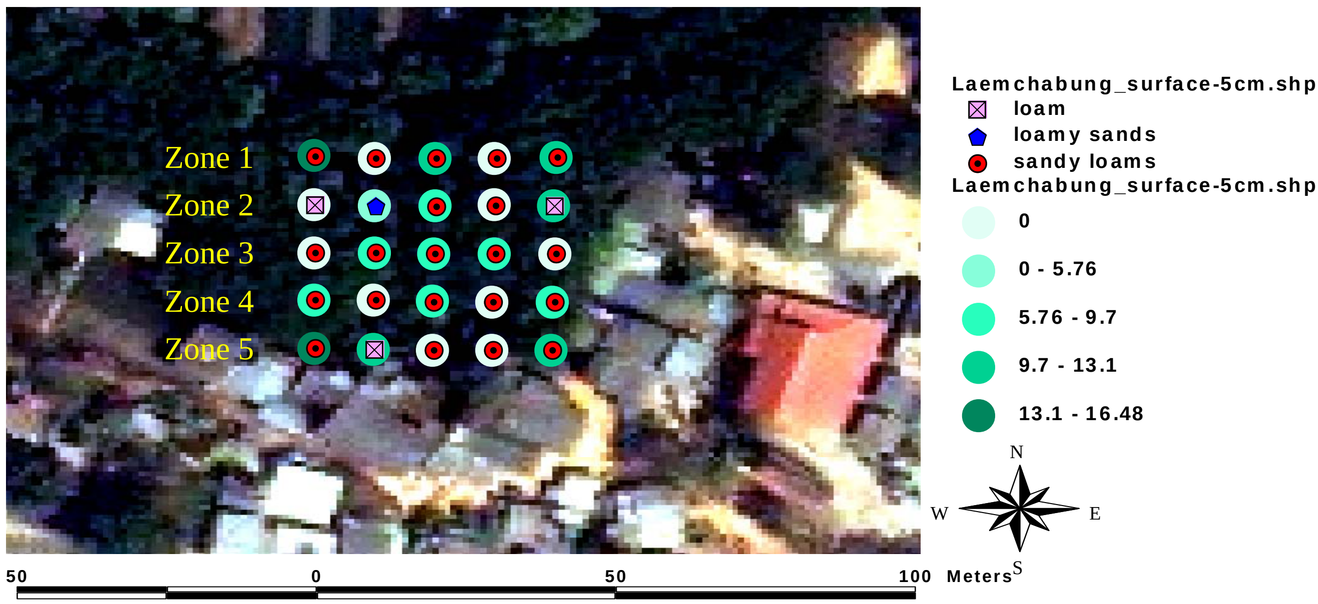


Figure 5-47. The relationship between TBT accumulation and soil texture at Laemchabung.

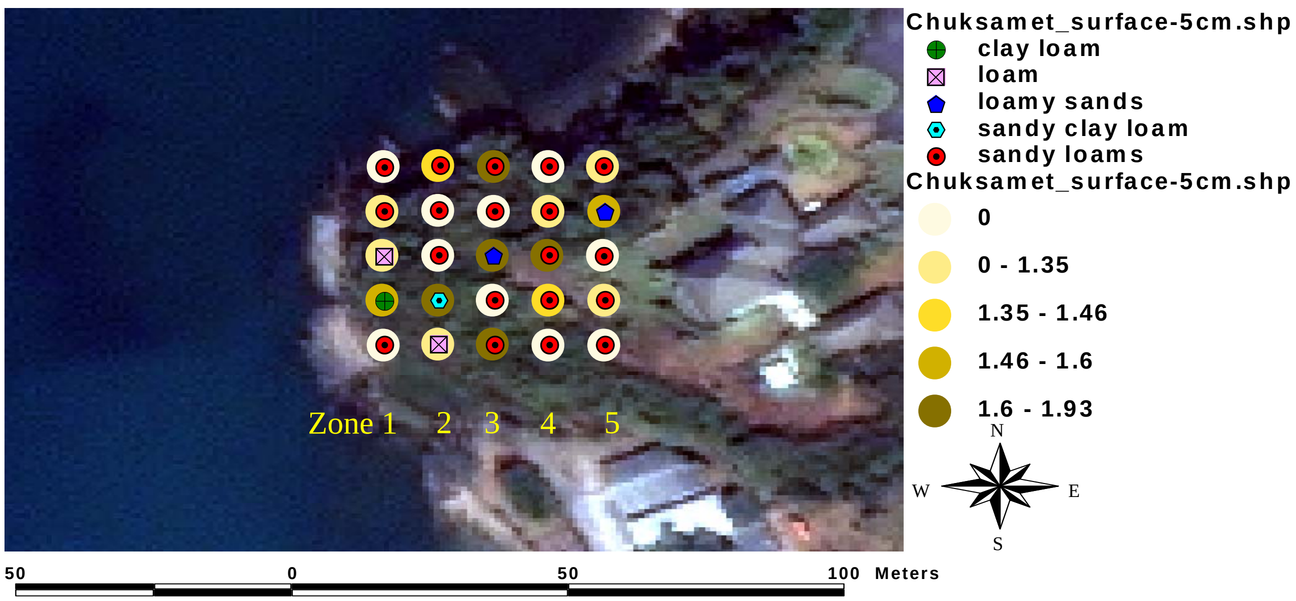


Figure 5-48. The relationship between TBT accumulation and soil texture at Chuksamet.

5.5.3 TBT accumulation and diversity index

The correlations between the TBT accumulation in soil and the diversity index in each zone of each studied area were shown in Table 5-20 and Figures 5-49 to 5-51. The Pearson Correlation showed no relationship between TBT accumulation in soil and soil texture in all study areas ($p>0.05$).

Table 5-20. The correlation between the diversity index and TBT accumulation in three study areas. P-value was indicated in the brackets.

Diversity index / Study area	TBT accumulation
Samet	
Pearson correlation	-0.290
P-value	(0.294)
Laemchabung	
Pearson correlation	0.168
P-value	(0.550)
Chuksamet	
Pearson correlation	0.449
P-value	(0.093)

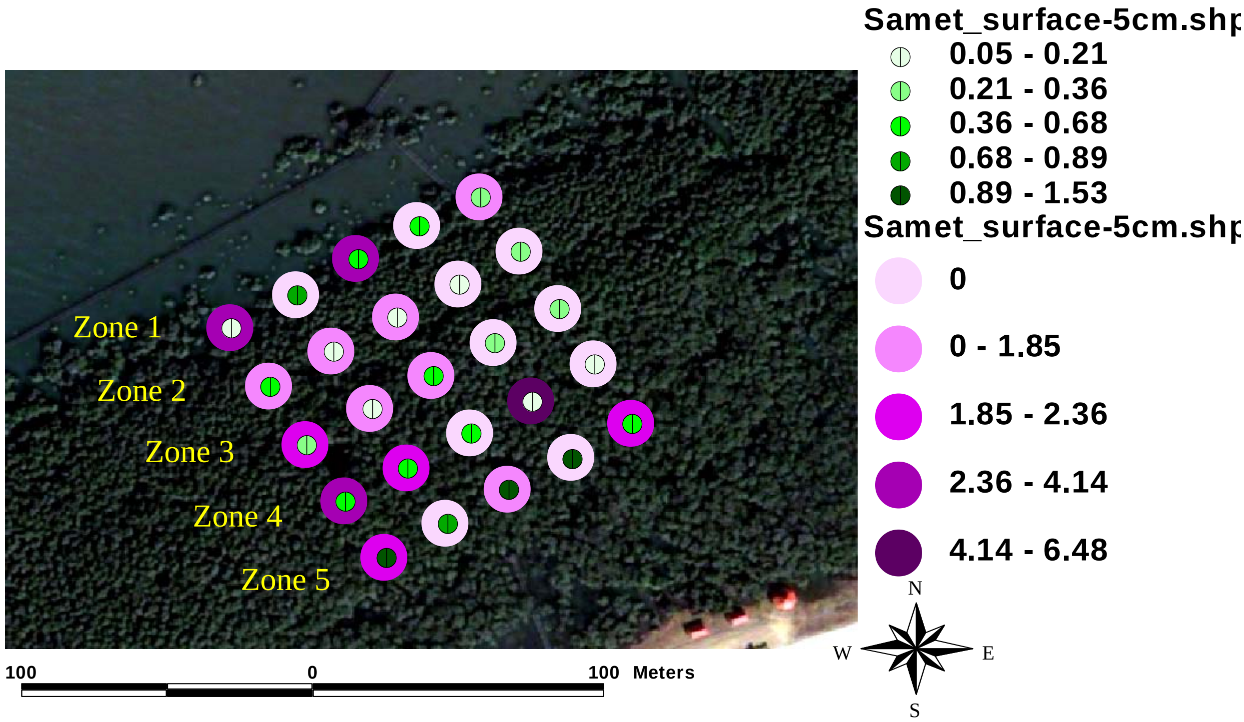


Figure 5-49. The relationship between the diversity index and TBT accumulation in soil at Samet.

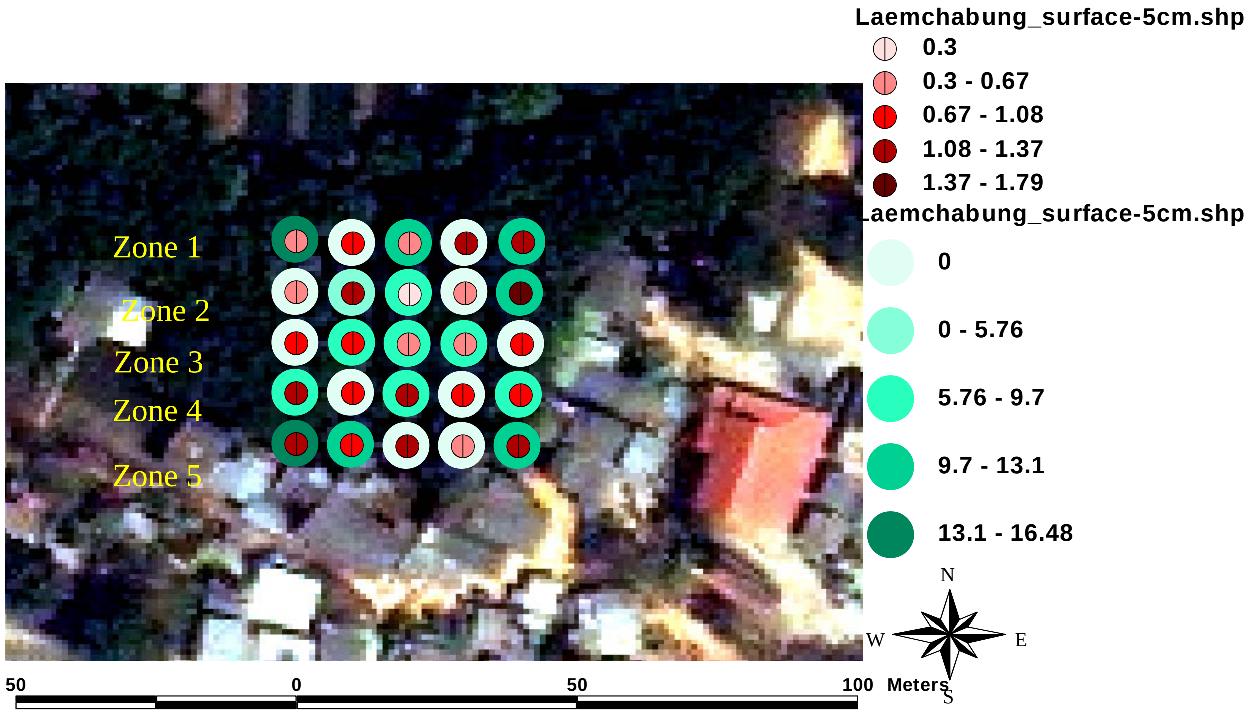


Figure 5-50. The relationship between the diversity index and TBT accumulation in soil at Laemchabung.

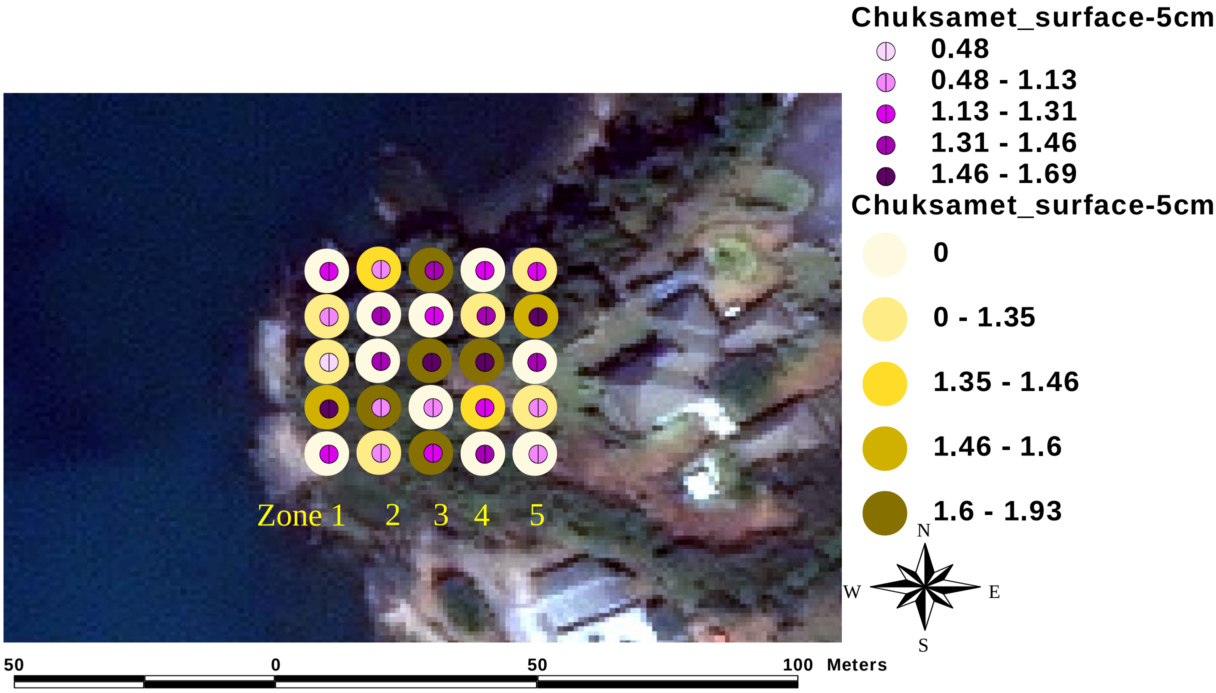


Figure 5-51. The relationship between the diversity index and TBT accumulation in soil at Chuksamet.

5.5.4 Diversity index and physical factors

Pearson Correlation showed the relationship between the diversity index and all physical factors. At Samet, the diversity index showed random relationship with all physical factors ($p>0.05$) except water temperature which showed the positive linear relationship ($r^2=0.456$, $p<0.05$). While at Laemchabung, and Chuksamet, the diversity index showed random relationship with all physical factors ($p>0.05$) (Table 5-21).

Table 5-21. The correlation between the diversity index and all physical factors in each study area. p-value was indicated in the brackets.

Diversity index / Study area	Physical factor						
	Soil pH	Water pH	Soil temperature (ºC)	Water temperature (ºC)	Water salinity (ppt)	Air temperature (ºC)	Humidity (%)
Samet	-0.272 (0.188)	0.256 (0.217)	0.131 (0.534)	0.456 (0.022*)	-0.172 (0.412)	0.280 (0.176)	-0.124 (0.553)
Laemchabung	-0.146 (0.485)	0.108 (0.609)	-0.090 (0.670)	-0.030 (0.888)	-0.011 (0.959)	0.004 (0.984)	0.124 (0.556)
Chuksamet	0.079 (0.708)	-0.158 (0.623)	0.084 (0.691)	-0.376 (0.229)	-0.293 (0.383)	0.181 (0.397)	0.112 (0.596)

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

5.5.5 Diversity index and soil texture

The Pearson Correlation showed the relationship between the diversity index and all soil textures. The results showed no relationship between the diversity index and all types of soil textures at Samet (r^2=0.057, p>0.05), Laemchabung (r^2=0.277, p>0.05), and Chuksamet (r^2=0.053, p>0.05) (Table 5-22, and Figures 5-52 to 5-54).

Table 5-22. The correlation between the diversity index and soil texture in three study areas. P-value was indicated in the brackets.

Diversity index / Study area	Soil texture
Samet	
Pearson correlation	0.057
P-value	(0.788)
Laemchabung	
Pearson correlation	0.277
P-value	(0.180)
Chuksamet	
Pearson correlation	0.053
P-value	(0.802)

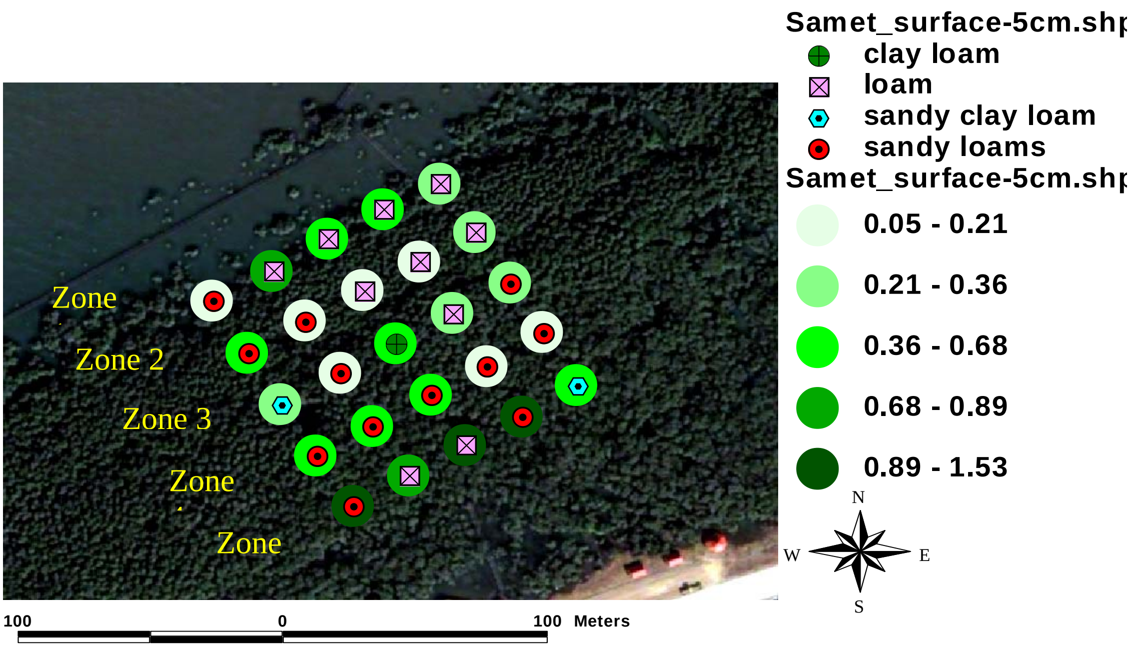


Figure 5-52. The relationship between the diversity index and soil texture at Samet.

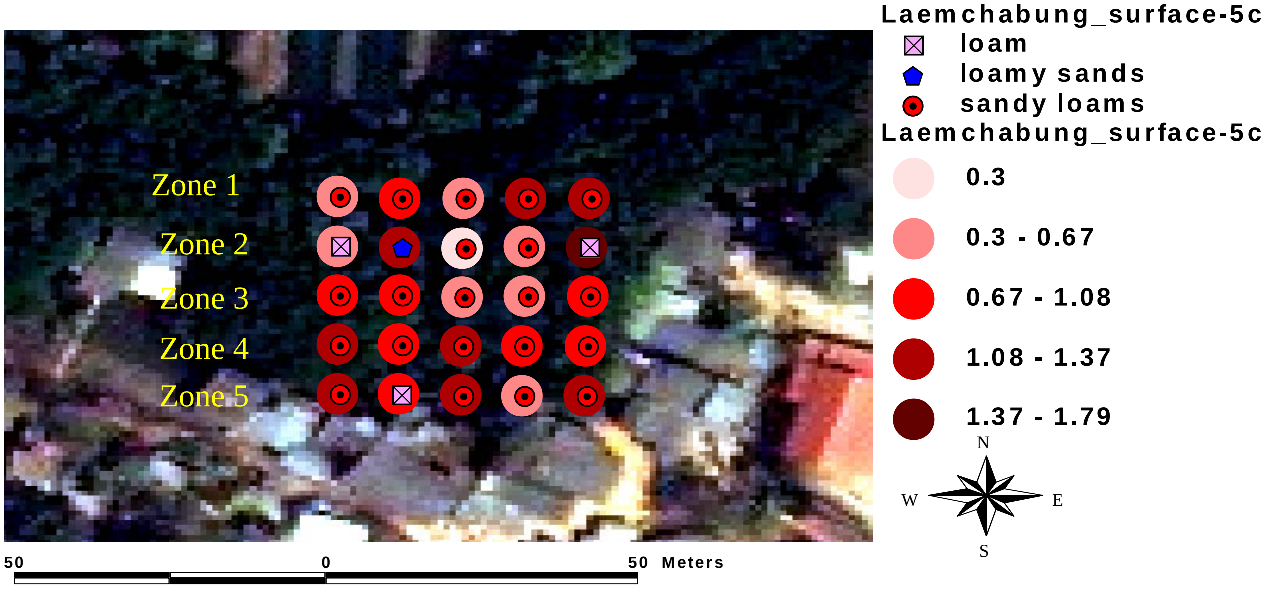


Figure 5-53. The relationship between the diversity index and soil texture at Laemchabung.

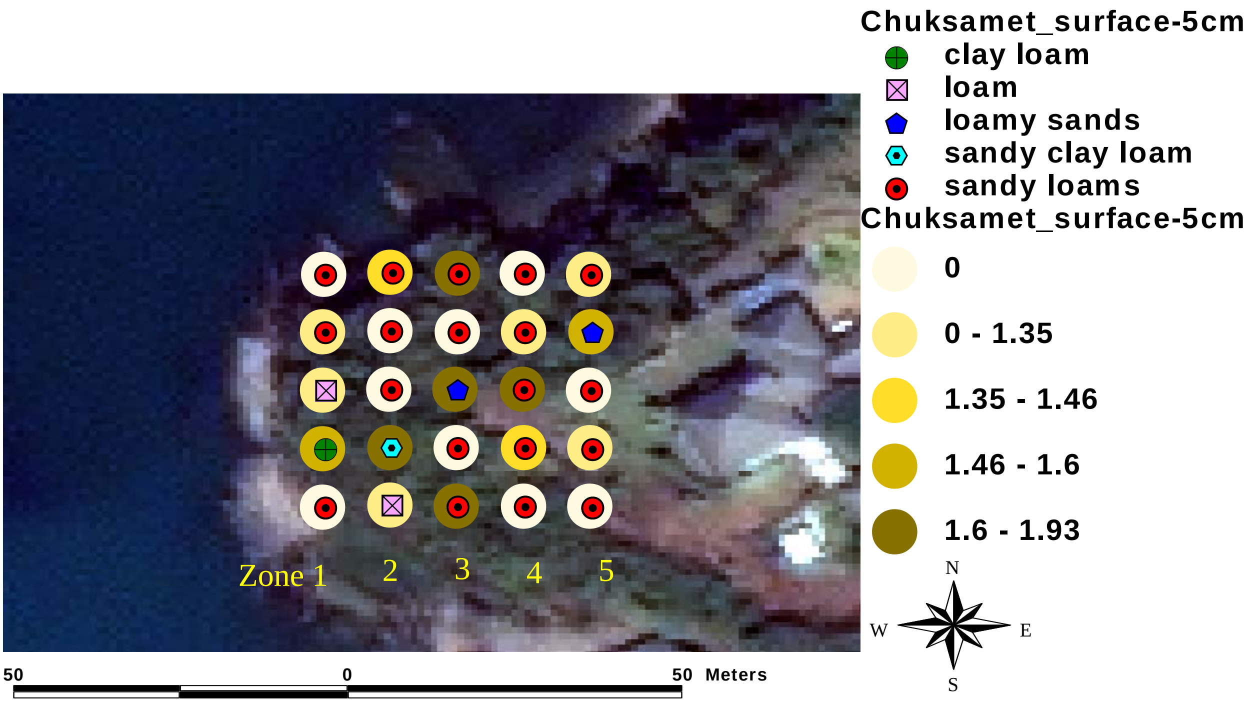


Figure 5-54. The relationship between the diversity index and soil texture at Chuksamet.

CHAPTER VI
DISCUSSIONS

6.1 Species diversity and distribution

In all three study areas, a total of 3,418 gastropod individuals were found. They belonged to 21 species. This was similar to Sasekumar (1974) who found only 25 gastropod species at Malayan mangrove shore. Berry (1972) recorded 32 species of gastropods from Selangor mangroves in Malaysia, Hegerl and Tarte (1974) found 21 species from wetlands near Rockhampton. Besides, Wells and Slack-Smith (1981) collected 14 gastropod species from a mangal in Admiralty Gulf in the Kimberley region of north-western Australia, Morgan and Hailstone (1986) noted 30 gastropod species in south-east Queensland, Bandel and Kowalke (1999) collected 18 species of gastropods at Cameroonian coast of the Atlantic Ocean, etc. The difference of number of species in each area was probably due to mangrove vegetation, sampling technique, area of sampling site, climate (especially temperature), physical factors (especially salinity), competition, tidal fluctuation, soil structure, food source and external disturbances (e.g., pollution), etc.

This study found only epifauna species probably because the underground of mangrove area produced a strong smell of H_2S and there were denser pneumatophores among the mangrove trees in all three study areas which led to the disappearance of infauna species. Anoxic and H_2S conditions that are present in soil layers, was high in the upper and higher in the depth of this zone, also controlled molluscs diversity (Macnae, 1968). According to Wells (1984), the dense root mat in the sediment of the *Avicennia* zone prevented infauna mollusks from being the arboreal species. This study was quite different from those of Wells (1990) who study the mangrove area at Sai Keng, New Territories, Hong Kong. He showed mainly 18 epifauna, and 2 infauna species. Gao and Li (1985) found 22 species of mollusks, 20 epifauna and 2 infauna species. Nevertheless, Jiang and Li (1995) found that there were 34 species, 23 epifauna and 11 infauna species of mangrove mollusks. Wells (1986) mentioned that mollusks among pneumatophores on the seaward fringe of *Avicennia* zone were more diversed and had a greater density and biomass than those among the trees.

The diversity index depended on the evenness value. The diversity index and evenness in this study were highest at Chuksamet and lowest at Samet. This may be because there were various number of individuals of each species at Chuksamet while most individuals represented to the number of one species, *Assiminea brevicula*, at Samet. According to Gray (1974) suggested that the diversity index was maximum when each individual represented a separate species and minimum when all individuals belonged to the same species. Moreover, the diversity indices of three study areas were significantly different (Samet, Laemchabung, and Chuksamet). Samet area contained mostly young *Avicennia* sp. and less dense of root in the sediment while Laemchabung, and Chuksamet areas contained mostly old complexity of mangrove trees and more dense of root. According to Sheridan (1997) and Vilardy and Polanía (2002) showed high diversity of mollusks communities associated with a large number of red mangrove roots. The large number of roots can provide for algae attachment, trapping other organic substances that used as food sources, and protecting them from washing away and predators. Therefore, their distribution pattern was mostly clumped. Boehs *et al.* (2004) suggested the feeding habit of the mollusks also affected their species distribution which directly on food. Guerra-Garcia and Carlos Garcia-Gomez (2004) found that the median grain size, organic matter and the depth of soil were the best explain of the faunal distribution patterns. In addition, Fondo and Martens (1998) mentioned that the physical, chemical, and biological factors might interact with one another in a complex fashion to give changing in macrofaunal densities and distribution patterns. So, the significance in diversity indices in 3 study areas may be because of the difference age of mangrove trees. Also, mature and more complex mangrove communities provided the highest macrofauna diversity (Macintosh *et al*., 2002), and epifaunal diversity, density and biomass in mature *Rhizophora apiculata* zone (Sasekumar and Chong, 1998).

Littorinidae and Ellobiidae were the most diversed families in this study. This was similar to the study of Macintosh *et al.* (2002). Macnae (1968) also suggested that these two families have been found in many mangrove areas in Southeast Asia. This abundance may be because they were large in size (more obvious), and they lived at the high levels from the sediment which could protect them from predators such as crabs. Sanpanich *et al*. (2004) showed in details that *Littoraria* sp. was the most occurred species in mangroves especially in the tree zones. Also, Reid (1986) mentioned that *Littoraria* was predominantly tropical and inhabited on mangrove trees, salt marsh vegetation, driftwood and wooden pilings. There were five species: *Littoraria carinifera, L. strigata, L. melanostoma L. articulata* and *L. pallescens* that are generally found in the upper Gulf of Thailand. Reid (1986) suggested that *Littoraria* sp. liked to feed on the hairs of *Avicennia* leaves, grazed on the surface layers of trunks and roots where they fed on micro-epiphytes. Lee *et al*. (2001) showed that they fed on the lower levels of the trees where there were more essential nutrients than the upper level. Sasekumar (1974) suggested that most of the gastropod species living at high levels in mangrove forests were adapted for partially terrestrial existence. Apart from air-breathing ellobiids, some of the tree-dwelling prosobranchs had their mantle cavities converted into the lung for gas exchanging.

Littoraria calinifera and *Assiminea brevicula* were found in all zones of this study. This may be because *L. calinifera* had larger sizes, making them particularly obvious, and they were well adapted to this habitat. Underwood and Chapman, (1996) supported that the distribution of littorinids was patchy, probably behaviorally determined which was known to cause individuals to aggregate in favorable locations. *A. brevicula* had smaller sizes that can be easily dispersed by floating or washing out by tidal currents. They were easily found because of they existed as red clumps on the mud. This was similar to Suzuki *et al*. (2002) who mentioned that this species generally inhabited the mangrove forest in great abundance which the population densities in the inner part of the forest tended to be greater than those on the mudflats. Frith *et al.* (1976) mentioned that *Assiminea brevicula* was the most widespread epifauna in southern Thailand.

Assiminea brevicula, *Melanoides tuberculata*, and *Clithon oualaniensis* were the dominant species at Samet, Laemchabung, and Chuksamet, respectively. At Samet, *Assiminea brevicula* was found at the highest density (19.6 to 73.6 snails /m^2). This may be because this area has the appropriate organic content in soil and more landward for *Assiminea brevicula*. According to Macintosh *et al*. (2002) suggested that assimineids played an important role in the detritus decomposition and Suzuki *et* *al*. (2002) who mentioned that this species found in great abundance which the population densities in the inner part of the forest. Also, Lee *et al*. (1996) reported that this species appeared in great abundance (>200 snails /m^2) in *Avicennia alba* dominated mangrove forest in Singapore. The mangrove forest at Laemchabung had the large freshwater channel near zone 1 which caused high densities of freshwater species, Thiaridae, *Melanoides tuberculata*. According to Brandt, (1974) who mentioned that among the freshwater mollusks which were at high salinity in mangrove habitats, Thiaridae such as *Melanoides tuberculata*, and *Sermyla riqueti*, etc. were generally considered as salinity sensitive in this ecosystem. *Clithon oualaniensis* were found to be the most abundant at Chuksamet at zone 1 (intertidal zone). This might be because they had the suitable physical factors, the organic content, and soil texture for this species. This is similar to Ohgaki, (2001) who found that *Clithon oualaniensis* were often dense on the intertidal sand-soil flat on Ishigaki Island of the Ryukyu Islands. Laemchabung and Samet had the similarity index of 78.56%. This is probably due to the location of these two areas. Laemchabung and Samet are located in the upper part of Chonburi province and are not far from each other while Chuksamet is located in the lower part of Chonburi province. This led to the differences in mangrove habitat, sediment, physical factors, tidal fluctuation, and external disturbances (e.g., pollution), etc.

6.2 Physical factors

The another reason, the differences in diversity index were due to the physical factors, soil textures, predators, urbanization, industrialization, and other pollutants, etc. The salinity was the most important factor compared with others such as temperature, tide, and sediment, etc. The diversity of mollusk species decreased with the decrease in salinity (Jiang and Li, 1995). The appropriate soil pH condition caused the high diversity of gastropods (Wells, 1983). The lack of moisture during extended emersion periods and also high stress due to exposure to sun might cause the low diversity of gastropods (Morgan and Hailstone, 1986). In contrast, this study found no relationship between diversity index and all physical factors at all three sites ($p>0.05$), except for water temperature at Samet. This may be because of new mangrove forest plantation that provides less shelter area. Therefore, high water temperature in the mangrove forests at Samet. In contrast to Laemchabung and Chuksamet that contained denser of mangrove trees that protected the sediment from heating dying during day time. Blanco & Catera (1999) found that temperature was an important factor for intertidal communities that control the number of mollusks in the mangrove vegetation. According to Blanco & Cantera (1999) suggested higher temperatures from more open canopies in an early stage of succession of mangrove forests offer less habitat or refuge for the mangrove animals. Fondo and Martens (1998) suggested that the cutting down of mangrove forests resulted in significant manipulation of physical factors such as temperature, through intense heating. The deforested area recorded higher temperature. This had an effect on the chemical factors such as salinity and manipulation of these environmental factors together, would affect the macrofauna populations. So, the greater the structural complexity of mangrove forests, the effects of temperature that may be also affect epifaunal mollusks community that show high diversity, density and biomass generally occurred at mangrove vegetated habitat (Wells, 1986; Jiang and Li, 1995; Sasekumar and Chong, 1998).

6.3 Soil texture

The soil texture is another important factor for diversity index of mollusks, especially bivalves. The multivariate analysis showed the percentage of sand in the sediments influenced the distribution of the macrofauna and the distribution of the mollusk fauna seemed to be more affected by the granulometry of sediment than the depth (Guerra-Garcia and Carlos Garcia-Gomez, 2004). Therefore, there were more affected to the infauna than the epifauna. Ruwa (1988) showed that species diversity increased when sediment textures changed from sand to mud. Because the soil texture of three study areas were usually sandy loams and the studied mollusks were epifauna gastropods, the soil texture in this study had no significant difference with diversity index in mangrove gastropods species.

6.4 TBT analysis

All samples in the three study areas showed TBT accumulations in their tissues detected by GC-MS. Greaves and Unger (1988) suggested that GC-MS method provided both sensitive quantification and structural identification of butyltins in every sample analysis. The results showed that these study areas had various used of TBT as antifouling paints on ships, boats, nets, crab pots, and water cooling towers, etc. According to Visoottiviseth *et al.* (1995), Thailand had a large and ready market for the application of organotins, especially in the agriculture sector. Besides, TBT concentrations in the marine environment have been strongly correlated with the presence of boating activity, as TBT is commonly applied to vessels for antifouling purposes (Huggett *et al*., 1992).

The TBT accumulation in soil samples showed the highest at Laemchabung (5.76-16.48 ng/g) and the lowest at Chuksamet (1.30-1.93 ng/g). In general, the high levels of TBT in water and sediment samples have been associated with boating activities where TBT-based antifouling paints were applied on boat hulls, and found within marinas, small boat harbors and adjacent to vessel repair facilities (Grovhoug *et al*., 1986) and shipyard hull washing/refinishing activities (Page *et al*., 1996). This TBT accumulations in these sediments were lower than those of the previous reports: 4-4,500 ng/g (Kan-atireklap *et al*., 1997), 60-1,160 ng/g at Marina area in Hong Kong (Lau, 1991), 70-3,400 ng/g in Mediterranean Sea (Gabrielides *et al*., 1990), 24-12,400 ng/g at Portland and Boothbay Harbor, USA. (Page *et al*., 1996). In the present study area, the quite low TBT accumulation in sediment at Chuksamet may be due to a ban on TBT use as antifouling agent in the Thai Navy ship which corresponding with National countries. The other reason probably because of the soil texture in this area (mostly sandy loams) has the low affinity to TBT concentration. According to Hoch *et al*. (2003), they mentioned that the adsorption of organotin to sediments was increased if there was an increase in clay content. Also, Dooley and Homer (1983) suggested that TBT sorption was reversible and the clay content in sediments had a profound effect on adsorption of organotin compounds. The adsorption and concentration onto this fraction is an important control mechanism concerning distribution and fate of organotins in the environment, and the higher levels of pollutants in sediments were associated with less content of sand and consequently, higher content of silt and clay

(Guerra-Garcia and Carlos Garcia-Gomez, 2004). However, there were no relationship between TBT accumulation and soil texture at Samet, Laemchabung, and Chuksamet. This may be because there are no adequate of samples for TBT analysis leading to hardly compare the correlation in statistic. Also, the physical factors in this area such as temperature, salinity, and pH, etc. maybe appropriate to TBT degradation products, monobutyltin (MBT) and dibutyltin (DBT). At Chuksamet, soil, water, and air temperature showed the highest value leading to found low TBT accumulation in all soil samples. According to Hoch (2001) suggested that photolysis by sunlight appears to be the fastest route of degradation of Butyltins. TBT half life in surface aerobic sediments was reported to be in the range of 113-775 days (Waldock *et al*., 1990, and Dowson *et al*., 1993) while in anaerobic sediments TBT half life was more than ten years (Dowson *et al*., 1993).

From the three study areas, tissue samples of *Cassidula aurisfelis* (1.06-3.85 ng/g) showed more TBT accumulation than that of *Cerithidea cingulata* (1.06-2.56 ng/g). This may be because *Cerithidea cingulata* can metabolize TBT better than *Cassidula aurisfelis*. Moreover, *Cerithidea cingulata* were found at high density on the sediment surface, therefore, they have to adapt themselves for TBT tolerance in the environment. While *Cassidula aurisfelis* were rare on the sediment surface and they were observed to climb up on trees. Also, they are the pulmonate species (no operculum) that can accumulate TBT more than *Cerithidea cingulata*. Moreover, TBT accumulations in tissue samples of *Cassidula aurisfelis* and *Cerithidea cingulata* were found to be highest at Lemchabung and lowest at Samet. This result probably was due to the location of Laemchabung area which is very close to the harbor. According to, Page and Widdows (1991) suggested that the source of TBT was from antifouling paints. Several studies have the existence of TBT contamination in harbors, marinas, shipyard, washing/refinishing and boating activities. Moreover, the concentrations of TBT in mussels collected from boating areas such as Sichang Island, Chonburi province (200 ng/g) and Yong Star, Trang province (89 ng/g) have higher TBT concentrations than this study. In addition, it is the bay area where TBT can be stored at higher concentration than other areas. Samet area was close to the household than the harbor but shipping activities and coastal aquaculture facilities still existed which led to the detection of low TBT in all tissue samples. However, this study found the low TBT accumulation in all tissue samples. This may be because TBT easily deposited in the sediment along the coastal area and around the harbor before penetrate to the mangrove forest.

TBT has been shown to produce the superimposition of male characteristics on female neogastropod snails (Gibbs and Bryan, 1987) and low concentrations of TBT present in the marine environment have been associated with the occurrence of imposex (Bryan *et al*., 1986; Gibbs and Bryan, 1987). However, this study did not show the imposex of female snails in *Cassidula aurisfelis* and *Cerithidea cingulata*. This may be because these two species were not sensitive to TBT and were not suitable as a biological indicator of TBT contamination but found TBT accumulations in their tissues. Similar to the study of Gibbs *et al*. (1990) who mentioned that *Ocenebra erinacea* did not show imposex at high TBT concentration (185 ng/g TBT dw.), but female organs were deformed. There were no clear sign of imposex seen in dogwhelk gastropods populations containing less than 10 ng/g TBT dw. (Folsvik *et al*., 1999). In contrast to Horiguchi (1995) the imposex was induced in adult females of *Thais clavigera* at about 20 ng/g ww. of TBT accumulation in gastropod species in Japan, Short and Sharp (1989) suggested that all *Nucella lima* near marinas exhibited imposex and contained 30-160 ng/g TBT dw. at Auke Bay. Bryan *et al*. (1993) and Barreiro *et al*. (2001) mentioned that *Nassarius reticulatus* showed well developed imposex in TBT tissue concentrations which varied between 100-500 ng/g TBT dw., and still higher than 2200 ng/g TBT dw. in this species in NW Spain (Barreiro *et al*., 2001). Thus, TBT pollution in environment might cause various symptoms on the affected organisms, such as thickening of shell and failure of spat in oysters (Alzieu *et al*., 1986), imposex of neogastropods and gastropods (Bryan *et al*., 1988 and Gibbs *et al*., 1991), retardation of growth in mussels (Salazar and Salazar, 1991), and immunological dysfunction in fish (Suzuki *et al*., 1992), etc. These symptoms shall be affected to diversity, and distribution of organisms in each habitat such as reduction of the dogwhelk population (Gibb *et al*., 1991). However, this study found no relationship between TBT accumulation and diversity index in all three sites. A possible explanation is quite low level of TBT concentration in all soil samples leading to no effect on population of gastropod species in three study areas. This study found widespread contamination along the coastal area in Chonburi province but the concentration lower than the previous study. Thus, the regulation of TBT used as antifouling paint may be under control at Chonburi province.

CHAPTER VII
CONCLUSION

All physical factors showed the strong significant difference in each zone of all study areas, except for the soil pH. The soil and water pH values the highest at Samet while the lowest at Chuksamet and Laemchabung. The soil, water and air temperatures were highest at Chuksamet and lowest at Samet. The air temperatures were correlated with the humidity values in all three sampling areas. Besides, the salinity value was highest at Laemchabung and lowest at Chuksamet.

Twenty-one gastropods species were found in all three study areas. Out of these, eight species were found in all three sampling sites; *Cassidula aurisfelis*, *Cassidula multiplicata*, *Cerithidea cingulata*, *Cerithidea obtusa*, *Melanoides tuberculata*, *Littoraria calinifera*, *Littoraria palescene*, and *Clithon oualaniensis*. Littorinidae was the most diverse family at Laemchabung, and Samet while Ellobiidae was the most abundant family at Chuksamet. In all three sites, Potamididae was the second order of diverse family from Littorinidae at Laemchabang and Samet, and Chuksamet, respectively. In all three study areas only epifauna gastropods species were found *Littoraria calinifera* was found in all zones of all three sites. Also, *Assiminea brevicula* was found in all zones at Laemchabung, and Samet but they were not found at Chuksamet. The highest and lowest number of individuals and density were at Samet and Laemchabung, respectively. Whereas, Laemchabung showed the highest and Samet showed the lowest richness value. The evenness, and diversity index values were the highest and lowest at Chuksamet and Samet, respectively. The similarity index value was the highest and lowest between Laemchabung and Samet, and Samet and Chuksamet, respectively. There were no significant differences, among zones, of evenness, richness, density, and diversity index values at Laemchabang and Chuksamet ($p>0.05$). Whereas there were significant differences these values among zones at Samet ($p<0.05$). *Assiminea brevicula*, *Melanoides tuberculata*, and *Clithon oualaniensis* were the dominant species at Samet, Laemchabung, and Chuksamet, respectively. However, the distribution pattern was mostly clumped in all three study areas.

There were four, three, and five types of soil textures at Samet, Laemchabung, and Chuksamet, respectively. However, the most common type of the soil texture in all three study areas was the sandy loams. TBT accumulation in soil sample was highest at Laemchabung and lowest at Chuksamet. TBT accumulations showed strong significant difference among sites of each sampling area in all three study areas ($p<0.05$).

At all three study areas, *Cassidula aurisfelis* accumulated more TBT than *Cerithidea cingulata*. The TBT accumulations in their tissues at Laemchabung showed a significant difference ($p<0.05$). However, *Cerithidea cingulata* showed no significant difference of TBT accumulation in all three areas ($p>0.05$) while *Cassidula aurisfelis* showed significant different between Laemchabung and Samet ($p<0.05$). The highest and lowest TBT accumulations in gastropod tissues were found at Laemchabung and Samet, respectively.

There was no correlation ($p>0.05$) between the diversity index and all physical factors in all three study areas, except for the water temperature at Samet. Also, the results showed no correlation ($p>0.05$) between the TBT accumulation and all physical factors in all three study areas, except for the salinity and water temperature at Laemchabung, and soil pH at Chuksamet. There was no correlation ($p>0.05$) between the TBT concentration and soil texture at Laemchabung, Chuksamet, and Samet. Similarly, there were no correlations ($p>0.05$) in soil texture, diversity index and TBT accumulation in all three study areas. According to this study, at all three study areas, the TBT accumulations in sediments and gastropod tissues did not exceed 10.5 and 3.40 ng/g TBT, respectively. These results showed that the global ban on the use of TBT as the antifouling paint at Chonburi Province is effective.

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APPENDIX

APPENDIX A

Mangrove forest characteristic

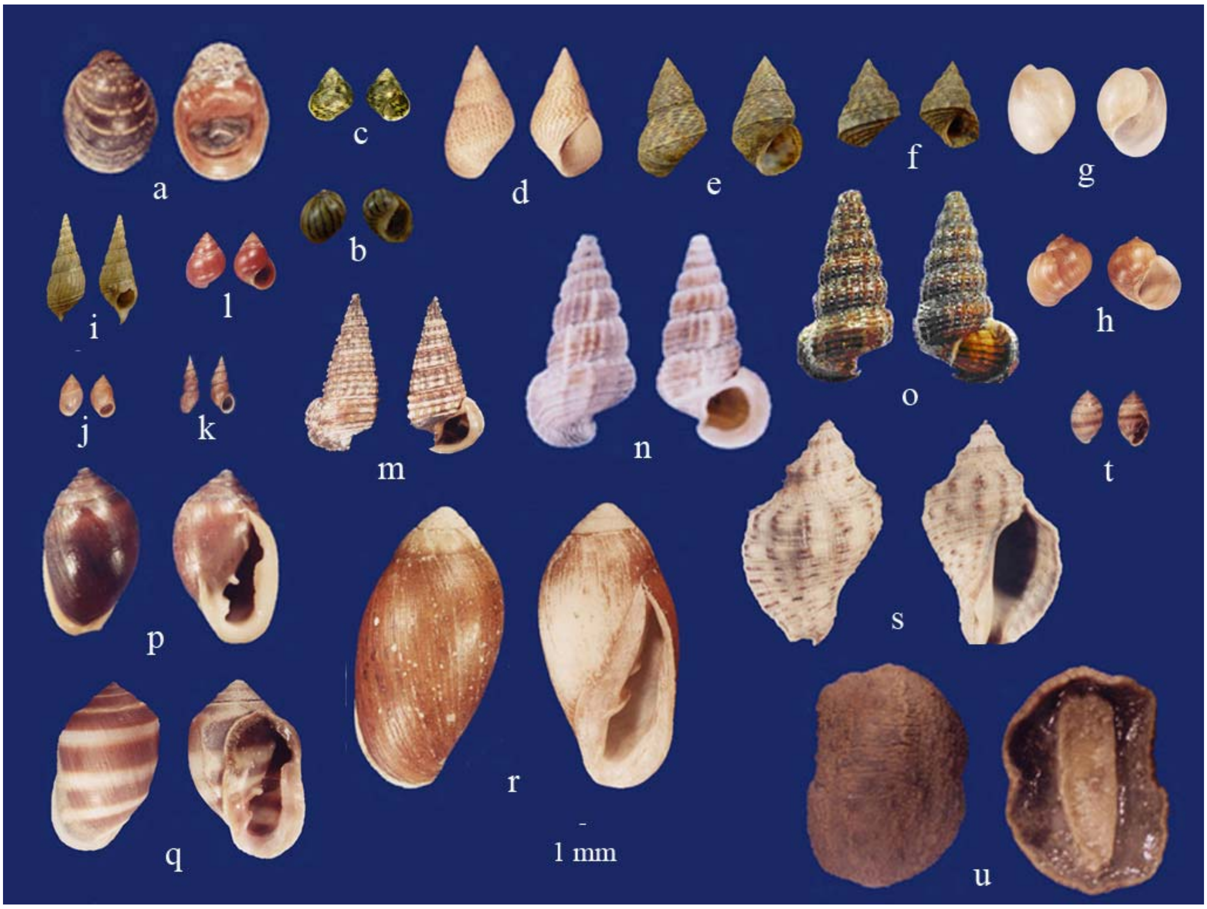
Representative of mangrove forest characteristic at Samet District.

Representative of mangrove forest characteristic at Laemchabung.

Representative of mangrove forest characteristic at Chuksamet.

APPENDIX B

Shell characteristic



a, *Neritina violacea;* b, *Clithon oualaniensis; c, Littoraria strigata; d, Littoraria melanostoma; e, Littoraria palescene; f, Littoraria calinifera; g, Haminoea succinea; h, Salinator burmana; i, Melanoides tuberculata; j, Stenothyra sp.; k, Fairbankia sp.; l, Assiminea brevicula; m, Cerithidea cingulata; n, Cerithidea obtusa; o, Cerithidea quadrata; p, Cassidula aurisfelis; q, Cassidula multiplicata; r, Ellobium aurismidae*; s, *Chicoreus capucinus; t, Laemodonta siamensis; u, Platevindex sp.*

APPENDIX C

GIS database table

Samet

COORD_X	COORD_Y	ID	Individuals	Species	*C. cingulata*	*C. obtusa*	*Cliton sp.*	*Melanoides sp.*	*C. aurisfelis*	*C. multipli cata*	*L. melanost oma*	*L. calinifer a*	*L. palescene*	*L. articulata*	*N. violacea*	*A. brevicula*	*Salina tor sp.*
710393.26850	1475981.65422	1	29	2	26			3									
710371.97992	1475970.68737	2	17	3	1			2								14	
710351.01390	1475958.10776	3	35	2	8											27	
710330.37043	1475944.56048	4	18	3	8						1					9	
710307.79164	1475931.98087	5	49	2								1				48	
710321.01636	1475909.72463	6	64	4	1						4				3	56	
710342.62749	1475923.27190	7	72	3							1				1	70	
710364.56118	1475936.17407	8	129	2							1					128	
710385.84976	1475948.43113	9	69	3								1				66	2
710406.81578	1475961.01075	10	53	3								1	4			48	
710420.04050	1475939.39961	11	85	4							1			1	4	79	
710398.10682	1475926.49745	12	62	3		1									3	58	
710376.81824	1475913.91783	13	48	6							1	1	4	1	1	40	
710355.85221	1475901.33822	14	94	2											2	92	
710333.59597	1475887.79094	15	43	3							1				3	39	
710346.82070	1475866.17981	16	50	5						1	1	1			4	43	
710368.10927	1475878.75942	17	38	3							1				8	29	
710390.04296	1475891.98415	18	62	4									1		3	54	4
710411.00898	1475904.24121	19	132	2											2	130	
710432.29756	1475918.43359	20	88	3							1				2	85	
710445.19973	1475895.85480	21	75	5							2	1			2	62	8
710424.55626	1475882.63007	22	42	6	5						3				12	6	15
710402.94513	1475870.69557	23	77	8	4		5		9	9	1				3	45	
710381.65655	1475857.79340	24	61	5					4	2	4				5	46	
710360.69053	1475844.89123	25	62	8					1	3	4				3	15	2

Samet (Cont.)

COORD_X	COORD_Y	ID	*Steno thyra* sp.	*H.suc cinea*	*Platev index* sp.	Evenness	Richness	Density	Diversity	Soil_ pH	Soil_ Temp	Humi dity	Air_ Temp	Water _pH	Water Temp	Salinit y	Soil Texture	TBT conc. (µg/kg)
710393.26850	1475981.65422	1				0.480	4.167	29	0.330	5.90	29.40	68.00	29.50	7.10	30.10	20.00	loam	1.77
710371.97992	1475970.68737	2				0.530	5.660	17	0.580	6.50	26.20	84.00	31.00	7.40	29.80	24.00	loam	
710351.01390	1475958.10776	3				0.780	2.564	35	0.540	6.40	28.40	83.00	32.00	7.30	29.10	26.00	loam	2.92
710330.37043	1475944.56048	4				0.790	3.797	18	0.870	6.50	28.50	86.00	30.50	7.10	29.20	29.00	loam	
710307.79164	1475931.98087	5				0.140	14.286	49	0.100	6.60	28.60	86.00	30.00	7.20	29.30	29.00	sandy loams	4.14
710321.01636	1475909.72463	6				0.360	11.111	64	0.500	6.40	28.30	84.00	30.00	7.50	28.50	22.00	sandy loams	1.56
710342.62749	1475923.27190	7				0.130	23.077	72	0.150	6.50	28.40	88.00	29.50	7.40	28.80	20.00	sandy loams	1.73
710364.56118	1475936.17407	8				0.070	28.571	129	0.050	6.40	28.70	87.00	29.00	7.20	29.20	16.00	loam	1.42
710385.84976	1475948.43113	9				0.190	15.789	69	0.210	6.30	28.10	84.00	29.50	7.00	29.60	20.00	loam	
710406.81578	1475961.01075	10				0.330	9.091	53	0.360	6.30	28.30	87.00	28.00	7.20	28.60	24.00	loam	
710420.04050	1475939.39961	11				0.230	17.391	85	0.320	6.30	28.00	88.00	28.00	7.20	28.60	21.00	sandy loams	
710398.10682	1475926.49745	12				0.250	12.000	64	0.280	7.30	28.20	88.00	28.00	7.30	27.80	20.00	loam	
710376.81824	1475913.91783	13				0.380	15.789	48	0.680	6.10	28.10	87.00	28.00	7.50	28.60	24.00	clay loam	1.78
710355.85221	1475901.33822	14				0.150	13.333	94	0.100	5.90	28.20	85.00	28.50	7.40	28.90	19.00	sandy loams	1.85
710333.59597	1475887.79094	15				0.330	9.091	43	0.360	6.20	28.00	85.00	28.50	7.30	28.80	20.00	sandy clay loam	2
710346.82070	1475866.17981	16				0.350	14.286	50	0.570	6.00	28.60	87.00	28.50	7.50	29.00	18.00	sandy loams	3.12
710368.10927	1475878.75942	17				0.570	5.263	38	0.630	6.20	28.70	88.00	29.50	7.30	29.70	19.00	sandy loams	1.95
710390.04296	1475891.98415	18				0.370	10.811	62	0.510	6.20	28.20	85.00	29.50	7.50	28.50	17.00	sandy loams	
710411.00898	1475904.24121	19				0.110	18.182	132	0.080	6.10	28.00	85.00	29.00	7.50	28.90	21.00	sandy loams	6.48
710432.29756	1475918.43359	20				0.160	18.750	88	0.170	6.10	28.40	88.00	29.00	7.50	29.10	21.00	sandy loams	
710445.19973	1475895.85480	21				0.400	12.500	75	0.650	6.10	28.90	85.00	29.50	7.40	29.80	20.00	sandy clay loam	2.36
710424.55626	1475882.63007	22		1		0.860	6.977	42	1.530	6.20	28.30	86.00	29.50	7.30	29.30	19.00	sandy loams	
710402.94513	1475870.69557	23		1		0.670	11.940	77	1.390	6.10	28.30	86.00	30.00	7.50	30.20	20.00	loam	1.83
710381.65655	1475857.79340	24				0.550	9.091	61	0.890	6.00	28.60	85.00	30.00	7.40	29.80	17.00	loam	
710360.69053	1475844.89123	25	32		2	0.690	11.594	62	1.440	5.90	29.20	86.00	29.50	7.50	30.00	15.00	sandy loams	2.02

Laemchabung

COORD_X	COORD_Y	ID	Individuals	Species	*C. cingulata*	*Cliton* sp.	*A. brevicula*	*Platevindex* sp.	*C. capucinus*	*Fairbankia sp.*	*L. calinifera*	*L. melanostoma*	*L. palescene*	*C. aurisfelis*	*C. multiplicata*	*C. obtusa*	*Melanoides* sp.
703813.47202	1447026.38279	1	434	3	11	68											355
703823.52541	1447025.91247	2	31	3		12	8										11
703833.67285	1447025.94206	3	32	3		24		1									7
703843.63218	1447025.91247	4	18	5		1	8	1	1								7
703853.80964	1447026.02377	5	32	6		11	3		1	1	1						15
703853.40782	1447015.97039	6	6	6			1				1	1	1	1			1
703843.53365	1447016.09445	7	5	2			3	2									
703833.57879	1447015.87186	8	11	2			10										1
703823.51370	1447015.97837	9	28	5			15	8	1					2	2		
703813.47202	1447016.20575	10	20	2			8	12									
703813.47202	1447006.15237	11	17	3			4	11	2								
703823.51263	1447006.15237	12	16	3			11		3					2			
703833.46749	1447005.81848	13	23	4			20	1						1	1		
703843.58535	1447005.94701	14	30	5			25		1		1			2		1	
703853.67278	1447005.92978	15	8	3					2				2	4			
703853.29848	1446995.79558	16	11	3			6						2	3			
703843.14463	1446995.76510	17	34	6			25	1					1	3	3	1	
703833.24490	1446995.86362	18	17	4			3	9			2			3			
703823.39140	1446996.09899	19	13	4			9	1				1	2				
703813.47202	1446996.09899	20	15	4			4	7					3		1		
703813.47202	1446986.04560	21	11	4			3	2	3				3				
703823.24963	1446985.91159	22	11	4			7	2					1				1
703833.22766	1446985.72853	23	22	5			13	1	1		2				5		
703843.07569	1446985.69893	24	14	3			11	1	2								
703853.05670	1446985.69893	25	13	4			5	1	1					6			

Laemchabung (Cont.)

COORD_X	COORD_Y	ID	Evenness	Richness	Density	Diversity	Soil_ pH	Soil_T emp	Humidity	Air_ Temp	Waiter_ pH	Water_ Temp	Salinity	Soil Texture	TBT conc. (µg/kg)
703813.47202	1447026.38279	1	0.480	0.140	456	0.530	5.00	30.40	72.00	34.00	6.70	33.50	20.00	sandy loams	14.32
703823.52541	1447025.91247	2	0.990	0.539	31	1.080	6.00	33.50	74.00	35.00	6.80	34.00	19.00	sandy loams	
703833.67285	1447025.94206	3	0.570	0.507	35	0.620	6.00	35.00	82.00	33.00	7.00	32.50	23.00	sandy loams	12.08
703843.63218	1447025.91247	4	0.750	1.179	18	1.210	6.00	31.30	84.00	32.50	6.40	31.80	25.00	sandy loams	
703853.80964	1447026.02377	5	0.710	1.061	32	1.270	6.20	31.50	81.00	33.50	6.50	33.00	24.00	sandy loams	13.1
703853.40782	1447015.97039	6	1.000	2.449	6	1.790	4.80	30.70	64.00	33.00	7.20	31.60	25.00	loam	11.1
703843.53365	1447016.09445	7	0.970	0.894	5	0.670	5.80	29.30	64.00	33.00	6.50	31.40	25.00	sandy loams	
703833.57879	1447015.87186	8	0.440	0.603	11	0.300	6.30	29.30	68.00	31.50	6.60	30.80	25.00	sandy loams	8.35
703823.51370	1447015.97837	9	0.740	0.945	28	1.190	6.50	29.00	80.00	30.50	6.60	30.00	26.00	loamy sands	5.76
703813.47202	1447016.20575	10	0.970	0.447	20	0.670	6.30	30.80	76.00	30.50	7.10	30.50	30.00	loam	
703813.47202	1447006.15237	11	0.800	0.728	17	0.870	5.60	29.60	80.00	30.50	7.10	30.50	29.00	sandy loams	
703823.51263	1447006.15237	12	0.760	0.750	16	0.830	5.50	30.60	84.00	30.00	6.50	30.20	30.00	sandy loams	9.7
703833.46749	1447005.81848	13	0.380	0.834	23	0.530	6.30	30.00	84.00	30.00	6.60	30.00	26.00	sandy loams	8.49
703843.58535	1447005.94701	14	0.420	0.913	30	0.670	6.40	31.70	86.00	29.50	6.60	30.70	25.00	sandy loams	9.13
703853.67278	1447005.92978	15	0.950	1.061	8	1.040	5.20	29.40	87.00	29.00	6.50	29.80	29.00	sandy loams	
703853.29848	1446995.79558	16	0.910	0.905	11	0.990	6.40	29.60	87.00	29.50	6.50	30.00	28.00	sandy loams	8.36
703843.14463	1446995.76510	17	0.540	1.029	34	0.970	6.30	29.60	88.00	29.50	6.40	29.80	30.00	sandy loams	
703833.24490	1446995.86362	18	0.870	0.970	17	1.200	6.30	30.00	88.00	30.00	6.60	30.30	29.00	sandy loams	8.27
703823.39140	1446996.09899	19	0.680	1.109	13	0.940	6.20	29.80	87.00	30.00	6.60	30.30	27.00	sandy loams	
703813.47202	1446996.09899	20	0.870	1.033	15	1.210	6.30	29.70	88.00	30.50	6.60	30.20	26.00	sandy loams	8.75
703813.47202	1446986.04560	21	0.990	1.206	11	1.370	6.20	29.30	84.00	29.50	6.80	30.30	25.00	sandy loams	16.48
703823.24963	1446985.91159	22	0.750	1.206	11	1.030	6.30	30.10	86.00	29.00	6.80	29.60	25.00	loam	10.95
703833.22766	1446985.72853	23	0.710	1.066	22	1.150	6.40	30.30	88.00	29.00	6.50	30.50	27.00	sandy loams	
703843.07569	1446985.69893	24	0.600	0.802	14	0.660	6.40	31.10	87.00	29.50	6.70	30.80	30.00	sandy loams	
703853.05670	1446985.69893	25	0.810	1.109	13	1.120	6.40	30.60	88.00	30.00	6.80	30.70	25.00	sandy loams	12.64

Chuksamet

COORD_X	COORD_Y	ID	Individuals	Species	*C. cingulata*	*C. quadata*	*C. obtusa*	*Cliton* sp.	*Laemodonta* sp.	*Melanoides* sp.	*C. aurisfelis*	*C. multiplicata*	*L. calinifera*	*L. palescene*	*N. violacea*
709186.13850	1397771.25771	1	12	4	1						3	4		4	
709186.10353	1397781.32652	2	30	5	3			10			8	3		6	
709186.10353	1397791.41453	3	426	5	62			360		2	1				1
709186.10353	1397801.39333	4	24	6	2	1		1			16	3		1	
709186.17334	1397811.35693	5	8	4	4						1		1	2	
709196.19154	1397811.62995	6	14	3							5	3		6	
709196.10855	1397801.66635	7	23	5		5					5	1	2	10	
709196.01252	1397791.57834	8	34	6		2					16	8	3	4	
709196.06712	1397781.49033	9	33	4		2					21	8		2	
709196.10855	1397771.54421	10	17	4		1					12	3		1	
709206.03504	1397771.42196	11	49	5		5			8		28	3			
709206.05467	1397781.49033	12	25	4		2					13	8	2		
709205.91062	1397791.36651	13	40	7	1	8		2			14	7	5	3	
709206.17693	1397801.46111	14	21	5		1					3	5	1	11	
709206.16130	1397811.45394	15	21	6	2	3	1				4	1		10	
709216.02473	1397811.50553	16	10	4		4					1	3	2		
709216.10125	1397801.47429	17	15	4		5					4	3		3	
709215.89601	1397791.47572	18	19	5		5					6	2	2	4	
709216.05970	1397781.38771	19	21	5	9			1			7	1		3	
709216.09454	1397771.33251	20	26	6		1			4		13	5	2	1	
709226.11274	1397771.30616	21	23	5	2	1					15	3		2	
709226.07131	1397781.36808	22	45	6	1			30			4	3	2	5	
709225.91408	1397791.41453	23	13	5		1	1					3	3	5	
709226.12591	1397801.39776	24	9	5	2	1					3	1		2	
709225.92929	1397811.39633	25	9	4		1					3		2	3	

Chuksamet (Cont.)

COORD_X	COORD_Y	ID	Evenness	Richness	Density	Diversity	Soil_ pH	Soil_ Temp	Humidity	Air_ Temp	Waiter_ pH	Water_ Temp	Salinity	Soil Texture	TBT conc. (µg/kg)
709186.13850	1397771.25771	1	0.930	1.155	12	1.29	5.00	33.20	64.00	34.00				sandy loams	
709186.10353	1397781.32652	2	0.930	0.913	30	1.5	5.90	33.70	62.00	35.00	7.90	36.10		clay loam	1.60
709186.10353	1397791.41453	3	0.300	0.242	426	0.48	4.80	29.80	63.00	33.00	7.10	34.20	14.00	loam	1.32
709186.10353	1397801.39333	4	0.630	1.225	24	1.13	5.60	24.70	74.00	32.00				sandy loams	1.35
709186.17334	1397811.35693	5	0.880	1.414	8	1.21	4.10	34.70	66.00	32.50				sandy loams	
709196.19154	1397811.62995	6	0.970	0.802	14	1.06	4.90	31.00	63.50	32.50				sandy loams	
709196.10855	1397801.66635	7	0.850	1.043	23	1.37	5.00	33.60	75.00	32.50	6.60	33.20	9.00	sandy loams	1.45
709196.01252	1397791.57834	8	0.800	1.029	34	1.43	5.00	30.00	72.00	32.00	7.60	32.10	5.00	sandy loams	
709196.06712	1397781.49033	9	0.700	0.696	33	0.97	5.80	33.20	70.00	32.00				sandy clay loam	1.93
709196.10855	1397771.54421	10	0.640	0.970	17	0.89	6.00	33.20	69.00	31.50				loam	1.33
709206.03504	1397771.42196	11	0.780	0.714	49	1.25	6.70	30.70	69.00	30.50			20.00	sandy loams	1.83
709206.05467	1397781.49033	12	0.800	0.800	25	1.11	5.90	32.60	71.00	32.00				sandy loams	
709205.91062	1397791.36651	13	0.870	1.107	40	1.69	5.90	33.60	72.00	32.00	6.90	32.00	10.00	loamy sands	1.81
709206.17693	1397801.46111	14	0.780	1.091	21	1.25	5.20	30.40	70.00	32.00				sandy loams	
709206.16130	1397811.45394	15	0.820	1.309	21	1.46	5.00	29.80	67.00	32.50	6.70	31.60	10.00	sandy loams	1.82
709216.02473	1397811.50553	16	0.920	1.265	10	1.28	4.00	30.80	68.00	33.00				sandy loams	
709216.10125	1397801.47429	17	0.980	1.033	15	1.36	3.80	32.90	63.00	33.50				sandy loams	1.32
709215.89601	1397791.47572	18	0.940	1.147	19	1.52	5.70	33.90	64.00	34.50				sandy loams	1.89
709216.05970	1397781.38771	19	0.810	1.091	21	1.3	5.20	37.80	68.00	34.50	6.90	35.20	7.00	sandy loams	1.46
709216.09454	1397771.33251	20	0.780	1.177	26	1.4	4.90	35.70	68.00	34.00	6.60	33.30	14.00	sandy loams	
709226.11274	1397771.30616	21	0.690	1.043	23	1.11	4.50	35.50	67.00	35.00	7.20	33.80	11.00	sandy loams	
709226.07131	1397781.36808	22	0.630	0.894	45	1.13	5.80	37.10	68.00		7.90	35.90		sandy loams	1.33
709225.91408	1397791.41453	23	0.890	1.387	13	1.44	6.00	30.90	65.00	32.00				sandy loams	
709226.12591	1397801.39776	24	0.950	1.667	9	1.52	5.80	28.90	68.00	33.00	6.60	30.90	13.00	loamy sands	1.60
709225.92929	1397811.39633	25	0.950	1.333	9	1.31	4.10	29.80	72.00	33.00	6.60	31.80	11.00	sandy loams	1.30

APPENDIX D

Physical Factors

Samet

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SOIL_PH	Between Groups	.492	4	.123	1.530	.232
	Within Groups	1.608	20	.080		
	Total	2.100	24			
WATER_PH	Between Groups	.208	4	.052	3.133	.037
	Within Groups	.332	20	.017		
	Total	.540	24			
SOIL_TEM	Between Groups	.882	4	.220	.639	.641
	Within Groups	6.900	20	.345		
	Total	7.782	24			
WATER_TE	Between Groups	4.990	4	1.248	7.081	.001
	Within Groups	3.524	20	.176		
	Total	8.514	24			
WATER_SA	Between Groups	162.560	4	40.640	5.856	.003
	Within Groups	138.800	20	6.940		
	Total	301.360	24			
AIR_TEMP	Between Groups	15.665	4	3.916	11.131	.000
	Within Groups	7.036	20	.352		
	Total	22.701	24			
HUMIDITY	Between Groups	6.160	4	1.540	.631	.646
	Within Groups	48.800	20	2.440		
	Total	54.960	24			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SOIL_PH	1.00	2.00	.0000	.17933	1.000	-.5366	.5366
		3.00	.0200	.17933	1.000	-.5166	.5566
		4.00	.2600	.17933	.605	-.2766	.7966
		5.00	.3200	.17933	.409	-.2166	.8566
	2.00	1.00	.0000	.17933	1.000	-.5366	.5366
		3.00	.0200	.17933	1.000	-.5166	.5566
		4.00	.2600	.17933	.605	-.2766	.7966
		5.00	.3200	.17933	.409	-.2166	.8566
	3.00	1.00	-.0200	.17933	1.000	-.5566	.5166
		2.00	-.0200	.17933	1.000	-.5566	.5166
		4.00	.2400	.17933	.672	-.2966	.7766
		5.00	.3000	.17933	.472	-.2366	.8366
	4.00	1.00	-.2600	.17933	.605	-.7966	.2766
		2.00	-.2600	.17933	.605	-.7966	.2766
		3.00	-.2400	.17933	.672	-.7766	.2966
		5.00	.0600	.17933	.997	-.4766	.5966
	5.00	1.00	-.3200	.17933	.409	-.8566	.2166
		2.00	-.3200	.17933	.409	-.8566	.2166
		3.00	-.3000	.17933	.472	-.8366	.2366
		4.00	-.0600	.17933	.997	-.5966	.4766
WATER_PH	1.00	2.00	-.0400	.08149	.987	-.2838	.2038
		3.00	-.1200	.08149	.591	-.3638	.1238
		4.00	-.2400	.08149	.055	-.4838	.0038
		5.00	-.2000	.08149	.142	-.4438	.0438
	2.00	1.00	.0400	.08149	.987	-.2038	.2838
		3.00	-.0800	.08149	.860	-.3238	.1638
		4.00	-.2000	.08149	.142	-.4438	.0438
		5.00	-.1600	.08149	.318	-.4038	.0838
	3.00	1.00	.1200	.08149	.591	-.1238	.3638
		2.00	.0800	.08149	.860	-.1638	.3238
		4.00	-.1200	.08149	.591	-.3638	.1238
		5.00	-.0800	.08149	.860	-.3238	.1638
	4.00	1.00	.2400	.08149	.055	-.0038	.4838
		2.00	.2000	.08149	.142	-.0438	.4438
		3.00	.1200	.08149	.591	-.1238	.3638
		5.00	.0400	.08149	.987	-.2038	.2838
	5.00	1.00	.2000	.08149	.142	-.0438	.4438
		2.00	.1600	.08149	.318	-.0838	.4038
		3.00	.0800	.08149	.860	-.1638	.3238
		4.00	-.0400	.08149	.987	-.2838	.2038
SOIL_TEM	1.00	2.00	-.1400	.37148	.995	-1.2516	.9716

		3.00	.1200	.37148	.997	-.9916	1.2316
		4.00	-.1600	.37148	.992	-1.2716	.9516
		5.00	-.4400	.37148	.760	-1.5516	.6716
	2.00	1.00	.1400	.37148	.995	-.9716	1.2516
		3.00	.2600	.37148	.954	-.8516	1.3716
		4.00	-.0200	.37148	1.000	-1.1316	1.0916
		5.00	-.3000	.37148	.925	-1.4116	.8116
	3.00	1.00	-.1200	.37148	.997	-1.2316	.9916
		2.00	-.2600	.37148	.954	-1.3716	.8516
		4.00	-.2800	.37148	.941	-1.3916	.8316
		5.00	-.5600	.37148	.570	-1.6716	.5516
	4.00	1.00	.1600	.37148	.992	-.9516	1.2716
		2.00	.0200	.37148	1.000	-1.0916	1.1316
		3.00	.2800	.37148	.941	-.8316	1.3916
		5.00	-.2800	.37148	.941	-1.3916	.8316
	5.00	1.00	.4400	.37148	.760	-.6716	1.5516
		2.00	.3000	.37148	.925	-.8116	1.4116
		3.00	.5600	.37148	.570	-.5516	1.6716
		4.00	.2800	.37148	.941	-.8316	1.3916
WATER_TE	1.00	2.00	.5600	.26548	.255	-.2344	1.3544
		3.00	.9600(*)	.26548	.013	.1656	1.7544
		4.00	.4600	.26548	.438	-.3344	1.2544
		5.00	-.3200	.26548	.748	-1.1144	.4744
	2.00	1.00	-.5600	.26548	.255	-1.3544	.2344
		3.00	.4000	.26548	.570	-.3944	1.1944
		4.00	-.1000	.26548	.995	-.8944	.6944
		5.00	-.8800(*)	.26548	.025	-1.6744	-.0856
	3.00	1.00	-.9600(*)	.26548	.013	-1.7544	-.1656
		2.00	-.4000	.26548	.570	-1.1944	.3944
		4.00	-.5000	.26548	.357	-1.2944	.2944
		5.00	-1.2800(*)	.26548	.001	-2.0744	-.4856
	4.00	1.00	-.4600	.26548	.438	-1.2544	.3344
		2.00	.1000	.26548	.995	-.6944	.8944
		3.00	.5000	.26548	.357	-.2944	1.2944
		5.00	-.7800	.26548	.056	-1.5744	.0144
	5.00	1.00	.3200	.26548	.748	-.4744	1.1144
		2.00	.8800(*)	.26548	.025	.0856	1.6744
		3.00	1.2800(*)	.26548	.001	.4856	2.0744
		4.00	.7800	.26548	.056	-.0144	1.5744
WATER_SA	1.00	2.00	5.2000(*)	1.66613	.038	.2143	10.1857
		3.00	4.8000	1.66613	.063	-.1857	9.7857
		4.00	6.4000(*)	1.66613	.008	1.4143	11.3857
		5.00	7.4000(*)	1.66613	.002	2.4143	12.3857
	2.00	1.00	-5.2000(*)	1.66613	.038	-10.1857	-.2143
		3.00	-.4000	1.66613	.999	-5.3857	4.5857
		4.00	1.2000	1.66613	.949	-3.7857	6.1857
		5.00	2.2000	1.66613	.682	-2.7857	7.1857
	3.00	1.00	-4.8000	1.66613	.063	-9.7857	.1857

		2.00	.4000	1.66613	.999	-4.5857	5.3857
		4.00	1.6000	1.66613	.869	-3.3857	6.5857
		5.00	2.6000	1.66613	.538	-2.3857	7.5857
	4.00	1.00	-6.4000(*)	1.66613	.008	-11.3857	-1.4143
		2.00	-1.2000	1.66613	.949	-6.1857	3.7857
		3.00	-1.6000	1.66613	.869	-6.5857	3.3857
		5.00	1.0000	1.66613	.973	-3.9857	5.9857
	5.00	1.00	-7.4000(*)	1.66613	.002	-12.3857	-2.4143
		2.00	-2.2000	1.66613	.682	-7.1857	2.7857
		3.00	-2.6000	1.66613	.538	-7.5857	2.3857
		4.00	-1.0000	1.66613	.973	-5.9857	3.9857
AIR_TEMP	1.00	2.00	1.5020(*)	.37514	.006	.3794	2.6246
		3.00	2.4000(*)	.37514	.000	1.2774	3.5226
		4.00	1.5000(*)	.37514	.006	.3774	2.6226
		5.00	.9000	.37514	.156	-.2226	2.0226
	2.00	1.00	-1.5020(*)	.37514	.006	-2.6246	-.3794
		3.00	.8980	.37514	.158	-.2246	2.0206
		4.00	-.0020	.37514	1.000	-1.1246	1.1206
		5.00	-.6020	.37514	.511	-1.7246	.5206
	3.00	1.00	-2.4000(*)	.37514	.000	-3.5226	-1.2774
		2.00	-.8980	.37514	.158	-2.0206	.2246
		4.00	-.9000	.37514	.156	-2.0226	.2226
		5.00	-1.5000(*)	.37514	.006	-2.6226	-.3774
	4.00	1.00	-1.5000(*)	.37514	.006	-2.6226	-.3774
		2.00	.0020	.37514	1.000	-1.1206	1.1246
		3.00	.9000	.37514	.156	-.2226	2.0226
		5.00	-.6000	.37514	.515	-1.7226	.5226
	5.00	1.00	-.9000	.37514	.156	-2.0226	.2226
		2.00	.6020	.37514	.511	-.5206	1.7246
		3.00	1.5000(*)	.37514	.006	.3774	2.6226
		4.00	.6000	.37514	.515	-.5226	1.7226
HUMIDITY	1.00	2.00	-.6000	.98793	.972	-3.5562	2.3562
		3.00	-1.2000	.98793	.743	-4.1562	1.7562
		4.00	-1.2000	.98793	.743	-4.1562	1.7562
		5.00	-.2000	.98793	1.000	-3.1562	2.7562
	2.00	1.00	.6000	.98793	.972	-2.3562	3.5562
		3.00	-.6000	.98793	.972	-3.5562	2.3562
		4.00	-.6000	.98793	.972	-3.5562	2.3562
		5.00	.4000	.98793	.994	-2.5562	3.3562
	3.00	1.00	1.2000	.98793	.743	-1.7562	4.1562
		2.00	.6000	.98793	.972	-2.3562	3.5562
		4.00	.0000	.98793	1.000	-2.9562	2.9562
		5.00	1.0000	.98793	.847	-1.9562	3.9562
	4.00	1.00	1.2000	.98793	.743	-1.7562	4.1562
		2.00	.6000	.98793	.972	-2.3562	3.5562
		3.00	.0000	.98793	1.000	-2.9562	2.9562
		5.00	1.0000	.98793	.847	-1.9562	3.9562
	5.00	1.00	.2000	.98793	1.000	-2.7562	3.1562

		2.00	-.4000	.98793	.994	-3.3562	2.5562
		3.00	-1.0000	.98793	.847	-3.9562	1.9562
		4.00	-1.0000	.98793	.847	-3.9562	1.9562

Laemchabung

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SOIL_PH	Between Groups	1.326	4	.331	1.675	.195
	Within Groups	3.956	20	.198		
	Total	5.282	24			
WATER_PH	Between Groups	.180	4	.045	.900	.483
	Within Groups	1.000	20	.050		
	Total	1.180	24			
SOIL_TEM	Between Groups	22.654	4	5.664	5.095	.005
	Within Groups	22.232	20	1.112		
	Total	44.886	24			
WATER_TE	Between Groups	27.794	4	6.949	22.158	.000
	Within Groups	6.272	20	.314		
	Total	34.066	24			
WATER_SA	Between Groups	109.040	4	27.260	5.825	.003
	Within Groups	93.600	20	4.680		
	Total	202.640	24			
AIR_TEMP	Between Groups	61.940	4	15.485	24.386	.000
	Within Groups	12.700	20	.635		
	Total	74.640	24			
HUMIDITY	Between Groups	1010.640	4	252.660	13.898	.000
	Within Groups	363.600	20	18.180		
	Total	1374.240	24			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SOIL_PH	1.00	2.00	-.1000	.28128	.996	-.9417	.7417
		3.00	.0400	.28128	1.000	-.8017	.8817
		4.00	-.4600	.28128	.493	-1.3017	.3817
		5.00	-.5000	.28128	.413	-1.3417	.3417
	2.00	1.00	.1000	.28128	.996	-.7417	.9417
		3.00	.1400	.28128	.987	-.7017	.9817
		4.00	-.3600	.28128	.706	-1.2017	.4817
		5.00	-.4000	.28128	.621	-1.2417	.4417
	3.00	1.00	-.0400	.28128	1.000	-.8817	.8017
		2.00	-.1400	.28128	.987	-.9817	.7017
		4.00	-.5000	.28128	.413	-1.3417	.3417
		5.00	-.5400	.28128	.339	-1.3817	.3017
	4.00	1.00	.4600	.28128	.493	-.3817	1.3017
		2.00	.3600	.28128	.706	-.4817	1.2017
		3.00	.5000	.28128	.413	-.3417	1.3417
		5.00	-.0400	.28128	1.000	-.8817	.8017
	5.00	1.00	.5000	.28128	.413	-.3417	1.3417
		2.00	.4000	.28128	.621	-.4417	1.2417
		3.00	.5400	.28128	.339	-.3017	1.3817
		4.00	.0400	.28128	1.000	-.8017	.8817
WATER_PH	1.00	2.00	-.1200	.14142	.912	-.5432	.3032
		3.00	.0200	.14142	1.000	-.4032	.4432
		4.00	.1400	.14142	.857	-.2832	.5632
		5.00	-.0400	.14142	.998	-.4632	.3832
	2.00	1.00	.1200	.14142	.912	-.3032	.5432
		3.00	.1400	.14142	.857	-.2832	.5632
		4.00	.2600	.14142	.380	-.1632	.6832
		5.00	.0800	.14142	.979	-.3432	.5032
	3.00	1.00	-.0200	.14142	1.000	-.4432	.4032
		2.00	-.1400	.14142	.857	-.5632	.2832
		4.00	.1200	.14142	.912	-.3032	.5432
		5.00	-.0600	.14142	.993	-.4832	.3632
	4.00	1.00	-.1400	.14142	.857	-.5632	.2832
		2.00	-.2600	.14142	.380	-.6832	.1632
		3.00	-.1200	.14142	.912	-.5432	.3032
		5.00	-.1800	.14142	.710	-.6032	.2432
	5.00	1.00	.0400	.14142	.998	-.3832	.4632
		2.00	-.0800	.14142	.979	-.5032	.3432
		3.00	.0600	.14142	.993	-.3632	.4832
		4.00	.1800	.14142	.710	-.2432	.6032

SOIL_TEM	1.00	2.00	2.5200(*)	.66681	.009	.5246	4.5154
		3.00	2.0800(*)	.66681	.038	.0846	4.0754
		4.00	2.6000(*)	.66681	.007	.6046	4.5954
		5.00	2.0600(*)	.66681	.041	.0646	4.0554
	2.00	1.00	-2.5200(*)	.66681	.009	-4.5154	-.5246
		3.00	-.4400	.66681	.963	-2.4354	1.5554
		4.00	.0800	.66681	1.000	-1.9154	2.0754
		5.00	-.4600	.66681	.956	-2.4554	1.5354
	3.00	1.00	-2.0800(*)	.66681	.038	-4.0754	-.0846
		2.00	.4400	.66681	.963	-1.5554	2.4354
		4.00	.5200	.66681	.934	-1.4754	2.5154
		5.00	-.0200	.66681	1.000	-2.0154	1.9754
	4.00	1.00	-2.6000(*)	.66681	.007	-4.5954	-.6046
		2.00	-.0800	.66681	1.000	-2.0754	1.9154
		3.00	-.5200	.66681	.934	-2.5154	1.4754
		5.00	-.5400	.66681	.925	-2.5354	1.4554
	5.00	1.00	-2.0600(*)	.66681	.041	-4.0554	-.0646
		2.00	.4600	.66681	.956	-1.5354	2.4554
		3.00	.0200	.66681	1.000	-1.9754	2.0154
		4.00	.5400	.66681	.925	-1.4554	2.5354
WATER_TE	1.00	2.00	2.1000(*)	.35418	.000	1.0402	3.1598
		3.00	2.7200(*)	.35418	.000	1.6602	3.7798
		4.00	2.8400(*)	.35418	.000	1.7802	3.8998
		5.00	2.5800(*)	.35418	.000	1.5202	3.6398
	2.00	1.00	-2.1000(*)	.35418	.000	-3.1598	-1.0402
		3.00	.6200	.35418	.428	-.4398	1.6798
		4.00	.7400	.35418	.263	-.3198	1.7998
		5.00	.4800	.35418	.662	-.5798	1.5398
	3.00	1.00	-2.7200(*)	.35418	.000	-3.7798	-1.6602
		2.00	-.6200	.35418	.428	-1.6798	.4398
		4.00	.1200	.35418	.997	-.9398	1.1798
		5.00	-.1400	.35418	.994	-1.1998	.9198
	4.00	1.00	-2.8400(*)	.35418	.000	-3.8998	-1.7802
		2.00	-.7400	.35418	.263	-1.7998	.3198
		3.00	-.1200	.35418	.997	-1.1798	.9398
		5.00	-.2600	.35418	.946	-1.3198	.7998
	5.00	1.00	-2.5800(*)	.35418	.000	-3.6398	-1.5202
		2.00	-.4800	.35418	.662	-1.5398	.5798
		3.00	.1400	.35418	.994	-.9198	1.1998
		4.00	.2600	.35418	.946	-.7998	1.3198
WATER_SA	1.00	2.00	-4.0000	1.36821	.058	-8.0942	.0942
		3.00	-5.6000(*)	1.36821	.005	-9.6942	-1.5058
		4.00	-5.8000(*)	1.36821	.003	-9.8942	-1.7058
		5.00	-4.2000(*)	1.36821	.043	-8.2942	-.1058
	2.00	1.00	4.0000	1.36821	.058	-.0942	8.0942
		3.00	-1.6000	1.36821	.768	-5.6942	2.4942
		4.00	-1.8000	1.36821	.685	-5.8942	2.2942
		5.00	-.2000	1.36821	1.000	-4.2942	3.8942

	3.00	1.00	5.6000(*)	1.36821	.005	1.5058	9.6942
		2.00	1.6000	1.36821	.768	-2.4942	5.6942
		4.00	-.2000	1.36821	1.000	-4.2942	3.8942
		5.00	1.4000	1.36821	.842	-2.6942	5.4942
	4.00	1.00	5.8000(*)	1.36821	.003	1.7058	9.8942
		2.00	1.8000	1.36821	.685	-2.2942	5.8942
		3.00	.2000	1.36821	1.000	-3.8942	4.2942
		5.00	1.6000	1.36821	.768	-2.4942	5.6942
	5.00	1.00	4.2000(*)	1.36821	.043	.1058	8.2942
		2.00	.2000	1.36821	1.000	-3.8942	4.2942
		3.00	-1.4000	1.36821	.842	-5.4942	2.6942
		4.00	-1.6000	1.36821	.768	-5.6942	2.4942
AIR_TEMP	1.00	2.00	1.9000(*)	.50398	.009	.3919	3.4081
		3.00	3.8000(*)	.50398	.000	2.2919	5.3081
		4.00	3.7000(*)	.50398	.000	2.1919	5.2081
		5.00	4.2000(*)	.50398	.000	2.6919	5.7081
	2.00	1.00	-1.9000(*)	.50398	.009	-3.4081	-.3919
		3.00	1.9000(*)	.50398	.009	.3919	3.4081
		4.00	1.8000(*)	.50398	.015	.2919	3.3081
		5.00	2.3000(*)	.50398	.002	.7919	3.8081
	3.00	1.00	-3.8000(*)	.50398	.000	-5.3081	-2.2919
		2.00	-1.9000(*)	.50398	.009	-3.4081	-.3919
		4.00	-.1000	.50398	1.000	-1.6081	1.4081
		5.00	.4000	.50398	.929	-1.1081	1.9081
	4.00	1.00	-3.7000(*)	.50398	.000	-5.2081	-2.1919
		2.00	-1.8000(*)	.50398	.015	-3.3081	-.2919
		3.00	.1000	.50398	1.000	-1.4081	1.6081
		5.00	.5000	.50398	.856	-1.0081	2.0081
	5.00	1.00	-4.2000(*)	.50398	.000	-5.7081	-2.6919
		2.00	-2.3000(*)	.50398	.002	-3.8081	-.7919
		3.00	-.4000	.50398	.929	-1.9081	1.1081
		4.00	-.5000	.50398	.856	-2.0081	1.0081
HUMIDITY	1.00	2.00	8.2000(*)	2.69666	.045	.1306	16.2694
		3.00	-5.6000	2.69666	.268	-13.6694	2.4694
		4.00	-9.0000(*)	2.69666	.024	-17.0694	-.9306
		5.00	-8.0000	2.69666	.053	-16.0694	.0694
	2.00	1.00	-8.2000(*)	2.69666	.045	-16.2694	-.1306
		3.00	-13.8000(*)	2.69666	.000	-21.8694	-5.7306
		4.00	-17.2000(*)	2.69666	.000	-25.2694	-9.1306
		5.00	-16.2000(*)	2.69666	.000	-24.2694	-8.1306
	3.00	1.00	5.6000	2.69666	.268	-2.4694	13.6694
		2.00	13.8000(*)	2.69666	.000	5.7306	21.8694
		4.00	-3.4000	2.69666	.717	-11.4694	4.6694
		5.00	-2.4000	2.69666	.897	-10.4694	5.6694
	4.00	1.00	9.0000(*)	2.69666	.024	.9306	17.0694
		2.00	17.2000(*)	2.69666	.000	9.1306	25.2694
		3.00	3.4000	2.69666	.717	-4.6694	11.4694
		5.00	1.0000	2.69666	.996	-7.0694	9.0694

	5.00	1.00	8.0000	2.69666	.053	-.0694	16.0694
		2.00	16.2000(*)	2.69666	.000	8.1306	24.2694
		3.00	2.4000	2.69666	.897	-5.6694	10.4694
		4.00	-1.0000	2.69666	.996	-9.0694	7.0694

* The mean difference is significant at the .05 level.

Chuksamet

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SOIL_PH	Between Groups	2.774	4	.693	1.319	.297
	Within Groups	10.512	20	.526		
	Total	13.286	24			
WATER_PH	Between Groups	.717	4	.179	.618	.664
	Within Groups	2.033	7	.290		
	Total	2.750	11			
SOIL_TEM	Between Groups	28.284	4	7.071	.838	.517
	Within Groups	168.776	20	8.439		
	Total	197.060	24			
WATER_TE	Between Groups	14.134	4	3.534	1.291	.359
	Within Groups	19.155	7	2.736		
	Total	33.289	11			
WATER_SA	Between Groups	91.833	4	22.958	1.463	.309
	Within Groups	109.833	7	15.690		
	Total	201.667	11			
AIR_TEMP	Between Groups	15.490	4	3.872	4.825	.007
	Within Groups	15.250	19	.803		
	Total	30.740	23			
HUMIDITY	Between Groups	74.560	4	18.640	1.617	.209
	Within Groups	230.600	20	11.530		
	Total	305.160	24			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SOIL_PH	1.00	2.00	-.2600	.45852	.978	-1.6321	1.1121
		3.00	-.6600	.45852	.611	-2.0321	.7121
		4.00	.3600	.45852	.932	-1.0121	1.7321
		5.00	-.1600	.45852	.997	-1.5321	1.2121
	2.00	1.00	.2600	.45852	.978	-1.1121	1.6321
		3.00	-.4000	.45852	.904	-1.7721	.9721
		4.00	.6200	.45852	.663	-.7521	1.9921
		5.00	.1000	.45852	.999	-1.2721	1.4721
	3.00	1.00	.6600	.45852	.611	-.7121	2.0321
		2.00	.4000	.45852	.904	-.9721	1.7721
		4.00	1.0200	.45852	.211	-.3521	2.3921
		5.00	.5000	.45852	.809	-.8721	1.8721
	4.00	1.00	-.3600	.45852	.932	-1.7321	1.0121
		2.00	-.6200	.45852	.663	-1.9921	.7521
		3.00	-1.0200	.45852	.211	-2.3921	.3521
		5.00	-.5200	.45852	.787	-1.8921	.8521
	5.00	1.00	.1600	.45852	.997	-1.2121	1.5321
		2.00	-.1000	.45852	.999	-1.4721	1.2721
		3.00	-.5000	.45852	.809	-1.8721	.8721
		4.00	.5200	.45852	.787	-.8521	1.8921
WATER_PH	1.00	2.00	.4000	.53885	.939	-1.5280	2.3280
		3.00	.7000	.53885	.700	-1.2280	2.6280
		4.00	.7500	.53885	.651	-1.1780	2.6780
		5.00	.4250	.46666	.884	-1.2447	2.0947
	2.00	1.00	-.4000	.53885	.939	-2.3280	1.5280
		3.00	.3000	.53885	.978	-1.6280	2.2280
		4.00	.3500	.53885	.961	-1.5780	2.2780
		5.00	.0250	.46666	1.000	-1.6447	1.6947
	3.00	1.00	-.7000	.53885	.700	-2.6280	1.2280
		2.00	-.3000	.53885	.978	-2.2280	1.6280
		4.00	.0500	.53885	1.000	-1.8780	1.9780
		5.00	-.2750	.46666	.972	-1.9447	1.3947
	4.00	1.00	-.7500	.53885	.651	-2.6780	1.1780
		2.00	-.3500	.53885	.961	-2.2780	1.5780
		3.00	-.0500	.53885	1.000	-1.9780	1.8780
		5.00	-.3250	.46666	.951	-1.9947	1.3447
	5.00	1.00	-.4250	.46666	.884	-2.0947	1.2447
		2.00	-.0250	.46666	1.000	-1.6947	1.6447
		3.00	.2750	.46666	.972	-1.3947	1.9447
		4.00	.3250	.46666	.951	-1.3447	1.9947
SOIL_TEM	1.00	2.00	-.9800	1.83726	.983	-6.4778	4.5178

		3.00	-.2000	1.83726	1.000	-5.6978	5.2978
		4.00	-3.0000	1.83726	.495	-8.4978	2.4978
		5.00	-1.2200	1.83726	.962	-6.7178	4.2778
	2.00	1.00	.9800	1.83726	.983	-4.5178	6.4778
		3.00	.7800	1.83726	.993	-4.7178	6.2778
		4.00	-2.0200	1.83726	.805	-7.5178	3.4778
		5.00	-.2400	1.83726	1.000	-5.7378	5.2578
	3.00	1.00	.2000	1.83726	1.000	-5.2978	5.6978
		2.00	-.7800	1.83726	.993	-6.2778	4.7178
		4.00	-2.8000	1.83726	.560	-8.2978	2.6978
		5.00	-1.0200	1.83726	.980	-6.5178	4.4778
	4.00	1.00	3.0000	1.83726	.495	-2.4978	8.4978
		2.00	2.0200	1.83726	.805	-3.4778	7.5178
		3.00	2.8000	1.83726	.560	-2.6978	8.2978
		5.00	1.7800	1.83726	.866	-3.7178	7.2778
	5.00	1.00	1.2200	1.83726	.962	-4.2778	6.7178
		2.00	.2400	1.83726	1.000	-5.2578	5.7378
		3.00	1.0200	1.83726	.980	-4.4778	6.5178
		4.00	-1.7800	1.83726	.866	-7.2778	3.7178
WATER_TE	1.00	2.00	2.5000	1.65422	.587	-3.4188	8.4188
		3.00	3.3500	1.65422	.344	-2.5688	9.2688
		4.00	.9000	1.65422	.979	-5.0188	6.8188
		5.00	2.0500	1.43259	.630	-3.0758	7.1758
	2.00	1.00	-2.5000	1.65422	.587	-8.4188	3.4188
		3.00	.8500	1.65422	.983	-5.0688	6.7688
		4.00	-1.6000	1.65422	.862	-7.5188	4.3188
		5.00	-.4500	1.43259	.997	-5.5758	4.6758
	3.00	1.00	-3.3500	1.65422	.344	-9.2688	2.5688
		2.00	-.8500	1.65422	.983	-6.7688	5.0688
		4.00	-2.4500	1.65422	.603	-8.3688	3.4688
		5.00	-1.3000	1.43259	.885	-6.4258	3.8258
	4.00	1.00	-.9000	1.65422	.979	-6.8188	5.0188
		2.00	1.6000	1.65422	.862	-4.3188	7.5188
		3.00	2.4500	1.65422	.603	-3.4688	8.3688
		5.00	1.1500	1.43259	.922	-3.9758	6.2758
	5.00	1.00	-2.0500	1.43259	.630	-7.1758	3.0758
		2.00	.4500	1.43259	.997	-4.6758	5.5758
		3.00	1.3000	1.43259	.885	-3.8258	6.4258
		4.00	-1.1500	1.43259	.922	-6.2758	3.9758
WATER_SA	1.00	2.00	9.0000	3.96112	.257	-5.1729	23.1729
		3.00	2.6667	3.61599	.941	-10.2714	15.6047
		4.00	5.5000	3.96112	.653	-8.6729	19.6729
		5.00	4.3333	3.61599	.753	-8.6047	17.2714
	2.00	1.00	-9.0000	3.96112	.257	-23.1729	5.1729
		3.00	-6.3333	3.61599	.464	-19.2714	6.6047
		4.00	-3.5000	3.96112	.894	-17.6729	10.6729
		5.00	-4.6667	3.61599	.705	-17.6047	8.2714
	3.00	1.00	-2.6667	3.61599	.941	-15.6047	10.2714

		2.00	6.3333	3.61599	.464	-6.6047	19.2714
		4.00	2.8333	3.61599	.928	-10.1047	15.7714
		5.00	1.6667	3.23424	.983	-9.9055	13.2388
	4.00	1.00	-5.5000	3.96112	.653	-19.6729	8.6729
		2.00	3.5000	3.96112	.894	-10.6729	17.6729
		3.00	-2.8333	3.61599	.928	-15.7714	10.1047
		5.00	-1.1667	3.61599	.997	-14.1047	11.7714
	5.00	1.00	-4.3333	3.61599	.753	-17.2714	8.6047
		2.00	4.6667	3.61599	.705	-8.2714	17.6047
		3.00	-1.6667	3.23424	.983	-13.2388	9.9055
		4.00	1.1667	3.61599	.997	-11.7714	14.1047
AIR_TEMP	1.00	2.00	1.2000	.56662	.253	-.5039	2.9039
		3.00	1.5000	.56662	.101	-.2039	3.2039
		4.00	-.6000	.56662	.825	-2.3039	1.1039
		5.00	.0500	.60099	1.000	-1.7573	1.8573
	2.00	1.00	-1.2000	.56662	.253	-2.9039	.5039
		3.00	.3000	.56662	.983	-1.4039	2.0039
		4.00	-1.8000(*)	.56662	.035	-3.5039	-.0961
		5.00	-1.1500	.60099	.344	-2.9573	.6573
	3.00	1.00	-1.5000	.56662	.101	-3.2039	.2039
		2.00	-.3000	.56662	.983	-2.0039	1.4039
		4.00	-2.1000(*)	.56662	.012	-3.8039	-.3961
		5.00	-1.4500	.60099	.155	-3.2573	.3573
	4.00	1.00	.6000	.56662	.825	-1.1039	2.3039
		2.00	1.8000(*)	.56662	.035	.0961	3.5039
		3.00	2.1000(*)	.56662	.012	.3961	3.8039
		5.00	.6500	.60099	.814	-1.1573	2.4573
	5.00	1.00	-.0500	.60099	1.000	-1.8573	1.7573
		2.00	1.1500	.60099	.344	-.6573	2.9573
		3.00	1.4500	.60099	.155	-.3573	3.2573
		4.00	-.6500	.60099	.814	-2.4573	1.1573
HUMIDITY	1.00	2.00	-4.1000	2.14756	.345	-10.5263	2.3263
		3.00	-4.0000	2.14756	.368	-10.4263	2.4263
		4.00	-.4000	2.14756	1.000	-6.8263	6.0263
		5.00	-2.2000	2.14756	.841	-8.6263	4.2263
	2.00	1.00	4.1000	2.14756	.345	-2.3263	10.5263
		3.00	.1000	2.14756	1.000	-6.3263	6.5263
		4.00	3.7000	2.14756	.443	-2.7263	10.1263
		5.00	1.9000	2.14756	.899	-4.5263	8.3263
	3.00	1.00	4.0000	2.14756	.368	-2.4263	10.4263
		2.00	-.1000	2.14756	1.000	-6.5263	6.3263
		4.00	3.6000	2.14756	.470	-2.8263	10.0263
		5.00	1.8000	2.14756	.915	-4.6263	8.2263
	4.00	1.00	.4000	2.14756	1.000	-6.0263	6.8263
		2.00	-3.7000	2.14756	.443	-10.1263	2.7263
		3.00	-3.6000	2.14756	.470	-10.0263	2.8263
		5.00	-1.8000	2.14756	.915	-8.2263	4.6263
	5.00	1.00	2.2000	2.14756	.841	-4.2263	8.6263

		2.00	-1.9000	2.14756	.899	-8.3263	4.5263
		3.00	-1.8000	2.14756	.915	-8.2263	4.6263
		4.00	1.8000	2.14756	.915	-4.6263	8.2263

* The mean difference is significant at the .05 level.

Comparing the soil pH in three studied areas.

ANOVA

SOIL_PH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.936	2	7.468	26.017	.000
Within Groups	20.667	72	.287		
Total	35.603	74			

Multiple Comparisons

Dependent Variable: SOIL_PH
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	.8200*	.15154	.000	.4574	1.1826
	3.00	-.2160	.15154	.333	-.5786	.1466
2.00	1.00	-.8200*	.15154	.000	-1.1826	-.4574
	3.00	-1.0360*	.15154	.000	-1.3986	-.6734
3.00	1.00	.2160	.15154	.333	-.1466	.5786
	2.00	1.0360*	.15154	.000	.6734	1.3986

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the water pH in three studied areas.

ANOVA

WATER_PH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.460	2	2.730	36.037	.000
Within Groups	4.470	59	.076		
Total	9.930	61			

Multiple Comparisons

Dependent Variable: WATER_PH
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.3700*	.09666	.001	-.6024	-.1376
	3.00	-.6600*	.07785	.000	-.8472	-.4728
2.00	1.00	.3700*	.09666	.001	.1376	.6024
	3.00	-.2900*	.09666	.011	-.5224	-.0576
3.00	1.00	.6600*	.07785	.000	.4728	.8472
	2.00	.2900*	.09666	.011	.0576	.5224

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the soil temperature in three studied areas.

ANOVA

SOIL_TEM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	196.083	2	98.042	28.267	.000
Within Groups	249.728	72	3.468		
Total	445.811	74			

Multiple Comparisons

Dependent Variable: SOIL_TEM
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.8120*	.52676	.003	-3.0726	-.5514
	3.00	2.1440*	.52676	.000	.8834	3.4046
2.00	1.00	1.8120*	.52676	.003	.5514	3.0726
	3.00	3.9560*	.52676	.000	2.6954	5.2166
3.00	1.00	-2.1440*	.52676	.000	-3.4046	-.8834
	2.00	-3.9560*	.52676	.000	-5.2166	-2.6954

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the water temperature in three studied areas.

ANOVA

WATER_TE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	143.513	2	71.756	55.801	.000
Within Groups	75.870	59	1.286		
Total	219.383	61			

Multiple Comparisons

Dependent Variable: WATER_TE
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-2.4297*	.39824	.000	-3.3871	-1.4722
	3.00	1.7440*	.32074	.000	.9729	2.5151
2.00	1.00	2.4297*	.39824	.000	1.4722	3.3871
	3.00	4.1737*	.39824	.000	3.2162	5.1311
3.00	1.00	-1.7440*	.32074	.000	-2.5151	-.9729
	2.00	-4.1737*	.39824	.000	-5.1311	-3.2162

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the water salinity in three studied areas.

ANOVA

WATER_SA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1661.172	2	830.586	69.444	.000
Within Groups	705.667	59	11.960		
Total	2366.839	61			

Multiple Comparisons

Dependent Variable: WATER_SA
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	14.2867*	1.21455	.000	11.3666	17.2067
	3.00	5.2800*	.97818	.000	2.9282	7.6318
2.00	1.00	-14.2867*	1.21455	.000	-17.2067	-11.3666
	3.00	-9.0067*	1.21455	.000	-11.9267	-6.0866
3.00	1.00	-5.2800*	.97818	.000	-7.6318	-2.9282
	2.00	9.0067*	1.21455	.000	6.0866	11.9267

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the air temperature in three studied areas.

ANOVA

AIR_TEMP

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	151.794	2	75.897	42.072	.000
Within Groups	128.081	71	1.804		
Total	279.874	73			

Multiple Comparisons

Dependent Variable: AIR_TEMP

Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.9742*	.38383	.000	-2.8930	-1.0553
	3.00	1.5404*	.37989	.000	.6310	2.4498
2.00	1.00	1.9742*	.38383	.000	1.0553	2.8930
	3.00	3.5146*	.38383	.000	2.5957	4.4334
3.00	1.00	-1.5404*	.37989	.000	-2.4498	-.6310
	2.00	-3.5146*	.38383	.000	-4.4334	-2.5957

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the humidity in three studied areas.

ANOVA

HUMIDITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4431.127	2	2215.563	91.977	.000
Within Groups	1734.360	72	24.088		
Total	6165.487	74			

Multiple Comparisons

Dependent Variable: HUMIDITY

Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	13.5400*	1.38819	.000	10.2179	16.8621
	3.00	-4.5600*	1.38819	.004	-7.8821	-1.2379
2.00	1.00	-13.5400*	1.38819	.000	-16.8621	-10.2179
	3.00	-18.1000*	1.38819	.000	-21.4221	-14.7779
3.00	1.00	4.5600*	1.38819	.004	1.2379	7.8821
	2.00	18.1000*	1.38819	.000	14.7779	21.4221

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

APPENDIX E

Ecological data in statistical test

Comparing the number of individual at Samet, Laemchabung, and Chuksamet.

ANOVA

INDIVIDU

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10414.91	2	5207.453	1.028	.363
Within Groups	364823.4	72	5066.992		
Total	375238.3	74			

Comparing the richness at Samet, Laemchabung, and Chuksamet.

ANOVA

RICHNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.138	2	2.069	20.107	.000
Within Groups	7.409	72	.103		
Total	11.548	74			

Multiple Comparisons

Dependent Variable: RICHNESS
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	-.1225	.09073	.373	-.3396	.0947
	3.00	.4256*	.09073	.000	.2085	.6428
2.00	1.00	.1225	.09073	.373	-.0947	.3396
	3.00	.5481*	.09073	.000	.3310	.7653
3.00	1.00	-.4256*	.09073	.000	-.6428	-.2085
	2.00	-.5481*	.09073	.000	-.7653	-.3310

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the diversity index at Samet, Laemchabung, and Chuksamet.

ANOVA

DIVERSIT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.666	2	3.333	28.943	.000
Within Groups	8.291	72	.115		
Total	14.957	74			

Multiple Comparisons

Dependent Variable: DIVERSIT
Tukey HSD

					95% Confidence Interval	
(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
1.00	2.00	-.3020*	.09598	.007	-.5317	-.0723
	3.00	.4248*	.09598	.000	.1951	.6545
2.00	1.00	.3020*	.09598	.007	.0723	.5317
	3.00	.7268*	.09598	.000	.4971	.9565
3.00	1.00	-.4248*	.09598	.000	-.6545	-.1951
	2.00	-.7268*	.09598	.000	-.9565	-.4971

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the evenness at Samet, Laemchabung, and Chuksamet.

ANOVA

EVENNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.491	2	1.245	32.591	.000
Within Groups	2.751	72	.038		
Total	5.242	74			

Multiple Comparisons

Dependent Variable: EVENNESS
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.0624	.05529	.500	-.1947	.0699
	3.00	.3516*	.05529	.000	.2193	.4839
2.00	1.00	.0624	.05529	.500	-.0699	.1947
	3.00	.4140*	.05529	.000	.2817	.5463
3.00	1.00	-.3516*	.05529	.000	-.4839	-.2193
	2.00	-.4140*	.05529	.000	-.5463	-.2817

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing the evenness, richness, and diversity index in each zone at Samet.

Evenness

ANOVA

EVENNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.672	4	.168	5.320	.004
Within Groups	.632	20	.032		
Total	1.303	24			

Multiple Comparisons

Dependent Variable: EVENNESS
Tukey HSD

(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	.3280	.11239	.058	-.0083	.6643
	3.00	.2760	.11239	.141	-.0603	.6123
	4.00	.2320	.11239	.273	-.1043	.5683
	5.00	-.0900	.11239	.927	-.4263	.2463
2.00	1.00	-.3280	.11239	.058	-.6643	.0083
	3.00	-.0520	.11239	.990	-.3883	.2843
	4.00	-.0960	.11239	.910	-.4323	.2403
	5.00	-.4180*	.11239	.011	-.7543	-.0817
3.00	1.00	-.2760	.11239	.141	-.6123	.0603
	2.00	.0520	.11239	.990	-.2843	.3883
	4.00	-.0440	.11239	.995	-.3803	.2923
	5.00	-.3660*	.11239	.029	-.7023	-.0297
4.00	1.00	-.2320	.11239	.273	-.5683	.1043
	2.00	.0960	.11239	.910	-.2403	.4323
	3.00	.0440	.11239	.995	-.2923	.3803
	5.00	-.3220	.11239	.065	-.6583	.0143
5.00	1.00	.0900	.11239	.927	-.2463	.4263
	2.00	.4180*	.11239	.011	.0817	.7543
	3.00	.3660*	.11239	.029	.0297	.7023
	4.00	.3220	.11239	.065	-.0143	.6583

*. The mean difference is significant at the .05 level.

Richness

ANOVA

RICHNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.610	4	.153	3.876	.017
Within Groups	.787	20	.039		
Total	1.398	24			

Multiple Comparisons

Dependent Variable: RICHNESS
Tukey HSD

(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	.1254	.12548	.853	-.2501	.5009
	3.00	.0172	.12548	1.000	-.3583	.3927
	4.00	.0468	.12548	.996	-.3287	.4223
	5.00	-.3282	.12548	.105	-.7037	.0473
2.00	1.00	-.1254	.12548	.853	-.5009	.2501
	3.00	-.1082	.12548	.907	-.4837	.2673
	4.00	-.0786	.12548	.969	-.4541	.2969
	5.00	-.4536*	.12548	.013	-.8291	-.0781
3.00	1.00	-.0172	.12548	1.000	-.3927	.3583
	2.00	.1082	.12548	.907	-.2673	.4837
	4.00	.0296	.12548	.999	-.3459	.4051
	5.00	-.3454	.12548	.081	-.7209	.0301
4.00	1.00	-.0468	.12548	.996	-.4223	.3287
	2.00	.0786	.12548	.969	-.2969	.4541
	3.00	-.0296	.12548	.999	-.4051	.3459
	5.00	-.3750	.12548	.050	-.7505	.0005
5.00	1.00	.3282	.12548	.105	-.0473	.7037
	2.00	.4536*	.12548	.013	.0781	.8291
	3.00	.3454	.12548	.081	-.0301	.7209
	4.00	.3750	.12548	.050	-.0005	.7505

*. The mean difference is significant at the .05 level.

Diversity index

ANOVA

DIVERSIT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.765	4	.691	9.315	.000
Within Groups	1.484	20	.074		
Total	4.249	24			

Multiple Comparisons

Dependent Variable: DIVERSIT
Tukey HSD

(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	.2300	.17228	.674	-.2855	.7455
	3.00	.1360	.17228	.931	-.3795	.6515
	4.00	.0920	.17228	.983	-.4235	.6075
	5.00	-.6960*	.17228	.005	-1.2115	-.1805
2.00	1.00	-.2300	.17228	.674	-.7455	.2855
	3.00	-.0940	.17228	.981	-.6095	.4215
	4.00	-.1380	.17228	.927	-.6535	.3775
	5.00	-.9260*	.17228	.000	-1.4415	-.4105
3.00	1.00	-.1360	.17228	.931	-.6515	.3795
	2.00	.0940	.17228	.981	-.4215	.6095
	4.00	-.0440	.17228	.999	-.5595	.4715
	5.00	-.8320*	.17228	.001	-1.3475	-.3165
4.00	1.00	-.0920	.17228	.983	-.6075	.4235
	2.00	.1380	.17228	.927	-.3775	.6535
	3.00	.0440	.17228	.999	-.4715	.5595
	5.00	-.7880*	.17228	.002	-1.3035	-.2725
5.00	1.00	.6960*	.17228	.005	.1805	1.2115
	2.00	.9260*	.17228	.000	.4105	1.4415
	3.00	.8320*	.17228	.001	.3165	1.3475
	4.00	.7880*	.17228	.002	.2725	1.3035

*. The mean difference is significant at the .05 level.

Comparing the evenness, richness, and diversity index in each zone at Laemchabung.

Evenness

ANOVA

EVENNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.084	4	.021	.514	.726
Within Groups	.813	20	.041		
Total	.897	24			

Richness

ANOVA

RICHNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.559	4	.140	.800	.540
Within Groups	3.497	20	.175		
Total	4.056	24			

Diversity index

ANOVA

DIVERSIT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.264	4	.066	.573	.685
Within Groups	2.301	20	.115		
Total	2.565	24			

Comparing the evenness, richness, and diversity index in each zone at Chuksamet.

Evenness

ANOVA

EVENNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.060	4	.015	.611	.659
Within Groups	.491	20	.025		
Total	.551	24			

Richness

ANOVA

RICHNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.399	4	.100	1.283	.310
Within Groups	1.556	20	.078		
Total	1.956	24			

Diversity index

ANOVA

DIVERSIT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.276	4	.069	1.151	.362
Within Groups	1.201	20	.060		
Total	1.477	24			

Comparing the density value at Samet, Laemchabung, and Chuksamet.

ANOVA

DENSITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10481.36	2	5240.680	1.034	.361
Within Groups	364826.6	72	5067.037		
Total	375308.0	74			

Comparing the density value in each zone at Samet.

ANOVA

DENSITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7278.160	4	1819.540	2.889	.049
Within Groups	12596.40	20	629.820		
Total	19874.56	24			

Multiple Comparisons

Dependent Variable: DENSITY
Tukey HSD

(I) ZONES	(J) ZONES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	-47.8000*	15.87224	.048	-95.2957	-.3043
	3.00	-37.2000	15.87224	.172	-84.6957	10.2957
	4.00	-44.4000	15.87224	.074	-91.8957	3.0957
	5.00	-33.8000	15.87224	.247	-81.2957	13.6957
2.00	1.00	47.8000*	15.87224	.048	.3043	95.2957
	3.00	10.6000	15.87224	.961	-36.8957	58.0957
	4.00	3.4000	15.87224	.999	-44.0957	50.8957
	5.00	14.0000	15.87224	.900	-33.4957	61.4957
3.00	1.00	37.2000	15.87224	.172	-10.2957	84.6957
	2.00	-10.6000	15.87224	.961	-58.0957	36.8957
	4.00	-7.2000	15.87224	.991	-54.6957	40.2957
	5.00	3.4000	15.87224	.999	-44.0957	50.8957
4.00	1.00	44.4000	15.87224	.074	-3.0957	91.8957
	2.00	-3.4000	15.87224	.999	-50.8957	44.0957
	3.00	7.2000	15.87224	.991	-40.2957	54.6957
	5.00	10.6000	15.87224	.961	-36.8957	58.0957
5.00	1.00	33.8000	15.87224	.247	-13.6957	81.2957
	2.00	-14.0000	15.87224	.900	-61.4957	33.4957
	3.00	-3.4000	15.87224	.999	-50.8957	44.0957
	4.00	-10.6000	15.87224	.961	-58.0957	36.8957

*. The mean difference is significant at the .05 level.

Comparing the density value in each zone at Laemchabung.

ANOVA

DENSITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38627.84	4	9656.960	1.313	.299
Within Groups	147112.8	20	7355.640		
Total	185740.6	24			

Comparing the density value in each zone at Chuksamet.

ANOVA

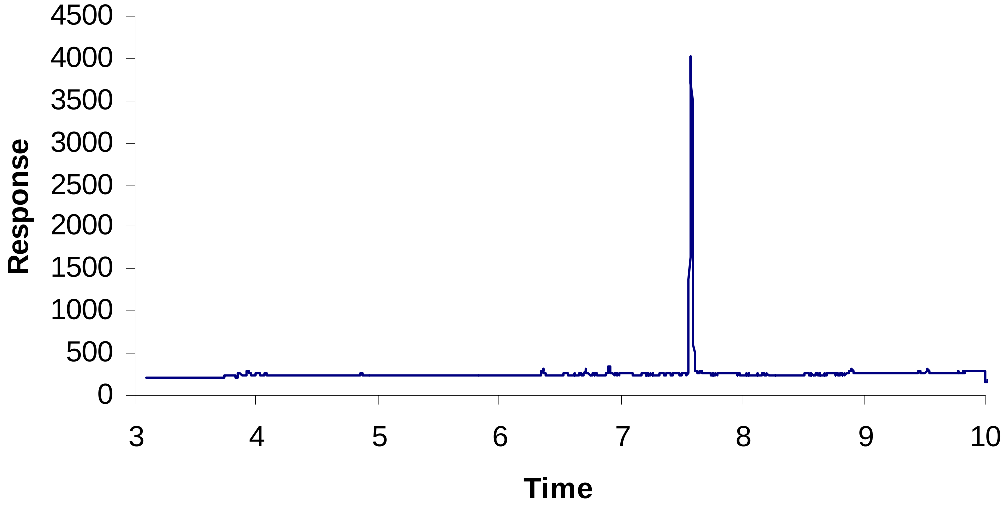
DENSITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	24008.24	4	6002.060	.888	.489
Within Groups	135203.2	20	6760.160		
Total	159211.4	24			

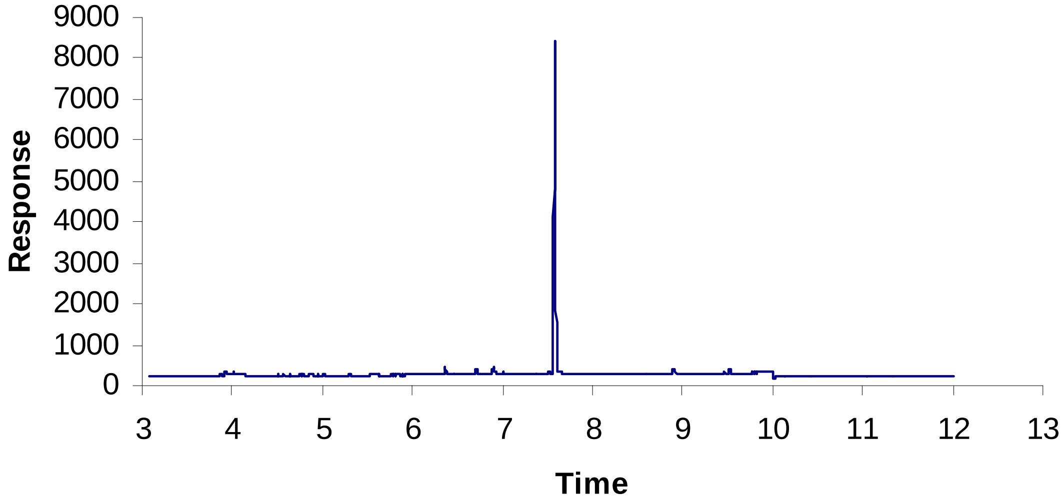
APPENDIX F

TBT Laboratory

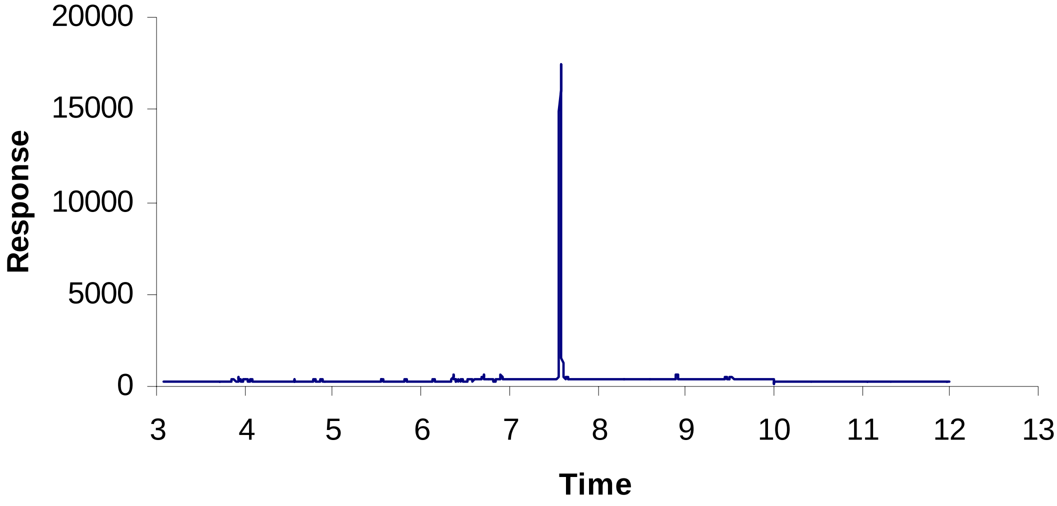
Sandard solution of hexylated tributyltin compound in concentration 15 ppb.



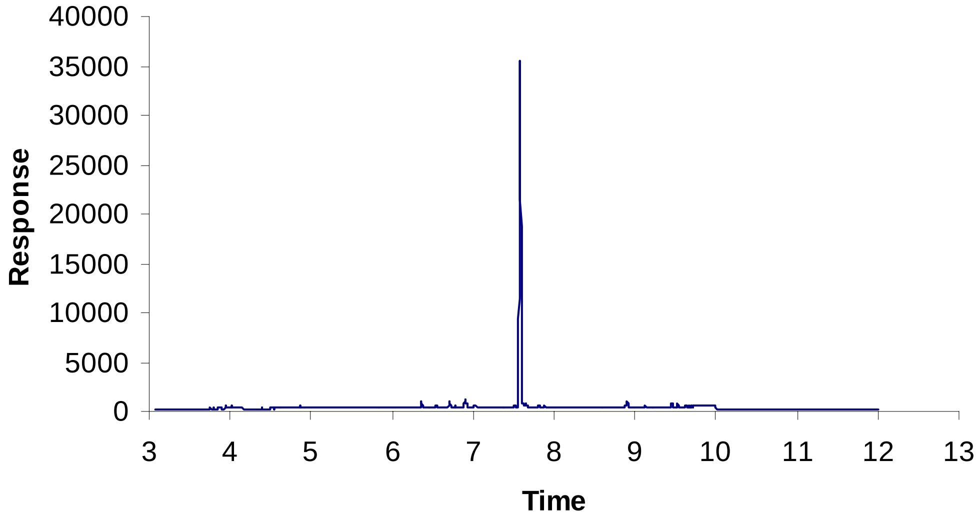
Standard solution of hexylated tributyltin compound in concentration 30 ppb.



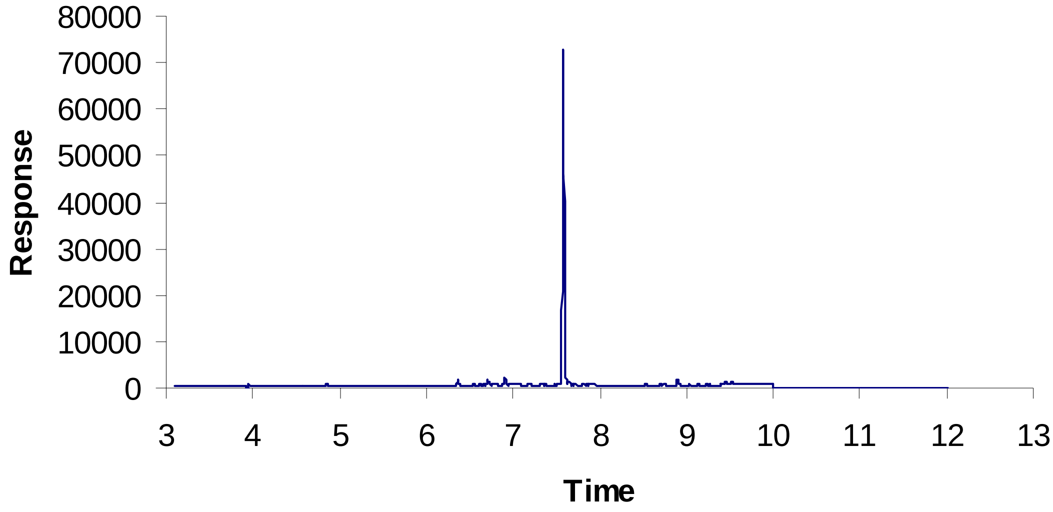
Standard solution of hexylated tributyltin compound in concentration 60 ppb.



Standard solution of hexylated tributyltin compound in concentration 120 ppb.



Standard solution of hexylated tributyltin compound in concentration 240 ppb.



Statistical test (Soil samples)

Comparing TBT concentration in soil in each plot at Samet.

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
TBT_SOIL	7.217	14	.000	2.4620	1.7304	3.1936

Comparing TBT concentration in soil in each plot at Laemchabung.

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
TBT_SOIL	14.440	14	.000	10.4987	8.9393	12.0581

Comparing TBT concentration in soil in each plot at Chuksamet.

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
TBT_SOIL	25.107	14	.000	1.5560	1.4231	1.6889

Comparing TBT concentration in soil at Samet, Laemchabung, and Chuksamet.

ANOVA

TBT_SOIL

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	726.901	2	363.450	112.030	.000
Within Groups	136.257	42	3.244		
Total	863.158	44			

Multiple Comparisons

Dependent Variable: TBT_SOIL
Tukey HSD

					95% Confidence Interval	
(I) SITE	(J) SITE	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
1.00	2.00	8.9427*	.65769	.000	7.3448	10.5405
	3.00	8.0367*	.65769	.000	6.4388	9.6345
2.00	1.00	-8.9427*	.65769	.000	-10.5405	-7.3448
	3.00	-.9060	.65769	.362	-2.5039	.6919
3.00	1.00	-8.0367*	.65769	.000	-9.6345	-6.4388
	2.00	.9060	.65769	.362	-.6919	2.5039

*. The mean difference is significant at the .05 level.

1 – Laemchabung

2 – Chuksamet

3 – Samet

Comparing TBT concentration in soil in each zone at Samet.

Test Statistics[a,b]

	TBT_SOIL
Chi-Square	8.700
df	4
Asymp. Sig.	.069

a. Kruskal Wallis Test

b. Grouping Variable: ZONE

Comparing TBT concentration in soil in each zone at Laemchabung.

Test Statistics[a,b]

	TBT_SOIL
Chi-Square	10.000
df	4
Asymp. Sig.	.040

a. Kruskal Wallis Test

b. Grouping Variable: ZONE

Comparing TBT concentration in soil in each zone at Chuksamet.

Test Statistics[a,b]

	TBT_SOIL
Chi-Square	4.482
df	4
Asymp. Sig.	.345

a. Kruskal Wallis Test

b. Grouping Variable: ZONE

Statistical test (Tissue samples)

Comparing TBT concentration in *Cerithidae cingulata* and *Cassidula aurisferis* at Samet.

Test Statistics[b]

	TBT
Mann-Whitney U	4.500
Wilcoxon W	10.500
Z	.000
Asymp. Sig. (2-tailed)	1.000
Exact Sig. [2*(1-tailed Sig.)]	1.000[a]

a. Not corrected for ties.

b. Grouping Variable: SPECIES

Comparing TBT concentration in *Cerithidae cingulata* and *Cassidula aurisferis* at Laemchabung.

Test Statistics[b]

	TBT
Mann-Whitney U	.000
Wilcoxon W	6.000
Z	-1.964
Asymp. Sig. (2-tailed)	.050
Exact Sig. [2*(1-tailed Sig.)]	.100[a]

a. Not corrected for ties.

b. Grouping Variable: SPECIES

Comparing TBT concentration in *Cerithidae cingulata* and *Cassidula aurisferis* at Chuksamet.

Test Statistics[b]

	TBT
Mann-Whitney U	4.000
Wilcoxon W	10.000
Z	-.218
Asymp. Sig. (2-tailed)	.827
Exact Sig. [2*(1-tailed Sig.)]	1.000[a]

a. Not corrected for ties.

b. Grouping Variable: SPECIES

Comparing TBT concentration in *Cerithidae cingulata* in three studied areas.

Test Statistics[a,b]

	TBT
Chi-Square	2.222
df	2
Asymp. Sig.	.329

a. Kruskal Wallis Test

b. Grouping Variable: SITE

Comparing TBT concentration in *Cassidula aurisferis* in three studied areas.

Test Statistics[a,b]

	TBT
Chi-Square	4.356
df	2
Asymp. Sig.	.113

a. Kruskal Wallis Test

b. Grouping Variable: SITE

APPENDIX G

Relationsip

TBT concentration and physical factors

The correlation between TBT concentration and all physical factor values at Samet.

Correlations

		TBT_SOIL	SOIL_PH	WATER_PH	SOIL_TEM	WATER_TE	WATER_SA	AIR_TEMP	HUMIDITY
TBT_SOIL	Pearson Correlation	1	.068	.135	-.266	-.139	.355	.067	-.263
	Sig. (2-tailed)	.	.809	.631	.338	.623	.194	.814	.344
	N	15	15	15	15	15	15	15	15
SOIL_PH	Pearson Correlation	.068	1	-.291	-.311	-.518**	.387	.045	.097
	Sig. (2-tailed)	.809	.	.158	.131	.008	.056	.831	.645
	N	15	25	25	25	25	25	25	25
WATER_PH	Pearson Correlation	.135	-.291	1	-.129	-.097	-.317	-.046	-.099
	Sig. (2-tailed)	.631	.158	.	.540	.645	.123	.829	.637
	N	15	25	25	25	25	25	25	25
SOIL_TEM	Pearson Correlation	-.266	-.311	-.129	1	.222	-.271	-.101	.351
	Sig. (2-tailed)	.338	.131	.540	.	.287	.190	.630	.085
	N	15	25	25	25	25	25	25	25
WATER_TE	Pearson Correlation	-.139	-.518**	-.097	.222	1	-.147	.498*	-.156
	Sig. (2-tailed)	.623	.008	.645	.287	.	.484	.011	.457
	N	15	25	25	25	25	25	25	25
WATER_SA	Pearson Correlation	.355	.387	-.317	-.271	-.147	1	.331	-.162
	Sig. (2-tailed)	.194	.056	.123	.190	.484	.	.106	.439
	N	15	25	25	25	25	25	25	25
AIR_TEMP	Pearson Correlation	.067	.045	-.046	-.101	.498*	.331	1	-.590**
	Sig. (2-tailed)	.814	.831	.829	.630	.011	.106	.	.002
	N	15	25	25	25	25	25	25	25
HUMIDITY	Pearson Correlation	-.263	.097	-.099	.351	-.156	-.162	-.590**	1
	Sig. (2-tailed)	.344	.645	.637	.085	.457	.439	.002	.
	N	15	25	25	25	25	25	25	25

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

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

The correlation between TBT concentration and all physical factor values at Laemchabung.

Correlations

		TBT_SOIL	SOIL_PH	WATER_PH	SOIL_TEM	WATER_TE	WATER_SA	AIR_TEMP	HUMIDITY
TBT_SOIL	Pearson Correlation	1	-.368	.400	.272	.536*	-.560*	.348	-.105
	Sig. (2-tailed)	.	.177	.140	.326	.039	.030	.204	.711
	N	15	15	15	15	15	15	15	15
SOIL_PH	Pearson Correlation	-.368	1	-.300	-.033	-.349	.182	-.424*	.509**
	Sig. (2-tailed)	.177	.	.146	.876	.087	.383	.035	.009
	N	15	25	25	25	25	25	25	25
WATER_PH	Pearson Correlation	.400	-.300	1	.308	.185	-.132	.212	-.372
	Sig. (2-tailed)	.140	.146	.	.134	.375	.530	.309	.067
	N	15	25	25	25	25	25	25	25
SOIL_TEM	Pearson Correlation	.272	-.033	.308	1	.664**	-.461*	.517**	-.036
	Sig. (2-tailed)	.326	.876	.134	.	.000	.020	.008	.863
	N	15	25	25	25	25	25	25	25
WATER_TE	Pearson Correlation	.536*	-.349	.185	.664**	1	-.774**	.923**	-.499*
	Sig. (2-tailed)	.039	.087	.375	.000	.	.000	.000	.011
	N	15	25	25	25	25	25	25	25
WATER_SA	Pearson Correlation	-.560*	.182	-.132	-.461*	-.774**	1	-.741**	.431*
	Sig. (2-tailed)	.030	.383	.530	.020	.000	.	.000	.031
	N	15	25	25	25	25	25	25	25
AIR_TEMP	Pearson Correlation	.348	-.424*	.212	.517**	.923**	-.741**	1	-.700**
	Sig. (2-tailed)	.204	.035	.309	.008	.000	.000	.	.000
	N	15	25	25	25	25	25	25	25
HUMIDITY	Pearson Correlation	-.105	.509**	-.372	-.036	-.499*	.431*	-.700**	1
	Sig. (2-tailed)	.711	.009	.067	.863	.011	.031	.000	.
	N	15	25	25	25	25	25	25	25

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

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

The correlation between TBT concentration and all physical factor values at Chuksamet.

Correlations

		TBT_SOIL	SOIL_PH	WATER_PH	SOIL_TEM	WATER_TE	WATER_SA	AIR_TEMP	HUMIDITY
TBT_SOIL	Pearson Correlation	1	.514*	-.229	.089	-.422	.244	-.123	.042
	Sig. (2-tailed)	.	.050	.586	.752	.297	.598	.676	.882
	N	15	15	8	15	8	7	14	15
SOIL_PH	Pearson Correlation	.514*	1	.400	-.036	.244	.479	-.376	.155
	Sig. (2-tailed)	.050	.	.197	.864	.444	.136	.070	.459
	N	15	25	12	25	12	11	24	25
WATER_PH	Pearson Correlation	-.229	.400	1	.272	.664*	-.502	.320	-.409
	Sig. (2-tailed)	.586	.197	.	.392	.018	.140	.337	.187
	N	8	12	12	12	12	10	11	12
SOIL_TEM	Pearson Correlation	.089	-.036	.272	1	.707*	-.229	.509*	-.231
	Sig. (2-tailed)	.752	.864	.392	.	.010	.498	.011	.267
	N	15	25	12	25	12	11	24	25
WATER_TE	Pearson Correlation	-.422	.244	.664*	.707*	1	-.063	.744**	-.512
	Sig. (2-tailed)	.297	.444	.018	.010	.	.862	.009	.088
	N	8	12	12	12	12	10	11	12
WATER_SA	Pearson Correlation	.244	.479	-.502	-.229	-.063	1	-.331	-.381
	Sig. (2-tailed)	.598	.136	.140	.498	.862	.	.320	.247
	N	7	11	10	11	10	11	11	11
AIR_TEMP	Pearson Correlation	-.123	-.376	.320	.509*	.744**	-.331	1	-.500*
	Sig. (2-tailed)	.676	.070	.337	.011	.009	.320	.	.013
	N	14	24	11	24	11	11	24	24
HUMIDITY	Pearson Correlation	.042	.155	-.409	-.231	-.512	-.381	-.500*	1
	Sig. (2-tailed)	.882	.459	.187	.267	.088	.247	.013	.
	N	15	25	12	25	12	11	24	25

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

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

TBT concentration and Soil texture

The Correlation between TBT concentration and soil texture at Samet.

Correlations

		TBT_SOIL	SOIL_TEX
TBT_SOIL	Pearson Correlation	1	-.256
	Sig. (2-tailed)	.	.356
	N	15	15
SOIL_TEX	Pearson Correlation	-.256	1
	Sig. (2-tailed)	.356	.
	N	15	25

The Correlation between TBT concentration and soil texture at Laemchabung.

Correlations

		TBT_SOIL	SOIL_TEX
TBT_SOIL	Pearson Correlation	1	-.360
	Sig. (2-tailed)	.	.188
	N	15	15
SOIL_TEX	Pearson Correlation	-.360	1
	Sig. (2-tailed)	.188	.
	N	15	25

The Correlation between TBT concentration and soil texture at Chuksamet.

Correlations

		TBT_SOIL	SOIL_TEX
TBT_SOIL	Pearson Correlation	1	.327
	Sig. (2-tailed)	.	.234
	N	15	15
SOIL_TEX	Pearson Correlation	.327	1
	Sig. (2-tailed)	.234	.
	N	15	25

TBT concentration and Diversity index

The correlation between the diversity index and TBT concentration at Samet.

Correlations

		TBT_SOIL	DIVERSIT
TBT_SOIL	Pearson Correlation	1	-.290
	Sig. (2-tailed)	.	.294
	N	15	15
DIVERSIT	Pearson Correlation	-.290	1
	Sig. (2-tailed)	.294	.
	N	15	25

The correlation between the diversity index and TBT concentration at Laemchabung.

Correlations

		TBT_SOIL	DIVERSIT
TBT_SOIL	Pearson Correlation	1	.168
	Sig. (2-tailed)	.	.550
	N	15	15
DIVERSIT	Pearson Correlation	.168	1
	Sig. (2-tailed)	.550	.
	N	15	25

The correlation between the diversity index and TBT concentration at Chuksamet.

Correlations

		TBT_SOIL	DIVERSIT
TBT_SOIL	Pearson Correlation	1	.449
	Sig. (2-tailed)	.	.093
	N	15	15
DIVERSIT	Pearson Correlation	.449	1
	Sig. (2-tailed)	.093	.
	N	15	25

Diversity index and Physical factors

The correlation between the diversity index and all physical factors at Samet.

Correlations

		DIVERSIT	SOIL_PH	WATER_PH	SOIL_TEM	WATER_TE	WATER_SA	AIR_TEMP	HUMIDITY
DIVERSIT	Pearson Correlation	1	-.272	.256	.131	.456*	-.172	.280	-.124
	Sig. (2-tailed)	.	.188	.217	.534	.022	.412	.176	.553
	N	25	25	25	25	25	25	25	25
SOIL_PH	Pearson Correlation	-.272	1	-.291	-.311	-.518**	.387	.045	.097
	Sig. (2-tailed)	.188	.	.158	.131	.008	.056	.831	.645
	N	25	25	25	25	25	25	25	25
WATER_PH	Pearson Correlation	.256	-.291	1	-.129	-.097	-.317	-.046	-.099
	Sig. (2-tailed)	.217	.158	.	.540	.645	.123	.829	.637
	N	25	25	25	25	25	25	25	25
SOIL_TEM	Pearson Correlation	.131	-.311	-.129	1	.222	-.271	-.101	.351
	Sig. (2-tailed)	.534	.131	.540	.	.287	.190	.630	.085
	N	25	25	25	25	25	25	25	25
WATER_TE	Pearson Correlation	.456*	-.518**	-.097	.222	1	-.147	.498*	-.156
	Sig. (2-tailed)	.022	.008	.645	.287	.	.484	.011	.457
	N	25	25	25	25	25	25	25	25
WATER_SA	Pearson Correlation	-.172	.387	-.317	-.271	-.147	1	.331	-.162
	Sig. (2-tailed)	.412	.056	.123	.190	.484	.	.106	.439
	N	25	25	25	25	25	25	25	25
AIR_TEMP	Pearson Correlation	.280	.045	-.046	-.101	.498*	.331	1	-.590**
	Sig. (2-tailed)	.176	.831	.829	.630	.011	.106	.	.002
	N	25	25	25	25	25	25	25	25
HUMIDITY	Pearson Correlation	-.124	.097	-.099	.351	-.156	-.162	-.590**	1
	Sig. (2-tailed)	.553	.645	.637	.085	.457	.439	.002	.
	N	25	25	25	25	25	25	25	25

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

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

The correlation between the diversity index and all physical factors at Laemchabung.

Correlations

		DIVERSIT	SOIL_PH	WATER_PH	SOIL_TEM	WATER_TE	WATER_SA	AIR_TEMP	HUMIDITY
DIVERSIT	Pearson Correlation	1	-.146	.108	-.090	-.030	-.011	.004	.124
	Sig. (2-tailed)	.	.485	.609	.670	.888	.959	.984	.556
	N	25	25	25	25	25	25	25	25
SOIL_PH	Pearson Correlation	-.146	1	-.300	-.033	-.349	.182	-.424*	.509**
	Sig. (2-tailed)	.485	.	.146	.876	.087	.383	.035	.009
	N	25	25	25	25	25	25	25	25
WATER_PH	Pearson Correlation	.108	-.300	1	.308	.185	-.132	.212	-.372
	Sig. (2-tailed)	.609	.146	.	.134	.375	.530	.309	.067
	N	25	25	25	25	25	25	25	25
SOIL_TEM	Pearson Correlation	-.090	-.033	.308	1	.664**	-.461*	.517**	-.036
	Sig. (2-tailed)	.670	.876	.134	.	.000	.020	.008	.863
	N	25	25	25	25	25	25	25	25
WATER_TE	Pearson Correlation	-.030	-.349	.185	.664**	1	-.774**	.923**	-.499*
	Sig. (2-tailed)	.888	.087	.375	.000	.	.000	.000	.011
	N	25	25	25	25	25	25	25	25
WATER_SA	Pearson Correlation	-.011	.182	-.132	-.461*	-.774**	1	-.741**	.431*
	Sig. (2-tailed)	.959	.383	.530	.020	.000	.	.000	.031
	N	25	25	25	25	25	25	25	25
AIR_TEMP	Pearson Correlation	.004	-.424*	.212	.517**	.923**	-.741**	1	-.700**
	Sig. (2-tailed)	.984	.035	.309	.008	.000	.000	.	.000
	N	25	25	25	25	25	25	25	25
HUMIDITY	Pearson Correlation	.124	.509**	-.372	-.036	-.499*	.431*	-.700**	1
	Sig. (2-tailed)	.556	.009	.067	.863	.011	.031	.000	.
	N	25	25	25	25	25	25	25	25

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

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

The correlation between the diversity index and all physical factors at Chuksamet.

Correlations

		DIVERSIT	SOIL_PH	WATER_PH	SOIL_TEM	WATER_TE	WATER_SA	AIR_TEMP	HUMIDITY
DIVERSIT	Pearson Correlation	1	.079	-.158	.084	-.376	-.293	.181	.112
	Sig. (2-tailed)	.	.708	.623	.691	.229	.383	.397	.596
	N	25	25	12	25	12	11	24	25
SOIL_PH	Pearson Correlation	.079	1	.400	-.036	.244	.479	-.376	.155
	Sig. (2-tailed)	.708	.	.197	.864	.444	.136	.070	.459
	N	25	25	12	25	12	11	24	25
WATER_PH	Pearson Correlation	-.158	.400	1	.272	.664*	-.502	.320	-.409
	Sig. (2-tailed)	.623	.197	.	.392	.018	.140	.337	.187
	N	12	12	12	12	12	10	11	12
SOIL_TEM	Pearson Correlation	.084	-.036	.272	1	.707*	-.229	.509*	-.231
	Sig. (2-tailed)	.691	.864	.392	.	.010	.498	.011	.267
	N	25	25	12	25	12	11	24	25
WATER_TE	Pearson Correlation	-.376	.244	.664*	.707*	1	-.063	.744**	-.512
	Sig. (2-tailed)	.229	.444	.018	.010	.	.862	.009	.088
	N	12	12	12	12	12	10	11	12
WATER_SA	Pearson Correlation	-.293	.479	-.502	-.229	-.063	1	-.331	-.381
	Sig. (2-tailed)	.383	.136	.140	.498	.862	.	.320	.247
	N	11	11	10	11	10	11	11	11
AIR_TEMP	Pearson Correlation	.181	-.376	.320	.509*	.744**	-.331	1	-.500*
	Sig. (2-tailed)	.397	.070	.337	.011	.009	.320	.	.013
	N	24	24	11	24	11	11	24	24
HUMIDITY	Pearson Correlation	.112	.155	-.409	-.231	-.512	-.381	-.500*	1
	Sig. (2-tailed)	.596	.459	.187	.267	.088	.247	.013	.
	N	25	25	12	25	12	11	24	25

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

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

Diversity index and Soil texture

The correlation between the diversity index and soil texture at Samet.

Correlations

		DIVERSIT	SOIL_TEX
DIVERSIT	Pearson Correlation	1	.057
	Sig. (2-tailed)	.	.788
	N	25	25
SOIL_TEX	Pearson Correlation	.057	1
	Sig. (2-tailed)	.788	.
	N	25	25

The correlation between the diversity index and soil texture at Laemchabung.

Correlations

		DIVERSIT	SOIL_TEX
DIVERSIT	Pearson Correlation	1	.277
	Sig. (2-tailed)	.	.180
	N	25	25
SOIL_TEX	Pearson Correlation	.277	1
	Sig. (2-tailed)	.180	.
	N	25	25

The correlation between the diversity index and soil texture at Chuksamet.

Correlations

		DIVERSIT	SOIL_TEX
DIVERSIT	Pearson Correlation	1	.053
	Sig. (2-tailed)	.	.802
	N	25	25
SOIL_TEX	Pearson Correlation	.053	1
	Sig. (2-tailed)	.802	.
	N	25	25

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