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The Diversity and Abundance of Gelatinous Zooplankton in the Gulf of Thailand

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The Diversity and Abundance of Gelatinous Zooplankton in the Gulf of Thailand

Kunita Kokubo

A Senior Project in Partial Fulfillment of the Requirements
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ชื่อโครงการ	ความหลากหลายและความชุกชุมของแพลงก์ตอนสัตว์กลุ่มเจลาตินัส (Gelatinous Zooplankton) บริเวณอ่าวไทย
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บทคัดย่อ

แพลงก์ตอนสัตว์กลุ่มเจลาตินัสคือกลุ่มของแพลงก์ตอนสัตว์ที่มีเนื้อเยื้อคล้ายวุ้นและมีองค์ประกอบของร่างกายมากกว่า 95% ประกอบด้วยน้ำ แพลงก์ตอนสัตว์กลุ่มนี้มีหลายชนิดซึ่งต่างเป็นตัวสำคัญในการส่งผ่านพลังงานไปยังระดับห่วงโซ่ต่าง ๆ แต่มีบางชนิดที่เป็นอันตรายต่อมนุษย์และส่งผลเสียต่ออุตสาหกรรมการประมงและเพาะเลี้ยง อย่างไรก็ตามการศึกษาเกี่ยวกับแพลงก์ตอนสัตว์กลุ่มเจลาตินัสในประเทศไทยยังมีอยู่จำกัด การศึกษาครั้งนี้จึงต้องการทราบความหลากหลายและความชุกชุมแพลงก์ตอนสัตว์กลุ่มเจลาตินัสในอ่าวไทย โดยนำตัวอย่างแพลงก์ตอนสัตว์กลุ่มเจลาตินัสจากโครงการสำรวจทรัพยากรประมงทะเลและสิ่งแวดล้อมในบริเวณอ่าวไทย โดยเรือ M.V.SEAFDEC 2 มาจำแนกชนิดและหาความหนาแน่น ผลการศึกษาพบแพลงก์ตอนสัตว์กลุ่มเจลาตินัสทั้งหมด 76 ชนิด จาก 8 คลาส 6 ไฟลัม มี 24 ชนิดที่ไม่เคยรายงานมาก่อนในประเทศไทย คลาสไฮโดรซัวเป็นคลาสที่มีความหลากชนิดสูงที่สุด พบทั้งหมด 57 ชนิดคิดเป็นร้อยละ 75% ของจำนวนชนิดทั้งหมดที่พบ ดัชนีความหลากหลายมีค่าสูงที่สุด 2.85 ที่สถานีในอ่าวไทยตอนกลาง (สถานี 15) และต่ำสุด 0.92 ในสถานีบริเวณอ่าวไทยตอนบน (สถานี 1) ความหนาแน่นรวมของแพลงก์ตอนสัตว์กลุ่มเจลาตินัสสูงที่สุด 113,365 ตัวต่อ 100 ลูกบาศก์เมตรพบที่สถานีบริเวณอ่าวไทยตอนบน (สถานี 1) และความหนาแน่นต่ำสุดพบที่สถานีบริเวณอ่าวไทยตอนกลาง (สถานี 29) 1,753 ตัวต่อ 100 ลูกบาศก์เมตร แต่หากพิจารณาความหนาแน่นเฉลี่ยของแต่ละส่วนของอ่าวไทยพบว่าอ่าวไทยตอนบนมีความหนาแน่นสูงที่สุดตามด้วยอ่าวไทยตอนกลางและตอนล่าง ตามลำดับ ส่วนปริมาตรชีวภาพมีค่าสูงที่สุดที่สถานีในอ่าวไทยตอนบน 3.26 มิลลิลิตรต่อลูกบาศก์เมตร (สถานี 3) และต่ำสุดที่สถานีในอ่าวไทยตอนล่าง 0.06 มิลลิลิตรต่อลูกบาศก์เมตร (สถานี 34) แพลงก์ตอนชนิดเด่นและพบได้ทั่วไปในอ่าวไทยได้แก่ หนอนธนู *Flaccisagitta enflata* และ *Aidanosagitta neglecta* และ appendicularian *Oikopleura longicauda* ประชาคมแพลงก์ตอนกลุ่มเจลาตินัสในอ่าวไทยแบ่งออกได้ 5 กลุ่ม โดยกลุ่มที่ 1 เป็นกลุ่มที่ใหญ่ที่สุดประกอบด้วยแพลงก์ตอนสัตว์จากอ่าวไทยตอนกลางและตอนล่าง มีความหนาแน่นค่อนข้างต่ำ *มี F. enflata, A. neglecta, O. dioica* และไฮโรเมดูซี *Aglaura hemistoma* เป็นกลุ่มเด่น กลุ่มที่ 2 ประกอบด้วยแพลงก์ตอนสัตว์จากอ่าวไทยตอนกลางบริเวณใกล้ชายฝั่ง มีความหนาแน่นสูงและพบ *F. enflata, O. longicauda, A. neglecta* และ *O. dioica* เป็นกลุ่มเด่น ส่วนกลุ่มที่ 3, 4 และ 5 ถูกจัดอยู่กันในคนละกลุ่มเพราะในแต่ละสถานีพบความหนาแน่นและแพลงก์ตอนชนิดเด่นแตกต่างกัน ดัชนีความหลากหลายและดุลยภาพการกระจายของแพลงก์ตอนแปรผันตรงกับความเค็มและความหนาแน่นของน้ำทะเลอย่างมีนัยสำคัญทางสถิติ ($p< 0.01$) แต่แปรผกผันกับปริมาณออกซิเจนละลาย ($p<0.05$) ในทางตรงกันข้ามความหนาแน่นและปริมาตรชีวภาพแปรผกผันกับความเค็มและความหนาแน่นของน้ำทะเลอย่างมีนัยสำคัญทางสถิติ ($p< 0.01$)

คำสำคัญ: ความหลากหลาย อ่าวไทย แพลงก์ตอนสัตว์กลุ่มเจลาตินัส ไฮโดรซัว

Project Title The Diversity and Abundance of Gelatinous Zooplankton in the Gulf of Thailand

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Abstract

Gelatinous zooplanktons (GZ) are zooplanktons that have jelly-like tissue and have more than 95% of their body made of water. They are diverse and play a role in energy transfer to higher trophic levels, but some species harm humans and affect fishing and aquaculture industries negatively. Knowledge on GZ in Thailand is limited. In this study, GZ samples from the Gulf of Thailand (GOT) collected by the Collaborative Research Survey on Marine Fisheries and Marine Environment in the Gulf of Thailand by M.V.SEAFDEC 2 were analyzed for diversity and abundance. Seventy-six species of GZ from 8 classes and 6 phyla were identified. I found 24 species are new records to Thai water. Class Hydrozoa was the most diverse group with 57 species which accounted for 75% of the total number of species. The Shannon-Weiner index was highest in the middle part of the GOT (St. 15) with a value of 2.85 and was lowest in the upper part of the GOT (St. 1) with a value of 0.92. The highest abundance of GZ was 113,365 individuals/100m^3 at St.1 in the upper GOT, and the lowest abundance was 1,753 individuals/100m^3 at St. 29 in the middle part of the GOT. Comparing the average abundance for each part of the GOT, the upper part of the GOT had the highest abundance, followed by the middle and lower GOT, respectively. The highest biovolume was 3.26 ml/m^3 the upper GOT (St. 3) and the lowest biovolume was found at St. 34 in the lower GOT (0.06 ml/m^3). The dominant and common GZ were arrow worm *Flaccisagitta enflata* and *Aidanosagitta neglecta* and appendicularian *Oikopleura dioica*. Non-metric multidimensional scaling showed that GZ communities were divided into 5 groups: 1) The biggest group formed by planktons from the middle and lower part of the GOT. This group has a relatively low abundance and dominated by *F. enflata, A. neglecta, O. dioica* and hydromedusae *Aglaura hemistoma* 2) planktons from near shore in the middle part of the GOT which is characterized by high abundance and dominated by *F. enflata, O. longicauda, A. neglecta* and *O. dioica*. The third, fourth and fifth groups each consists of a single station from upper GOT and lower GOT that had different dominant species. Shannon-Weiner index and evenness index of the GZ were positively correlated with salinity and seawater density ($p<0.01$), but negatively correlated with dissolved oxygen ($p<0.05$). In contrast, abundance and biovolume of GZ were negatively correlated with salinity and seawater density ($p< 0.01$).

Keywords: Diversity Gulf of Thailand, Gelatinous zooplanktons, Hydrozoa,

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Finally, I would like to thank my family for their support and love they have given me all my life. Thank you for always being there for me.

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Introduction

1.1 Introduction

Gelatinous Zooplanktons (GZ) are a group of zooplanktons that have jelly-like tissue and have more than 95% of their body made of water (Condon et al., 2012). This group of plankton comprises of organisms from 12 groups including radiolaria (Phylum Retaria) medusae and siphonophore (Phylum Cnidaria), ctenophore (Phylum Ctenophora), heteropod, pteropod and cephalopod (Phylum Mollusca), polychaete worms (Phylum Annelida), crustaceans (Phylum Arthropoda), holothurians (Phylum Echinodermata), pelagic tunicates (Phylum Chordata) (Madin and Harbison, 2001) and also arrow worms (Phylum Chaetognatha) (Aguilar et al., 2015). The GZ have evolved this jelly-like tissue in order to adapt to the open ocean environment that they live in. For example, transparent tissue conceals them in the upper layers of the sea, furthermore the high-water content makes them almost the same density as sea water (Madin and Harbison, 2001). GZ play an important role in energy transfer from lower trophic levels to higher trophic levels, for example they can be food for fish (Purcell & Arai, 2001), and some species of turtles (Bjorndal, 1997). One study reported that 80% of the bluefin tuna diet is composed of GZ (Cardona et al., 2012) and jellyfish carcasses that sink to the bottom of the sea are food sources for the benthic community that live on the ocean floor (Sweetman and Chapman, 2015). Additionally, jellyfish, which are a group of GZ are consumed in Japan and China and have benefits such as having medical properties for healing high blood pressure, arthritis and bronchitis (Purcell et al., 2013). Also, showcasing jellyfish in aquariums are beneficial for education, the economy and is very useful for researchers to conduct studies on them (Purcell et al., 2013).

Although jellyfish have a lot of advantages, they can cause many problems. Poisonous stings of jellyfish are directly harm to human when contacted. The Bureau of Epidemiology from the Department of Disease Control reported that there were 53 injuries and 1 death caused by jellyfish stings in Thailand during 2003-2008 (Sontichai, 2009), and from the report of Toxic Jellyfish Injuries at Bangsaen Beach, Chon Buri during the years 2015-2017 there were 622 injuries caused by the jellyfish sting (Prongnamjai, 2019. These injuries from jellyfish will cause loss of tourism in affected areas and will increase costs for treatment and prevention. GZ can also cause damages in other areas such as fishery and aquaculture. In fishery, a study by Shiganova and Bulgakova (2000) found that in the Black Sea, *Mnemiopsis*, a species of ctenophore consumes anchovy egg and competes with their larvae for food source, causing a significant decline in the number of anchovies in the black sea. In another study by Lynam and others in 2005 which investigated the effect of jellyfish on the number of herring in the North Sea found that jellyfish had negative impacts on the number of herring. The jellyfish both preyed on herring fish larvae and competed with them for food. In aquaculture, GZ can float into the pens and inflict injuries on fish from their nematocysts, furthermore with rapid increase in their number they can also suffocate the farmed fish (Purcell et al., 2013). Dense of GZ attached to aquaculture equipment can reduce waterflow and increase costs for maintenance (Purcell et al., 2013).

From the information mentioned above, it is clear that GZ have advantages and disadvantages. However, the study of GZ in Thailand is still limited. There have been only two studies in the past and the studies were conducted only in the upper Gulf of Thailand (Chaiburin, 2007 and Jitrapat, 2018). Other than that, several studies have been conducted on one or two specific groups of GZ. For example, Tandavanitj (2001) studied Species Diversity and Abundance of Rhizostome Scyphozoans along the coast of Chonburi and Petchburi province during 1999-2000. Narawasut (2002) investigated the abundance and distribution of the arrow worm population in the inner Gulf of Thailand in 2002, Wuttijaroenmonkol (2004) described planktonic Hydrozoan in the upper Gulf of Thailand from Chonburi province to Huahin, Prachuap Khiri Khan province, Pannarak (2004) studied the diversity of arrow worms along the coast of Klong Pak Meng, Trung province in 2003), and Department of Marine and Coastal Resources (DMCR) reported the species and the distribution of jellyfish along the coast of the Andaman sea and the Gulf of Thailand covering 21 provinces during 2010-2018 (DMCR, 2019). This shows that the study of GZ is limited by the area of study. Moreover, researches on the diversity of GZ are yet unable to identify the organisms' species for all of the organisms.

This study aims to determine the diversity and abundance of GZ in the Gulf of Thailand covering the upper, middle and lower gulf area. Seven groups of GZ were studied including hydromedusae and siphonophores (Phylum Cnidaria), ctenophores (Phylum Ctenophora), pteropods (Phylum Mollusca), polychaete worms (Phylum Annelida), arrow worms (Phylum Chaetognatha), and pelagic tunicates (Phylum Chordata) which is divided into 3 sub-groups which are salps, doliolids and larvaceans. The result of this study will provide knowledge about the diversity and abundance of GZ in the Gulf of Thailand that has never been explored and will be a database which can be used for other researches such as studying the ecology of the marine ecosystem.

1.2 Objectives

1.2.1 To determine the diversity and abundance of GZ in the Gulf of Thailand.

1.2.2 To investigate the relationships between the diveristy and abundance of GZ and some physical parameters in the Gulf of Thailand.

1.3 Scope of Study

Study the diversity and abundance of 6 groups from 6 Phyla of GZ including hydromedusae and siphonophores (Phylum Cnidaria), ctenophores (Phylum Ctenophora), arrow worms (Phylum Chaetognatha), pteropods (Phylum Mollusca), polychaete worms (Phylum Annelida) and pelagic tunicates (Phylum Chordata) which is divided into 3 groups which are salps, doliolids and larvaceans from 20 stations covering the upper, middle, and lower Gulf of Thailand.

1.4 Benefits of the Study

Gain the knowledge of the diversity and abundance of GZ in the Gulf of Thailand that has never been known before. This information will provide a database which can be used for future research purposes. Furthermore, this study will indicate the importance of GZ that may have been overlooked before, whether it be the diversity or the productivity.

Chapter 2
Literature Review

2.1 Gelatinous zooplankton

Gelatinous zooplankton (GZ) are a group of zooplankton that have jellylike tissues with water contents of 95% or higher (Condon et al, 2012). This group of plankton comprises of organisms from 12 groups in 9 Phyla including radiolaria (Phylum Retaria) medusae and siphonophore (Phylum Cnidaria), ctenophore (Phylum Ctenophora), heteropod, pteropod and cephalopod (Phylum Mollusca), polychaete worms (Phylum Annelida), crustaceans (Phylum Arthropoda), holothurians (Phylum Echinodermata), pelagic tunicates (Phylum Chordata) (Madin and Harbison, 2001) and also arrow worms (Phylum Chaetognatha) (Aguilar et al., 2015).

The gelatinous body plan has evolved to suit the open ocean environment which has little and unpredictable food sources and a relatively constant physical parameter. They display a number of common adaptations to this environment (Madin and Harbison, 2001). For instance, the GZ's transparent tissue disguises them in the upper layers of the ocean where there is no physical cover (Madin and Harbison 2001). High water content in GZ facilitates them to have similar density as seawater, reducing the need to expend energy in floating. Moreover, the high-water content also permits rapid growth and reduces their food value, deterring predators. GZ do not need strong structures in their body because the environment they live in does not have strong turbulence or physical barriers. Lastly, their relatively large size makes them too big for some predators to attack (Madin and Harbison, 2001).

The charateristics of GZ from 6 Phyla that were investigated in this study are decribed here, consisting of Phylum Cnidaria (Class Hydrozoa, Class Scyphozoa and Class Cubozoa), Phylum Ctenophora, Phylum Mollusca, Phylum Annelida, Phylum Chaetognatha and Phylum Chordata including Class Appendicularia and Class Thaliacea.

<u>Phylum Cnidaria</u>

Cnidarians are radially symmetrical aquatic invertebrates that have stinging cells called *cnida* which are used for hunting. These stinging cells are arranged into special structures called nematocysts; these cells can make Cnidarians venomous in different degrees (Licandro et al., 2017c). Cnidarians have a simple body plan; the body wall is composed of an outer ectoderm and inner endoderm enclosing the gastrovascular cavity called the enteron. Between the two layers is a structureless layer called the mesoglea. They have no defined muscular system, but muscular elements are included in the epithelial cells of both the endoderm and ectoderm. They have a primitive nervous sytem consisting of the nerve net (El-Bawab, 2020). Cnidarians have widely different shapes and sizes, they can be solitary or colonial, may live as free-living planktons or settle as sessile benthos. They can be found at all latitudes and depths (Licandro et al., 2017c). Cnidarians have a complex life cycle with 2 body forms, the sessile polyp and the free-swimming medusa, although one or the other form can be lost in some groups (Dumont, 2009). Normally, the polyp is the asexual stage and the medusa is the sexual stage. In meroplanktonic species, the ciliated larva (planula) turns into a benthic polyp that will then produce several medusae (ephyra) by budding. In holoplanktonic species the planula directly changes into an ephyra-like stage (Licandro et al., 2017c). Male and Females medusae usually release sperms and eggs into the water where fertilization occurs. Some hydromedusae may reproduce asexually by budding or longitudinal fission (Licandro et al., 2017a).

Cnidarians which spend a part of their life as a GZ in form of a free-swimming medusae are Class Hydrozoa, Class Scyphozoa and Class Cubozoa (Licandro et al., 2017c).

Class Hydrozoa

There are two stages of life for the Hydrozoa, the benthic polyp and the free-swimming planktonic medusa stage (Dumont, 2009). The planktonic stage of the hydromedusae are solitary animals with tetramerous radial symmetry. It has a body shaped like a mushroom called the umbrella (Figure 2.1), the convex upper surface of the umbrella is called the exumbrella and the concave lower surface is called the subumbrella (Russel, 1953). Most of its volume is occupied by a gelatinous mass, the mesoglea. The space encased by the umbrella is called the subumbrellar cavity which is narrowed by the velum, used for locomotion, leaving a cicular opening called the velar opening. The rim of the umbrella bears marginal tentacles and sense organs. The tentacles may be solid or contain the extension of the circular canal. The base of each tentacle is generally swollen into a tentacular bulb. (Russel, 1953)

There is a tubular or quadrangular projection of differing length hanging from the center of the subumbrella called the manubrium. The cavity of the manubrium (gastric cavity) opens into the mouth and extends into the gastrovascular canals. There are usually four of these canals, but sometimes it can be more numerous. These canals connect the gastric cavity to the circular canal, which runs around the rim of the umbrella. The gastric cavity, the radial canals, the ring canal and the tentacular canals (if present) make up the gastrovascular system which handles the digestion and distribution of food, waste and gametes. The mouth is situated at the end of the manubrium. It may be simple of have lips, lobes or tentacles. (Russel, 1953)

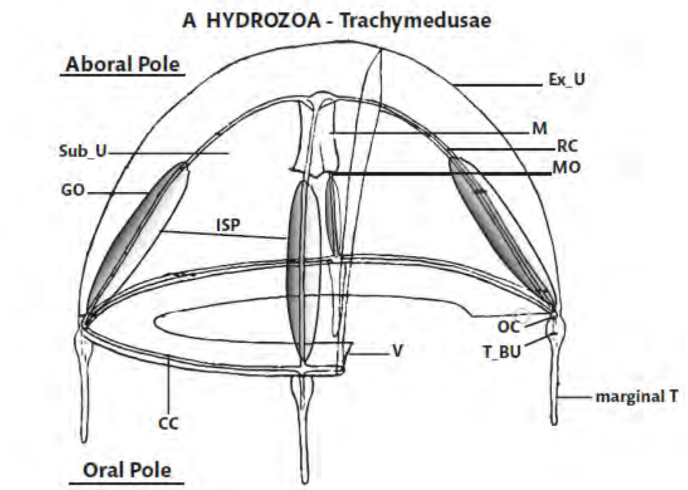


Figure 2.1 Diagram of a hydromedusa CC=Circular canals, GO=Gonads, ISP=Interradial space, M=Manubrium, MO=Mouth, RC= Radial canals, U=Umbrella, OC= Ocelli, T_BU=Tentacle bulb , T=Tentacles, V=Velum (Licandro et al., 2017c; modified from Trégouboff and Rose (1957))

The hydromedusae can be devided into 5 orders namely Anthomedusae, Leptomedusae, Limnomedusae, Trachymedusae and Narcomedusae (Kramp, 1968). For purpose of description, Russel (1953) devided the umbrella into radial planes (Figure 2.2). The four planes meeting at right angles at the apex of the umbrella are the *perradial* plane. Halfway between perradial planes are the *interradial* planes. Halfway between the interradial planes and the perradial planes are *adradial* planes, deviding the umbrella into 16 sectors.

The umbrellas of the hydromedusae are typically bell shaped like *Sarisia* (Figure 2.3A), but have considerable variation from species to species. It can have considerable height e.g. *Aglantha* (Figure 2.3B), or may be spherical in shape e.g. *Bougainvillia ramosa* (Figure 2.3C). Or it can be flattened to a hemispherical shape e.g. *Phialella* (Figure 2.3D), saucer shaped e.g. *Aequorea* (Figure 2.3E), or even flat like a disc e.g. *Obelia* (Figure 2.3F). The umbrella also varies in its solidity which is dependent on the presence of the mesoglea. In some species like *Obelia*, the jelly is extremely thin while others like *Phialidium* or *Bougainvillia* may have moderate to very thick jellies. In some species the jelly is much thicker at the apex of the umbrella e.g

Amphinema (Figure 2.3G), this thickening of the summit is known as an apical projection or process. An unusual type of umbrella thickening is where there are lateral papillos protrusions e.g *Halicreas minimum* (Figure 2.3H). (Russel, 1953)

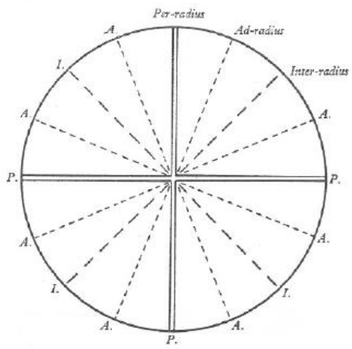


Figure 2.2 Diagram explaining the radial planes of a hydromedusa. Where P=Perradii which devide the plane into 4 equal parts, I=Interradii situated halfway between P and A=Adradii which are placed halfway between P and I (Russel, 1953)

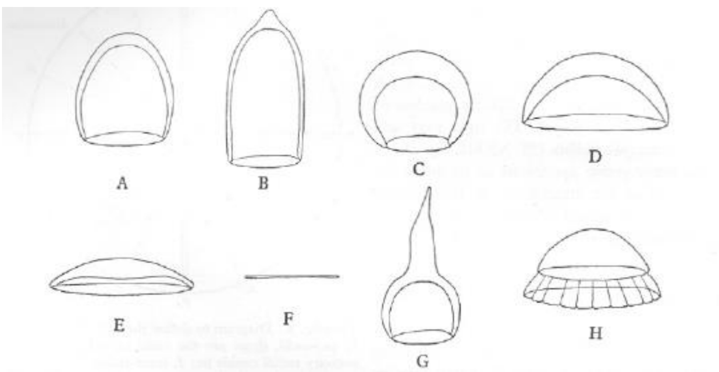


Figure 2.3 Different types of umbrellas in hydromedusae. A=*Sarsia*; B=*Aglantha*; C=*Bougainvillia*; D=*Phialella*; E=*Aeqquorea*; F=*Obelia*; G=*Amphinema*; H=a narcomedusa. (Russel, 1953)

The stomach, which hangs down form the center of the subembrella is a simple sack, at the end of the stomach is the mouth. There can also be a gelatinous projection projecting downwards into the cavity with the stomach attached at the end. This jelly is called the peduncle. The peduncle may be very shallow and unnoticeable, or it may be more noticeably conical, or it may form a very elongate cone resulting in the protrusion of the stomach beyond the umbrella margin. The mouth and the lips of the medusae are very important characters for the classification of the Anthomedusae. The mouth can be simple and circular e.g. *Sarsia* and *Steenstrupia* (Figure 2.4A). It may have 4 simple perradial lips e.g. *Phialidium* (Figure 2.4B). These 4 lips may be folded to different degrees e.g. *Cosmetira* and *Leuckartiara* (Figure 2.4C) or pointed e.g. *Eirene* (Figure 2.4D). Some species have a circular mouth opening and oral tentacles above the mouth with a cluster of nematocysts at the tentacle tip. These oral tentacles may be simple and undivided like *Lizzia* (Figure 2.4G), or dichotomously branched like *Bougainvillia* (Figure 2.4H). (Russel, 1953)

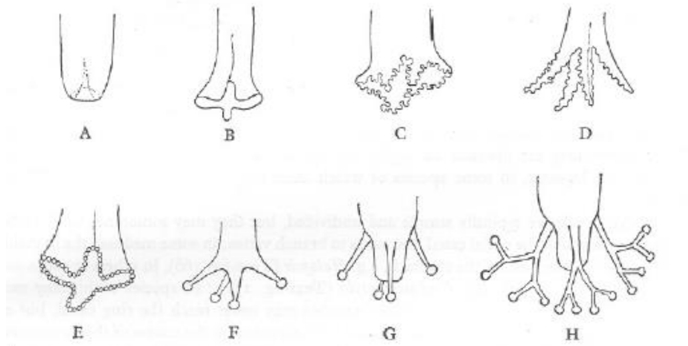


Figure 2.4 Mouths of different hydromedusae. A=*Sarsia*; B=*Phialiduim*; C=*Cosmetira*; D=*Eirene*; E=*Turritopsis*; F=*Podocoryne*; G=*Lizzia*; H=*Bougainvillia*. (Russel, 1953)

The position and shape of gonads are also important characters used for classification. The gonads of Anthomedusae are attached on the walls of the stomach, while of the Leptomedusae are located on the radial canals. The gonad may be cylindrical and completely surrounding the stomach e.g. *Sarisa, Rathkea* (Figure 2.5A) or split into many cylindrical bands (Figure 2.5B) e.g. *Dipurena*. If the gonads are not cylindrically surrounded the stomach, their position on the wall of the stomach is important for the classification. They may be interradial (Figure 2.5C) or adradial (Figure 2.5D). When situated on the radial canals, the gonads are generally completely separated from the stomach. But in some cases, the ends of the gonads can be touching the stomach or be present on the walls of the stomach and a short distance along the radial canal. The gonads on the radial canals can have various shapes such as oval (Figure 2.5E), or elongated into varying degrees. When elongated they can be straight, folded or sinuous (Figure 2.5F, G, H). In some medusae, gonadal tissue is continuous over the ventral wall (Figure 2.5I). When the gonadal tissue is present only on the lateral wall of the radial canal, the gonad is devided along its lower surface by a medium furrow (Figure 2.5J). In other species, the gonads can develop to a high degree and hang down into the subumbrellar cavity like pouches (Figure 2.5K), these pouches can also be sausage shaped e.g. *Aglantha* (Figure 2.5L). (Russel, 1953)

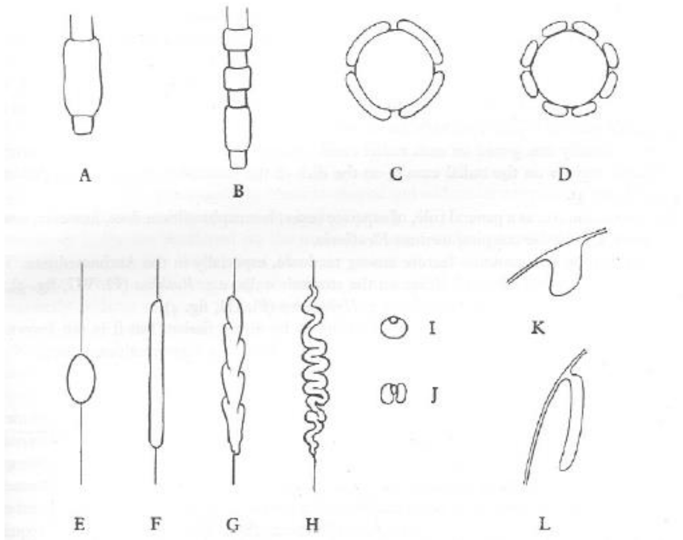


Figure 2.5 Gonads of different hydromedusae. A & B=Laterral view of stomach; A=*Sarsia*, B=*Dipurena*. C & D=Cross section of stomach; C=*Bougainvillia ramosa*, D=*B.principis*. E-H=Types of gonad on radial canals; E=oval, F=linear, G=folded, H=sinuous. I & J=Cross section of gonad on radial canals; I=*Phialidium,* J=*Tiaropsis*. K & L=Lateral view of gonad; K=*Craspedacusta*, L=*Aglantha*. (Russel, 1953)

The marginal tentacles around the bell of hydromedusae can be various forms. A hollow tentacles has a continuation of the cavity of the ring canal into the tentacle, whereas a solid tentacle has a core of single cells formed by the endoderm. The swelling at the base of the tentacles are called tentacle bulbs. The marginal tentacle bulbs vary in shape and size. They can be swollen with a horseshoe shaped nematocyst tissue (Figure 2.6B), spherical, conical (Figure 2.6H) or tapering (Figure 2.6A). In some medusae like *Bougainvillia* and *Rathkea,* a few tentacles emerge from a single bulb with additional tentacle developing from the outer corners of the bulb (Figure 2.6G). Sometimes bulbs can develop without tentacles (non-tentacular marginal bulbs) or develop tentacles later (developing tentacular marginal bulbs). In some grown medusae with may marginal tentacles there will be a few marginal bulbs without tentacles. These bulbs could grow tentacles, but they never actually do, these are called rudimentary marginal bulbs. The marginal tentacles are armed with nematocysts which may be clustered together in small masses of swellings or irregularly distributed over the length of the marginal tentacle. Some species have nematocyst rings which are nematocysts that are grouped together to form complete rings around the marginal tentacle (Figure 2.6C). (Russel, 1953)

The number of tentacles may vary in different species and at different ages in the same species. In some species the number is reduced or may have no marginal tentacles. Increase in number during development usually follows a regular law until about 24 or 32 tentacles: 4 perradial = 4 interradial+ 8 adradial = 16 and then one between every two = 32 or 4 perradial = 8 adradial = 12 and then one between every two = 24 After these numbers the the distribution becomes more irregular. (Russel, 1953)

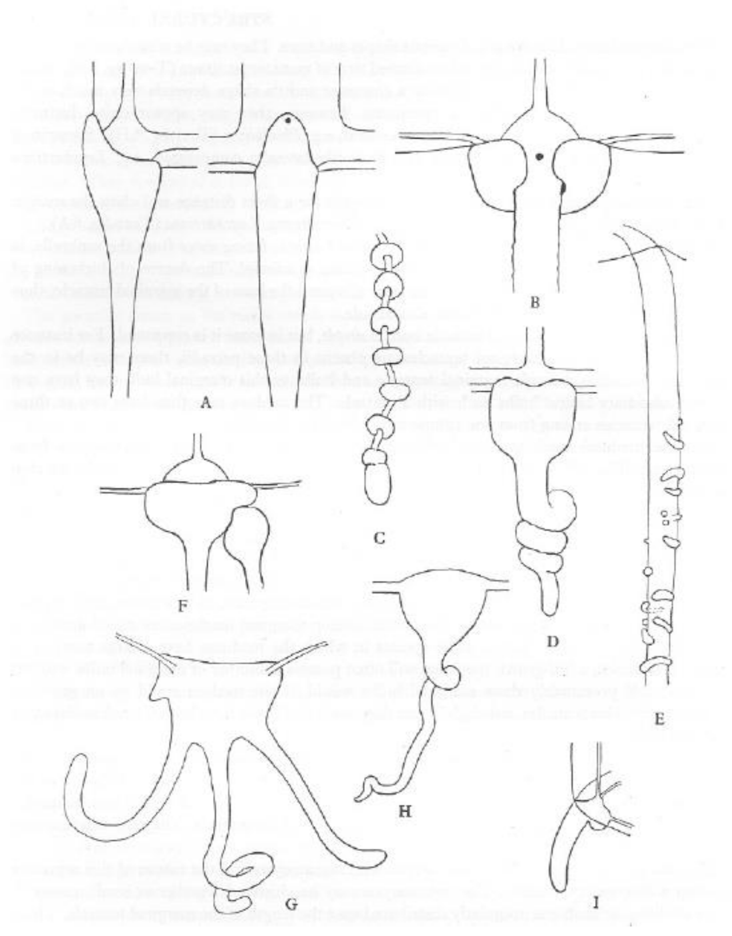


Figure 2.6 Marginal tentacles of different hydromedusae. A=*Leuckartiara octana*; B=*Sarsia tubulosa*; C=*Steenstrupia nutans*; D=*Cosmetira pilosella*; E= *Gossea coryntes*; F=*Hybocodon prolifer*; G=*Bougainvillia Britannica*; H=*Phialidium hemisphaericum*; I=*Proboscidactyla ornate* (Russel, 1953)

Hydromedusae have two kinds of sense organs, ocelli and statocysts. The Ocellis are organs for light perception. They are round spots of black, chocolate brown or red pigments.

They are generally placed on the marginal tentacle bulbs. The statocysts are possibly organs of orientation which can be used for classification. The ectodermal statocysts (Figure 2.7C,D), develop in the velum just where it joins the margin of the umbrella. Their structures are small pits in the velum which may remain open or become closed so the organ is a small vesicle known as marginal vesicles. The endodermal statocysts (Figure 2.7A,B) are sensory clubs which are small tentacle-like structures growing out of the umbrella margin. (Russel, 1953)

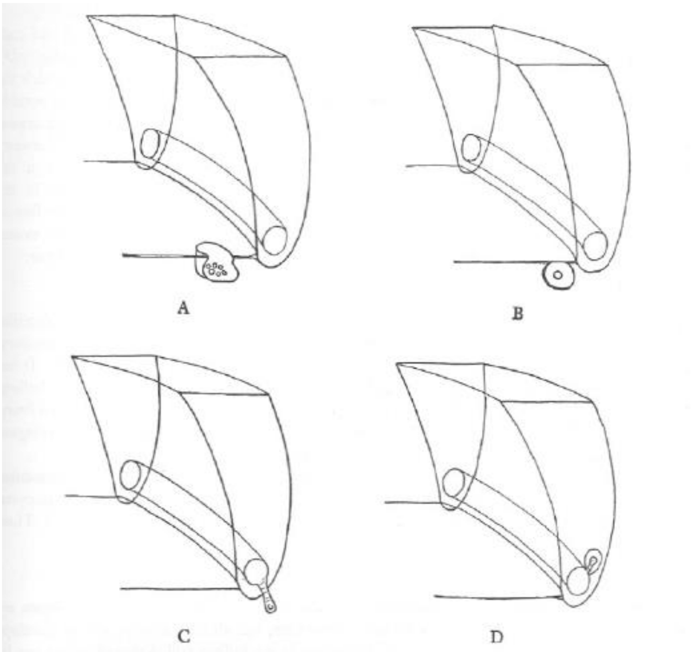


Figure 2.7 Types of statocysts. A=open marginal vesicle; B=closed marginal vesicle; C=free marginal sensory club; D=enclosed marginal sensory club. (Russel, 1953)

Order Siphonophorae

Siphonophores are colonial, polymorphic mainly marine Hydrozoa. They are pelagic oganisms that can be found at all lattitudes and depths (Alvarino, 1971). Like all hydrozoans, they carry tentacles with nematocysts used for immobilizing and killing their prey. Siphonophores are one of the most abundant carnivores in the ocean (Mackie. Et al, 1987) which eat small copepods and other zooplanktons by entrapping them by their tentacles (Mapstone, 2014)

Licandro and others (2017) stated that each siphonophore colony is made up of a collection of zooids with a certain role: (1) medusozoid zooids such as the swimming bells called nectophores and the reproductive units called sexual gonophores; (2) polypoid zooids which regulates the buyoncy of the colony called pneumatophore; (3), gastrozooids are responsible for feeding and digestion; and (4) dactylozooids which are palpons, aidin manipulation. All zooids are arranged along a stem which is a tube surrounding the main gastrovascular canal. The tip of the stem called the anterior/aboral pole is where the nectophore is situated, this part is called the nectosome (Figure 2.8). The distal posterior/oral pole which carries the rest of the zooid is called the siphosome. (Licandro et al., 2017b)

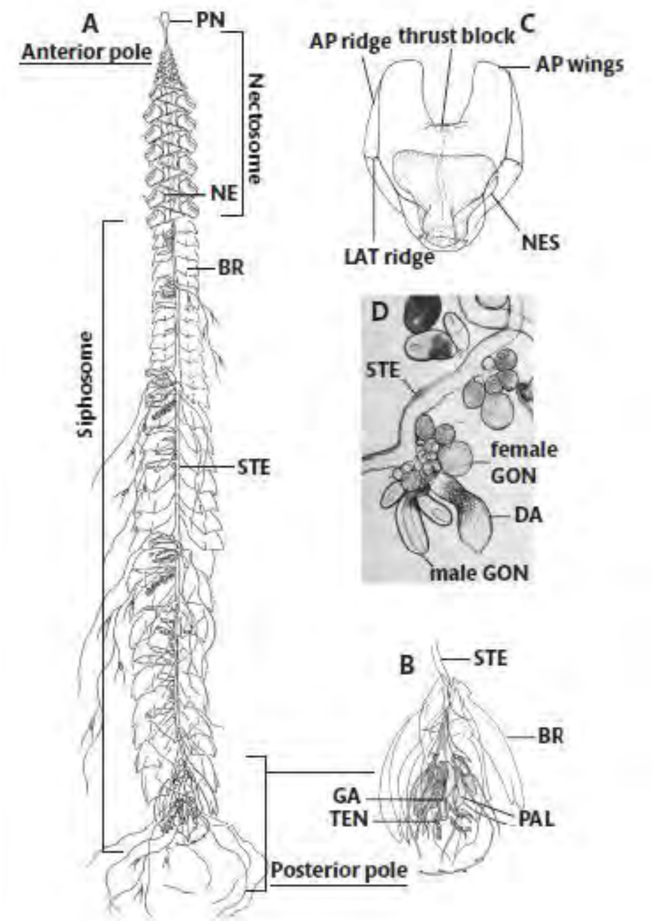


Figure 2.8 General structure of the siphonophore. A, Agalma elegans. B, Distal/posterior part of the siphonophore. C, Nectophore, upper view. PN=Pneumatophore; NE=Nectophore; BR=Bract; STE=Stem; AP= Apical; LAT=Lateral; NES=Nectosac; GON=Gonophore; DA=Dactylozooid; PAL=Palon; GA=Gastrozooid; TEN=Tentilla (Licandro et al., 2017b; obtained from Totton, 1965)

Class Scyphozoa and Class Cubozoa

Scyphozoa (Figure 2.9A) and Cubozoa (Figure 2.9B) are larger marine cnidarians. They have a thick mesoglea which gives them skeletal support and the appearance of 'jelly' (Boltovskoy, 1999).

Scyphozoans are big and can grow up to 2 meters in diameter and have no velum (Licandro et al., 2017a). There are approximately 200 species of Scyphozoans which are exclusively marine. The Scyphozoa is devided into (1) Coronatae having deep furrow deviding the exumbrella into inner and outer zones, (2) Semaestomeae which are large, inverted dish-shaped medusae and (3) Rhizostomae which are quite hemispherical and are found in warm-water coasts and have countless mouthlets instead of a single central mouth. (Boltovskoy, 1999)

Cubozoans are fairly small (up to 25 centimeters tall) and have a cubic shape. They possess a velarium instead of a velum (Licandro, et al. 2017a). There are some 15 species of Cubozoa that can cause severe illness to a man by their sting (Boltovskoy, 1999).

Usually samples that can be collected in a plankton net are small ephyra stages of these animals (Jittrapat, 2018).

Phylum Ctenophora

Ctenophores are mainly carnivorous marine GZ usually feeding on copepods, amphipods, fish eggs and larvae of different sizes, and some species have been observed to feed on marine snow. Some ctenophores also feed on other GZ such as medusae, salps and other ctenophores. Ctenophore use tentacles that have sticky adhesive cells called colloblasts to capture prey, some use their large, flexible mouth to engulf their prey (Gershwin et al., 2014a)

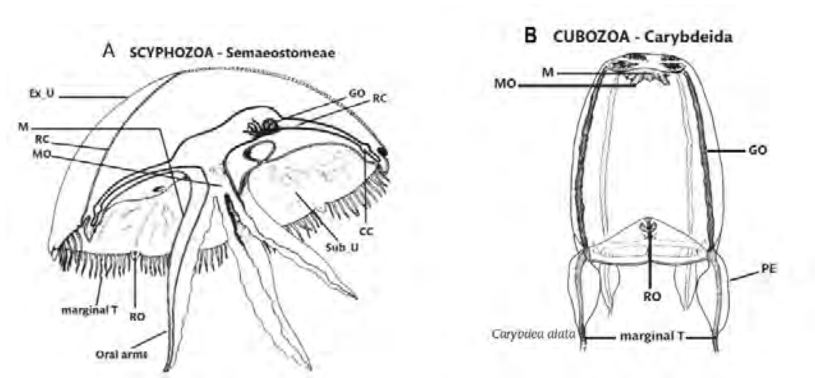


Figure 2.9 A, Scyphozoa – Semaeostomeae lateral view. B, Cubozoa – Carybdeida lateral view. U=Umbrella M=Mouth; RC=Radial canals; MO=Mouth; T=Tentacle; RO=Rhopalium; GO=Gonad; CC=Circular canals; PE=Pedalia (Licandro et al. 2017c; A, Modified from Naumov, 1960. B, obtained from Corbera in Pagés et al., 1992)

Ctenophores have biradial symmetries, their body can have a round or ribbon like shape. The body of ctenophores are composed of a gelatinous mesoglea between external and internal epitheliums. Their bodies have eight bands of cilia called comb rows. All ctenophores have these comb rows at some stage in their life, even though some may lose them at maturity. The locomotion of the animal is facilitated by the beating of the comb rows coordinated by the statocyst. The gastrovascular system in ctenophores is composed of an axial and peripheral part. The axial part consists of a mouth, a pharynx, a gut, excretory canals and anal pores. The peripheral part is composed of a net of canals including the perradial, interradial and adradial canals, eight meridional canals each one being under a comb row, the tentacular and finally the paragastric canals. All ctenophores must have the adradial canal and the meridional canals. The connections, morphology and number of the peripheral canals are important taxonomic features (Licandro and Lindsay, 2017).

Most ctenophores are hermaphrodites capable of self-fertilization. Their gonads are usually located in the wall of the meridional canals and they release eggs and sperms through different gonoducts or the mouth. (Licandro and Lindsay, 2017)

Ctenophores can be divided into two classes: Class Tentaculata and Class Nuda. Class Tentaculata consists of the order Cydippida or the sea gooseberries which have a spherical or oval shape with two long tentacles with branches to the side called “tentilla”, and the orders Platyctenida, Cambojiida, Ganeshida, Cryptobiferida, Thalassocalycida most of which have only one family each, order Lobata or sea walnuts have two large lobes at one end of their body and order Cestida. Class Nuda consists of only one order which is order Beroida. Beroids are shaped like a sac with one open end. (Gershwin et al., 2014a; Licandro and Lindsay, 2017)

Phylum Mollusca

GZ in this phylum consist of Pterotracheoidea (formerly Heteropods) (Lischka and Ossenbrügger, 2017), Pteropods and Cephalopods (Madina nd Harbison, 2001). Pterotracheoiea is a superfamily of prosobranch gastropods that includes the family Atlantidae, Carinariidae and Pterotracheidae. The family Atlantidae have thin, flattened shells where they can completely withdraw their bodies. They feed on small crustaceans and other mollusks. Carinarids have a greatly reduced shell covering only a small part of the body. They feed on other GZ such as salps, doliolids and chaetognaths. The family Pterotracheidae have no shell.

Pteropods can be devided into two groups, Thecosomata and Gymnosomata. Thecostomata are pteropods that have calcerous shells and are not truly gelatinous. They feed by using a mucous web to collect particulate food. This group comprises of five families namely Limacinidae, Cavoliniidae, Peraclididae, Cymbuliidae and Desmoperidae. Gymnosomata on the other hand do not have calcerous shells. Members of this order are poorly known because most of them live in the deep sea. They feed specifically on thecosome pteropods. They comprise of the families Pneumodermatidae, Notobrancheidae, Clionidae, Cliopsidae, Hydromylidae and Laginiopsidae (Madin and Harbison, 2001).

Lastly, there are several gelatinous cephalopods including the family Cranchiidae which is composed entirely of gelatinous species. These relatively large slow-moving squids capture their prey through stealth rather than pursuit (Madin and Harbison, 2001).

Phylum AnnelidaPolychaete is a group of annelids found in the marine environment (Fauchald, 2013). There are two major families of gelatinous polychaetes, the Alciopidae and the Tomopteridae (Madin and Harbison, 2001). Madin and Harbison describe the Alcopidae as polychaetes with well-developed eyes that have lenses and have GZ as their diet. Tomopterids, on the other hand don't have well developed eyes. Both of them can produce bioluminescence to attract mates for reproduction (Castellani and Camp, 2017)

The polychaete body is elongated and profoundly segmented, the body is devided into four zones which are the prostomium (a pre-oral lobe carrying sensory organs), the peristomium (where the mouth is situated), the trunk (carrying the parapodia) and the pygidium (bearing the anus) (Castellani and Camp, 2017).

Phylum Chaetognatha

Chaetognaths are also known as arrow worms which are zooplanktons found in every marine habitat (Bone et al., 1991). They are often abundant and are the primary predators of copedods so they play an important role in transferring energy from lower to higher trophic levels (Bone et al., 1991)

Chaetognaths are bilaterally symmetrical, usually transparent with one or two pairs of lateral fins and a tail fin. Its body consists of a head, trunk and tail. The head is round and somewhat flattened, having grasping spines, teeth, vestibular organs and a ventral mouth. Most epi- and meso-pelagic species have two dorsal eyes with either a pigment spot or ommatidia. The head is separated from the trunk by a transverse septum. The trunk is long and muscular having another transverse septum deviding it from the tail. Paired female reproductive organs are situated in the trunk, the male reproductive organs are situated on the tail. Apart from the gut and gonads, there are no internal organs (Kapp, 1991). The body cavity is filled with fluid which serve as a hydro-skeleton. Its surface is coverd with receptors that detect vibrations (Pierrot-Bults, 2017).

All species of chaetognaths are carnivores and may prey on several trophic levels, but itselves are food for a variety of bigger organisms (Feigenbaum, 1991). Chaetognaths spot prey by sensing movements. They attack preys when it swims overhead by a rapid jerk of the forward part of the body and grasping them by the hooks. Young chaetognaths mainly feed on copepod nauplii while adults eat adult copepods, other chaetognaths, cladocerans, euphausiids, barnacle nauplii and appendicularians. The diet of the chaetognath can vary seasonally. (Feigenbaum, 1991)

Chaetognaths are protandric hermaphdrodites and generally cross fertilize, although self-fertilization has been reported in some species. Sperm is deposited as a package near the gonopore of another individual and retained in the ovi-spermaduct until the eggs are ripe. Fertilization happens in the ovary and the fertilized eggs are released into the water in pelagic species. Eggs hatch as small version of adulst so there are no larval stages. In tropical waters chaetognaths can reproduce several times a year. (Pierrot-Bults, 2017)

Chaetognaths are one of the most isolated phyla in the Animal kingdom, their roots and evolutionary development of the groups are yet unknown. About 28 generas have been listed and about 100 species are known (Bieri, 1991). Environmental factors can cause morphological variability in chaetognaths. Therefore, Toioka (1974) has listed seven characters that are relatively stable for identification of species:

1. General appearance of the boy such as proportional length of the tail segment, location of maximum body width, relative width of the head compared to that of the body.
2. The structure and arrangement of lateral fins.
3. The corona ciliata's position, shape and length.
4. Outline of the pigment cell in the eye.
5. Location and structure of the seminal vesicle in repect to the tail fin and posterior fins.
6. Armature.
7. Presence or absence of intestinal diverticula.

Molecular techniques may provide a more acceptable arrangement of chaetognath systematics in the future (Bone et al., 1991)

Phylum Chordata

GZ in the phylum Chordata include class Appendicularia and class Thaliacea.

Class Appendicularia

Appendicularians or larvaceans are filter-feeding, free-swimming pelagic zooplanktons (Fenaux, 1998). They have three features that are customary in all chordates at some stage in their life including gill slits, a tubular nerve cord and the notochord. They posess the notochord also in their adult form. Appendicularians can be found around the world, but are common in warm waters.

The body of the appendicularians are composed of a trunk and chordate tail. Most are just a few millimeters long, but some can be as big as 8-9 cm. All appendicularians secrete and live in a mucous house (Bone, 1998). Appendicularians pump water through the house filter to concentrate the particles for feeding. The mesh size of the filter is very fine in some species so they can feed on nanoplanktons, a food resource unavailable to most metazoan filter feeders. (Gorsky and Castellani, 2017)

All appendicularians except *Oikopleura dioica* are hermaphroditic. Sexually mature adults release gametes into the sea where fertilization take place. The egg hatches and produces a tadpole larva with a trunk and a tail. The larva grows until the tail twists and shifts. This rapid development is followed by the formation of the first house. Once the development is completed, the somatic cell number remains the same and further growth is by enlargement of the cells. The life cycle of an appendicularaian is less than two days. (Fenaux 1998)

There are three families of appendicularians namely Oikopleuridae, Fritillariidae and Kowalevskiidae. Oikopleuridae have compact trunks with straight endostyle and the spiracles close to the anus. The tail is straight and the length is several times that of the trunk with tapering at the end. Fritillariidae have elongated trunks with a dorsoventrally compressed or spindle shaped endostyle. The spiracles are located on the anterior part of the pharyngeal cavity and connects the pharynx with the exterior. The tail is rarely longer than the trunk. Lastly, Kowalevskiidae have short trunks with the fore part depressed. No endostyle and heart, but with large, elipsoidal branchial openeings. The tail is spindle shaped. Currently, 13 genera and 70 species have been described. (Gorsky and Castellani, 2017)

Class Thaliacea

Thaliacea are marine zooplankton that have an alternation of generation life cycle alternating between the asexual stage called the oozoid and the sexual stage called the blastozooid (Licandro and Brunetta, 2017). They have a body covered by a transparent cellulose tunic. These include salps, doliolids and pyrosomas. (Godeaux et al., 1998)

Order Salpida

Salps are tubular zooplanktons that can be found in all seas down to 1,500 meters. Same as other Thaliaceas, salps have an alternation of generation between aggregated sexual blastozooids and solitary asexual oozoids. These two stages have quite a large anatomical difference. The oozoid is a bilaterally symmetrical transparent hollow tube with visible internal organs such as the heart, the ciliated gill bar and nerve bundles from the brain crossing the muscle bands. The dorsal surface is occupied with muscle bands of which the different number and disposition are used for taxonomic identification. They have a U shaped ventral endostyle. The blastozooid is very similar to the oozoid, but it is asymmetrical and have fewer numbers and a different disposition of muscle bands. The oozoid has both ovaries and testis, the testis maturing after the ovary. After the fertilization by sperm from an older blastozooid, the egg devides inside the follicle and forms an embryo attached to the maternal blastozooid. The embryo matures, then swims off as an oozoid continuing the cycle. (Godeaux et al., 1998)

Only a singly family of Salpidae has been recognized (Boltovskoy, 1999) with about 40 species of salps have been described presently. Thy are widely distributed especially in tropical and warm temperate seas. There are few species known from the Antarctic (Godeaux 1998).

Order Doliolida

Doliolids are tiny free-swimming zooplanktons which can be found in warm continental shelf waters. The oozoid is barrel shaped and transparent with 9 bands of muscle encircling the body. Inside the body lies the internal organs such as the dorsal brain, ventral heart and stolon. In the gonozooid, the location and shape of the endostyle, digestive gear, testis and gill bar are used for taxonomic identification. (Godeaux et al., 1998)

There is an alternation between the asexual oozooid stage and the hermaphroditic sexuall blatozooid stage. After fertilization, the egg hatches into a free-living larva then develops into an oozoid. As the oozoids age (this stage is called the nurse), the internal organs disappear, the posterior dorsal process lengthens and this part bears the buds that will form the next blastozooid stage. These buds develop into gastrozooids and phorozooids. The phorozooids then give rise to gonozooids. The gonozooid can sexually reproduce by producing eggs and sperms. The ovary of the gonozooid produces eggs wich are fertilized in the oviduct and then released into the sea, after releasing the eggs, the oviduct disappears and the testis matures to release sprerm to fertilize the eggs of other gonozooids. The eggs then develop into larvae which become the next generation of oozoids. (Godeaux et al., 1998)

There are 3 families of the order Doliolida which are, Doliolidae, Doliopsoididae and Doliopsidae (Godeaux, 1998).

Order Pyrosomatida

Pyrosomes are colonial animals which are quite common in tropical and warm temperate waters. The blastozooids are independent and remain fixed side by side in a test. These blastozooids are responsible for the reproducing and the growth of the colony. On the other hand, the oozooid is a short-lived stage. The colony is cylindrical or conical, the surface is either smooth or with protruding processes. It is closed at one end which is the oldest part of the colony and opens at the other end. The size of the adult colony differs greatly in different species: from a few centimeters upto 20 meters long. (Godeaux, et al. 1998)

The order Pyrosomatida consist of a single family, the Pyrosomatidae with less than 10 species have been described (Godeaux 1998).

2.2 The Importance of Gelatinous Zooplankton

GZ occupy diverse trophic niche from grazers (pteropods and pelagic tunicates) to predators (medusae, siphonophores, ctenophores and chaetognaths) (Madin and Harbison 2001). Furthermore, GZ provide a food source for upper trophic levels such as different types of fish and turtles (Cardona, et al. 2012). They are also important transporters of particles into the deep sea (Anderson 1998; Gorsky and Fenaux 1998; Sweetman and Chapman, 2015).

Ctenophores and cnidarian medusae are important predators. They prey on crustacean zooplanktons, fish eggs and larvae, chaetognaths, appendicularians, rotifers, protozoa as well as other GZ (Sullivan and Kremer 2011). Ctenophores and medusae can have a very large impact on fish populations as seen in the study of Lynam and others (2005) where *Aurelia aurita* depleted the herring stock in the North Sea through a combination of herring larvae predation and competition for zooplankton food. Shiganova and Bulgakova (2000) also reported the effect of hydromedusae and ctenophores on fish in the Black sea. In their study, they found that the hydromedusa and ctenophore compete between each other and with planktivorous fish for edible zooplankton which resulted in the reduction in number of the pelagic fish due to lack of food. Furthermore, a study by Sweetman and Chapman (2015) showed that jellyfish that sink to the bottom of the ocean contributes to the downward flux of C and N.

Another predator are the chaetognaths which are carnivorous zooplanktons that have great abundance in the world’s ocean. It was speculated that most of the energy converted into biomass by copepods was transferred to higher trophic levels through chaetognaths. Chaetognaths can also influence prey populations by consuming a substantial part of the prey population at certain times of the year. (Feigenbaum, 1991)

Moving on to the grazers, salps have high grazing impacts on phytoplankton populations and have an important role in the downward flux of matter. Anderson (1998) reported that the nutritional ecology of salps is characterized by their high filtration rates, the ability to remove miniscule particles and microorganisms with high efficiency and their high defaecation rate of big faecal pellets which sink rapidly. These faecal material is enriched with several elements (C, N, Ca, Al) compared to the salp itself, and the degredation of the pellets are very slow. Salps can periodically occur in large masses covering a large amount of area, thus grazing of salps can be important in the rapid, periodic vertical flux of particles and therefore play a significant role in geochemical fluxes and the ecology of deep-sea benthos (Anderson, 1998). Doliolids are also very efficient grazers. They have the ability to ingest free-living bacteria as well as large diatoms, directly and efficiently transferring microbial biomass to faecal pellets and to the larger predators of the doliolid. It is reported by Seapy (1980) and Larson et al., (1989) that adult heteropods and epipelagic narcomedusae prey on doliolids. Furthermore, the high excretion rates of doliolids suggest that they may play an important role in the nitrogen cycle of coastal seas. (Diebel, 1998)

Appendicularians are also filter feeders, they have a unique filtration system using the house that they secrete. These houses have mesh sizes that can capture submicron sized particles, thus the houses can filter particles and obtain energy from the microbial ecosystem and transfer it directly to the larger metazoans, in marine food webs (Gorsky and Fenaux, 1998). Appendicularians are consumed by higher trophic predators as listed by Gorsky and Fenaux (1998) such as adult and larval fish, scyphozoans, chaetognaths and copepods. Many fish are almost completely dependent upon them at some stage fo life, the abundance of appendicularians can even determine the successful larva development in some commercially important fishes (Gorsky and Fenaux., 1998). Discarded appendicularian houses are consumed by many predators such as medusae, ctenophores, siphonophores, chaetognaths, adult and larval fish, as well as benthic organisms. These discarded houses make up an important part of the ‘marine snow’, which are important transport agents of organic matter into the deep sea. (Gorsky and Fenaux, 1998)

2.3 Factors that Affect Gelatinous Zooplanktons Abundance and Diversity

For Cnidarians and ctenophores, temperature has an obvious effect on population size and asexual reproduction. It was associated with greater abundance of jellyfish and ctenophores, and increased asexual reproduction in scyphozoans and hydrozoans (Purcell, 2005). Salinity had direct effects to the jellyfish and ctenophores in estuaries where there are ranges in salinity, additionally extremely low salinity may have insufficient iodine for strobilation causing scyphozoans to be unable to reproduce effectively (Purcell, 2005). Arai (1992) mentioned a few factors that impacted budding rates of a few hydromedusae. These include light, temperature, food supply or a combination of these factors. Light plays a role in triggering gonophore production in *Sarsia princeps*, tempretarue primarily controls budding of the hydroids of *Rathkea octopunctata* and *Bougainvillia superciliaris* and *Sarsia cliffordi* had maximum abundance during rising temperature two weeks after peak copepod abundance. However, different species in the same environment may respond differently to condition changes (Purcell 2005). In studies in Thaliand, Wuttijaroenmongkol (2004), Chaiburin (2007) and Jittrapat (2018) reported salinity to have a negative correlation with the abundance of hydrozoans. Chaiburin (2007) also mentioned water transparency and temperature to be negatively correlated with hydrozoan abundance. Furthermore, Tandavanij (2001) reported water current, salinity, food concentration and the life history of each species to affect rhizomedusae abundance.

For arrow worms, Stone (1966) studied the fecundity of *F. enflata* between areas of higher (offshore) and lower (inshore) temperatures. He found that the neritic individuals always contained more eggs than the oceanic individuals. Stone speculated that the amount of food and the temperature had a role to play in the fecundity, but with greater importance to the amount of food. Futhermore, Jittrapa (2018) found that arrow worns were more abundant in high saline waters.

Thaliacean patches require a broad, shallow continental shelf, a strong boundary current with eddies and meanders and upwelling favourable winds that leads to high rates of phytoplankton production necessary for thaliacean patches (Diebel and Paffenhöfer, 2009). There have been reports of appendicularian blooms in Saanich Inlet (Vancouver Island, Canada) which occurred during a heavy phytoplankton bloom (Seki, 1973) The generation time of appendicularians are temperature dependent having shorter generation time in warmer waters (Fenaux, 1998) hence they are able to multiply quickly and exploit favourable conditions.

2.4 The Study of Gelatinous Zooplankton in Thailand

The study of diversity and abundance of GZ in Thailand is quite limited. There are only two studies conducted by Chariburin (2007) and Jitrapat (2018) which obtained GZ samples from the upper Gulf of Thailand. Though, there are several works that invesitigated a specific group of GZ in the Gulf of Thailand and the Andaman Sea. For example, the study of Rhizostome Scyphozoans by Tandavanij (2001), planktonic Hydrozoans by Wuttijaroenmonkol (2004) and Phongphattarawat (2013), jellyfish by DMCR (2019) and arrow worms by Narawisut- (2002) and Pannarak (2004) as shown in Table 2.1.

Chaiburin (2007) conducted a study of the species and the abundance of GZ in the western part of the upper Gulf of Thailand in December 2005 and May 2006. She found 49 species from 19 families with Hydrozoa as the dominant group because it had an abundance ratio of more than 50-80% of the total abundance. The dominant species were hydromedusae *Eirene* spp., *Bougainvillia* spp., *Cunina* spp. and *Liriope* spp. She found that generally there would be more numbers of families found in December than in May. The abundance during December was in the range of 476-25,599 individuals/100m^3, the highest value was further from shore and the lowest value was in the middle of the upper Gulf of Thailand. In May the abundance was between 0-65,556 individuals/100m^3 with the highest abundance at the mouth of Tha Chin river and the lowest abundance at the mouth of Mae Klong river. Shannon-Weiner index was found to be higher near the shore and river mouths while lower values were found further from shore and the middle of the upper Gulf of Thailand. Evenness index had higher values in December than May.

Jitrapat (2018) studied the abundance and diversity of GZ in the upper Gulf of Thailand in June and October 2017 and April 2018. She reported 63 species from 45 families of GZ of which 45 species belonged to class Hydrozoa. The dominant species in this study were arrow worm *Flaccisagitta enflata* in all three months of study, salp *Doliolum sp*. in October and April, hydromedusae *Liriope tetraphyla* and *Proboscidactyla ornata* in June, salp *Thalia democratica* in October and a siphonophore*Diphyes chamissonis* in April. The abundance of GZ differs in each month, the highest abundance was in April with 324,000±292,000 individuals/100m^3 followed by October with 305,000±353,000 individuals/100m^3 and the lowest abundance was in June with 248,000±150,000 individuals/100m^3. Areas close to river mouths had higher abundance of GZ than areas further away from the shore in all three months. The highest abundance was found at the upper western corner of the upper Gulf of Thailand between the Mae Klong and Tha Chin river mouths in June. In October, the abundance was highest in the eastern Upper Gulf of Thailand at the Bang Pa Kong river mouth, and in April it was highest in the upper middle of the upper Gulf of Thailand between the Chao Praya and Tha Chin river mouths. The Shannon-Weiner index in the inner upper Gulf of Thailand had a significantly higher value than other areas, whereas the evenness index had higher values in the outer upper Gulf of Thailand.

Department of Marine and Coatal Resources of Thailand did a survey on the diversity and distribution of jellyfish during 2010-2019 covering 22 coastal provinces of the Gulf of Thailand and the Andaman Sea, where they found 31 species of jellyfish with 9 species of Cubozoa, 17 species of Scyphozoa and 5 species of Hydrozoa (DMCR, 2019). Tandavanij (2001) conducted a study of rhizostome scyphozoans and reported 6 species along the coasts of Chonburi and Phetchaburi during 13 months of monthly sampling from December 1999 to December 2000. Rhizomedusae were found along the coast of Chonburi in January, February, March, May and October 2000 with the highest abundance in May (> 23 individuals/1000 m^3). In comparison, rhizhomedusae were found along the coast of Phetchaburi every month except March and September with the highest abundance in November (>300 individuals/1000m^3). The abundance of medusae was more than 10 times higher in magnitude at Phetchaburi compared to Chonburi. Furthermore, Wuttijaroenmonkol (2004) examined the diversity and abundance of planktonic hydrozoans in the upper Gulf of Thailand in 2000. She collected the samples in Janaury, March, May, July and September and reported 63 species from 34 families of Hydrozoa of which 34 species were new records in Thailand. The hydrozoans were most abundant in September with an average of 716 individuals/ 100 m^3 and had lowest abundance in May with 80.3 individuals/100 m^3. The Shannon-Weiner index was highest in January (H'=1.73) and lowest in July (H'= 0.93). It was found that the Shannon-Weiner index was high in stations near the shore with a depth of less than 20 meters, indicating an inclination of higher diversity in hydrozoans near the shore. The hydrozoans were found to be more abundant and widely distributed during pre northeast monsoon. Another study on Hydrozoans in February and November 2012 by Phongphattarawat (2013) reported 31 species from 15 families of Hydrozoan in the upper Gulf of Thailand. The dominant species were *Liriope tatraphyla, Phialucium carolinae, Cunina* sp. and *Eutima* sp. The average abundance in February was 779 individuals/m^3 and 1,485 individuals/m^3 in November. The Shannon-Weiner index in Febrary was highest at the Chao Phraya river mouth and in November it was highest in the middle of the upper Gulf of Thailand, same as the study of Wuttijaroenmongkol (2004) and Chauburin (2007).

In the Upper Gulf of Thailand, Narawisut (2002) investigated the diversity and abundance of arrow worms during January, February and September of 2002. She found that abundance during January and February, which is around the end of the northeastern monsoon season was highest in the Tha Chin river mouth with an abundance of 8,899 individuals/m^3. In September (the southwestern monsoon season), it was highest in the middle of the upper Gulf of Thailand with 27,436 individuals/m^3. Arrow worm abundance was higher in the southwestern monsoon season and was high at the river mouth of Chao Praya, Bang Pakong and Petchburi rivers, at Huahin and in the middle of the upper Gulf of Thailand. Whereas during the northeastern monsoon season the abundance were high at the Tha Chin, Mae Klong and Chao Praya river mouths. The dominant species of arrow worms in the upper Gulf of Thailand were *Flaccisagitta enflata, Aidanosagitta neglecta,* and *Flaccisagitta hexaptera*. Similary, *F. enflata* and *A. neglecta* were the dominant species in the coast of Trang Privince (Punnarak, 2004), while *Ferosagitta ferox* and *Zonosagitta bedoti* were two additional species found in this area. (Punnarak, 2004)

Table 2.1 The study of the abundance and diversity of GZ in the Gulf of Thailand

Gelatinous zooplanktons Taxa	Gulf of Thailand							Andaman Sea	
	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Phylum Cnidaria									
Class Hydrozoa									
Family Corymorphidae									
Corymorpha nutans						X			
Corymorpha bigelowi						X			
Corymorpha forbesii						X			
Family Zancleidae									
Halocoryne orientalis						X			
Family Cytaeididae									
Cytaeis tetrastyla			X			X			
Family Oceaniidae									
Turritopsis nutricula			X			X			
Family Bougainvillidae									
Bougainvillia britannica			X			X			
Bougainvillia muscus			X		X	X			
Bougainvillia platygaster			X			X			
Bougainvillia principis			X			X			
Bougainvillia muscoides			X						
Koellikerina fasciculata			X						
Family Pandeidae									
Pandeopsis ikarii						X			

Gelatinous zooplanktons Taxa	Gulf of Thailand							Andaman Sea	
	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Family Proboscidactylidae									
Proboscidactyla ornata			X	X	X	X			
Family Hydractiniidae									
Hydractinia apicata						X			
Hydractinia carnea						X			
Family Tubulariidae									
Steenstrupia nutans			X						
Euphysora bigelowi			X	X					
Hybocodon sp.					X				
Family Protiaridae									
Halitiara formosa						X			
Family Porpitidae									
Porpita porpita			X				X		X
Family Laodiceidae									
Laodicea indica			X			X			
Laodicea minuscula			X			X			
Laodicea undulata			X						
Family Campanulariidae									
Obelia sp.			X	X		X			
Clytia uchidai						X			
Phialidium malayense			X						
Phialidium uchida			X		X				

Gelatinous zooplanktons Taxa	Gulf of Thailand							Andaman Sea	
	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Family Lovenellidae									
Eucheilota menoni			X		X	X			
Eucheilota paradoxica						X			
Eucheilota comata			X						
Family Malagazzidae									
Malagazzia carolinae			X		X	X			
Octophialucium multitentaculatum						X			
Octophialucium medium			X			X			
Octophialucium indicum			X		X				
Octophialucium funerarium			X		X				
Family Eirinidae									
Eirene brevigona			X			X			
Eirene ceylonensis			X			X			
Eirene hexanemalis			X		X	X			
Eirene menoni			X			X			
Eirene palkensis			X		X	X			
Eirene viridula			X			X			
Eutima orientalis						X			
Eutima curva						X			
Eutima gracilis			X						
Helgicirrha malayensis			X			X			
Helgicirrha schulzei			X						

Gelatinous zooplanktons	Gulf of Thailand							Andaman Sea	
Taxa	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Family Aequoreidae									
Aequorea conica			X			X			
Aequorea macrodactyla						X			
Aequorea pensilis			X			X			
Aequorea globosa			X						
Aequorea parva			X		X				X
Family Geryoniidae									
Liriope tetraphylla			X		X	X			
Family Rhopalonematidae									
Amphogona apicata			X						
Aglaura hemistoma			X						
Family Solmundaeginidae									
Solmundella bitentaculata			X	X	X	X			
Family Cuninidae									
Cunina octonaria			X		X	X			
Cunina duplicata			X						
Cunina tenella			X						
Cunina peregrina						X			
Family Agalmatidae									
Agalma elegans			X						
Agalma okeni			X						
Family Diphyidae									
Diphyes chamissonis			X			X			
Diphyes bojani			X						

Gelatinous zooplanktons	Gulf of Thailand							Andaman Sea	
Taxa	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Diphyes dispar			X						
Lensia subtilis						X			
Lensia subtiloides			X			X			
Lensia campanella			X						
Lensia gnanamuthui			X						
Chelophyes contorta			X						
Sulculeolaria quadrivalvis			X			X			
Sphaeronectes koellikeri			X			X			
Family Abylidae									
Ceratosymba leuckartii			X						
Abyla trigona			X						
Abylopsis eschscholtzii			X						
Abylopsis tetragona			X						
Bassia bassensis			X						
Enneagonum hyalinum			X						
Family Physaliidae									
Physalia physalis							X		X
Class Cubozoa									
Family Carukiidae									
Morbakka sp.							X		X
Family Chirodropidae									
Chironex indrasaksajiae							X		
Family Chiropsalmidae									
Chiropsoides buitendijki							X		X

Gelatinous zooplanktons Taxa	Gulf of Thailand							Andaman Sea	
	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Family Chiropsellidae									
Meteorona sp.							X		
Family Tripedaliidae									
Copula sivickisi							X		
Tripedalia cystophora									X
Class Scyphozoa									
Family Nausithoidae									
Nausithoe punctata						X	X		
Family Pelagiidae									
Pelagia sp.						X	X		X
Chrysaora sp.							X		X
Family Cepheidae									
Cephea cephea							X		X
Family Cyaneidae									
Cyanea buitendijki							X		X
Family Ulmaridae									
Aurelia aurita						X			X
Family Cassiopeidae									
Cassiopea andromeda	X								
Cassiopea ornata									X
Family Catostylidae									
Acromitus flagellatus	X						X		X
Acromitus hardenbergi	X								
Catostylus townsendi	X						X		X

Gelatinous zooplanktons Taxa	Gulf of Thailand							Andaman Sea	
	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Crambione sp.									X
Family Lobonemidae									
Lobonema smithii	X								
Lobonemoides sp.							X		X
Family Lychnorhizidae									
Anomalorhiza shawi							X		
Lychnorhiza malayensis							X		X
Family Mastigiidae									
Phyllorhiza punctata							X		X
Family Rhizostomatidae									
Rhopilema hispidum	X						X		X
Family Thysanostomatidae									
Thysanostoma sp.									X
Family Versurigidae									
Versuriga anadyomene							X		X
Phylum Ctenophore									
Class Tentaculata									
Family Pleurobranchiidae									
Hormiphora sp.						X			
Class Nuda									
Family Beroidae									
Beroe sp.						X			
Phylum Annelida									
Class Polychaeta									

Gelatinous zooplanktons	Gulf of Thailand							Andaman Sea	
Taxa	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Family Tomopteridae									
Tomopteris nationalis						X			
Phylum Mollusca									
Class Gastropoda									
Family Creseidae									
Creseis acicula						X			
Styliola subula									
Diacavolinia longirostris						X			
Family Cliidae									
Clio pyramidata									
Family Clionidae									
Clione sp.						X			
Family Pneumodermatidae									
Pneumoderma sp.						X			
Family Atlantidae									
Atlanta sp.						X			
Phylum Chaetognatha									
Class Sagittoidae									
Family Sagittidae									
Aidanosagitta neglecta		X				X		X	
Ferosagitta ferox								X	
Flaccisagitta enflata		X				X		X	
Flaccisagitta hexaptera		X							
Zonosagitta bedoti								X	

Gelatinous zooplanktons Taxa	Gulf of Thailand							Andaman Sea	
	Tandavanij (2001)[1]	Narawisut (2002)[2]	Wutticharoen-mongkol (2004)[3]	Chaiburin (2007)[4]	Phongphattarawat (2013)[5]	Jitrapat (2018)[6]	DMCR (2019)[7]	Pannuruk (2004)[8]	DMCR (2019)
Phylum Chordata									
Class Appendicularia									
Family Oikopleuridae									
Oikopleura longicauda						X			
Family Fritillariidae									
Fritillaria borealis						X			
Class Thaliacea									
Family Doliolidae									
Doliolum sp.						X			
Dolioloides spp.				X					
Family Salpidae									
Iasis cylindrica						X			
Thalia democratica				X		X			

Remarks for study areas: 1 – Coast of Chonburi and Phetchaburi Province, 2,3,5,6 – Upper GOT, 4 – Western Upper GOT, 7 – 21 Coastal provinces of Andaman Sea and GOT, 8 – Coast of Trang Province

Chapter 3
Materials and Methods

3.1 Study Area

Samples of GZ in this study have been collected under the Collaborative Research Survey on Marine Fisheries and Marine Environment in the Gulf of Thailand by M.V.SEAFDEC 2 between 17 August 2018 and 11 October 2018. They have collected zooplankton from 49 stations in the Gulf of Thailand, but samples from 20 stations covering the Gulf of Thailand from the upper, middle and lower part of the Gulf of Thailand were examined in this study (Figure 3.1, Table 3.1)

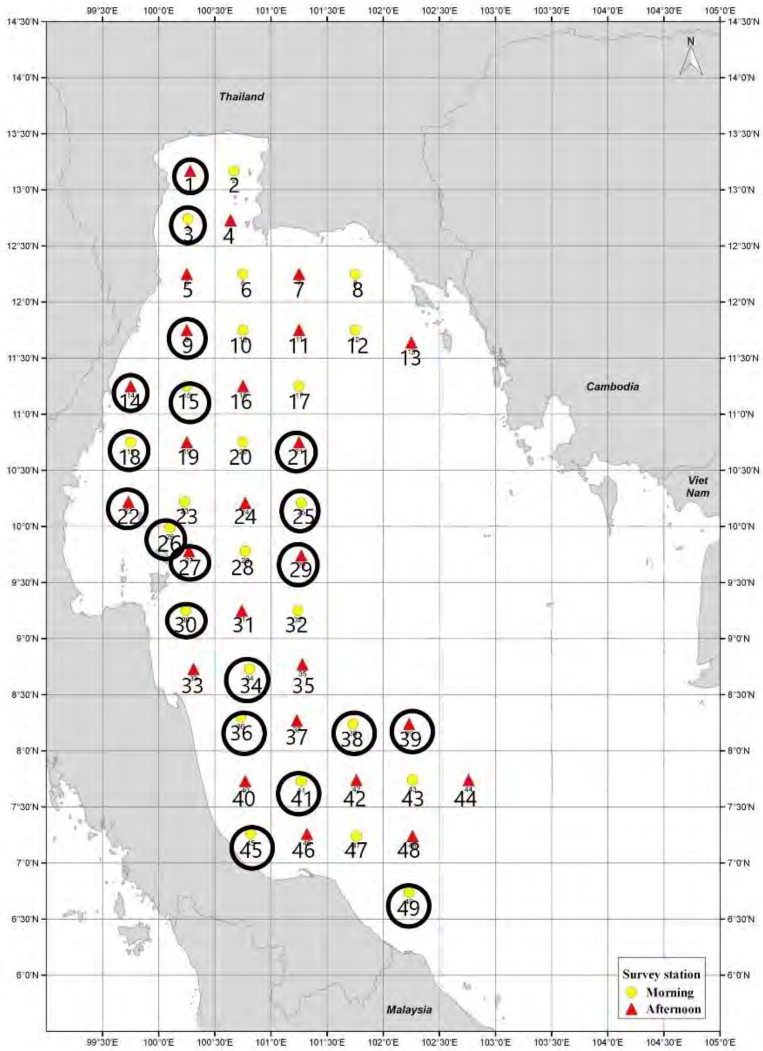


Figure 3.1 Study sites of zooplankton conducted during 17 August 2018 and 11 October 2018. The circles indicate 20 selected stations for GZ in this study.

Table 3.1 Coordinates of 20 selected stations for the study of GZ in the Gulf of Thailand

Station	Lattitude (°N)	Longitude (°E)	Area in GOT
1	13 09.074	100 18.082	Upper GOT
3	12 43.636	100 15.854	
9	11 45.590	100 18.333	Middle GOT
14	11 14.082	99 45.248	
15	11 14.284	100 14.644	
18	10 45.143	99 45.568	
21	10 43.469	101 05.589	
22	10 23.900	99 40.423	
25	10 11.379	101 04.789	
26	09 53.787	99 34.416	
27	09 46.475	100 16.480	
29	09 45.967	101 04.354	
30	09 13.752	100 15.432	Lower GOT
34	08 43.199	100 49.267	
36	08 16.402	100 43.920	
38	08 12.458	101 39.418	
39	08 22.605	102 00.816	
41	07 43.375	101 17.660	
45	07 14.891	100 49.742	
49	06 43.679	102 15.221	

3.2 Sample Collection

The process of sampling was done by a vertical trawl from 1 meter above the sea floor using a plankton net with a mesh size of 330 micrometer and a flowmeter was attached at the mouth of the net. The zooplankton sample was stored in a 250 ml plastic bottle and preserved with neutral formalin which had the final concentration of 4%.

Furthermore, depth and environmental data of sea water including temperature, salinity, water density, dissolved oxygen (DO) and pH were measured by a CTD during sampling.

3.4 Sample Processing for Gelatinous Zooplankton

In this study, I examined GZ from 7 groups in 6 Phyla including hydromedusae and siphonophore (Phylum Cnidaria), ctenophores (Phylum Ctenophora), pteropod (Phylum Mollusca), polychaete worms (Phylum Annelida), arrow worms (Phylum Chaetognatha), and pelagic tunicates (Phylum Chordata) which is divided into 3 sub-groups which are salps, doliolids and larvaceans. GZ were sorted out from the zooplankton samples under a stereo microcope. Each specimen was indentified to the species level if possible by using identification keys from Rucker (1962), Kramp (1968), Bone (1997), Boltovsky (1999), Hereu and Suarez-Morales (2012) and Gershwin *et al.* (2014 a,b,c). The numbers of each species of GZ were counted and calculated the abundance as individuals/100 m^3. Additionally, biovolume of each group of GZ were estimated using the Settled-volume measurement following the ICES Zooplankton Methodology Manual (Postel *et al.,* 2000).

Calculating the abundance of GZ

$$T = \frac{100\ x\ t}{V}$$

When T is the number of plankton in individuals/100 m^3 seawater

t is the number of plankton individuals counted in the sample

V is the volume of water that passed through plankton net (m^3)

Volume of water passing through plankton net can be calculated as follow:

$$V = a \times n \times N \quad \text{or} \quad (a \times n)/N_1$$

When a is the area of the mouth of the plankton net (m^2)

n is the number of revolutions of the flowmeter's rotor

N is the rotor constant of revolution in 1 meter

N_1 is the rotor constant in distance (meter) of 1 revolution of the flowmeter

3.5 Data Analysis

Using the abundance and number of species data of the GZ to calculate the Shannon-Weiner Index (Shannon, 1948) and the Evenness index (Pielou, 1966).

Calculating the Shannon-Wiener index

$$H' = -\sum_{i=1}^{S} P_i \ln P_i$$

When H' is Shannon- Wiener index

S is total number of species in the community

P_i is proportion of S made up of the *i*th species

The Shannon-Weiner index has a value between 0 and infinity depending on the number of species and number of individual GZ. A high Shannon-Weiner value indicates a high diversity of GZ.

Calculating the (Evenness index)

$$E = \frac{H'}{H'_{max}}$$

When E is Evenness index

H' is Shannon- Wiener index

H'max is the maximum Shannon- Wiener index

where H'max = ln(S) when S is total number of species in the community

The evenness index has a value between 0 and 1. A low evenness index indicates that each species of GZ have different abundances and that there is a species that is dominant. An evenness value close to 1 indicates that each species of GZ have similar abundance values.

Relationships between the diversity and abundance of GZ and different physical parameters of sea water were determined using the Pearson Correlations and Multiple Regression Analysis (Vanichbuncha, 2018), where the Shannon-Weiner index and the abundance of GZ were the dependent variable and the physical paramters of sea water including depth, temperature, salinity, DO and pH were the independent variables. Furthermore, communities of GZ in the studied area were characterized by Cluster analysis and Non-metric Multidimensional Scaling analysis (nMDS) with the PRIMER V 6.0 (Clarke and Gorley, 2006).

Chapter 4

Results and Discussion

4.1 Physical Parameters in the Gulf of Thailand

Physical parameters in the Gulf of Thailand varied depending on the station (Figure 4.1). The depth of each station was between 16-69 meters. The following parameters were calculated as the average of the entire water column. Temperature was between 27.25-29.45°C, it was relatively constant throughout the entire gulf but had a slightly lower value in the lower Gulf of Thailand. Salinity was between 29.59-33.21 PSU, the upper gulf had lower salinity compared to the middle and lower gulf, suggesting the influence of freshwater that emptied into the upper Gulf of Thailand by numerous rivers. Seawater density was between 17.89-21.26 kg/m^3, as salinity directly affects water density, both graphs showed the same trend. DO value was between 4.18-7.63 mg/l (measurement for dissolved oxygen were not made in station 1, 3 and 9). The average value of DO in the lower Gulf of Thailand was more than 1.5 mg/l higher than that of the middle Gulf of Thailand. The pH was between 7.84-8.21 and was constant throughout the gulf.

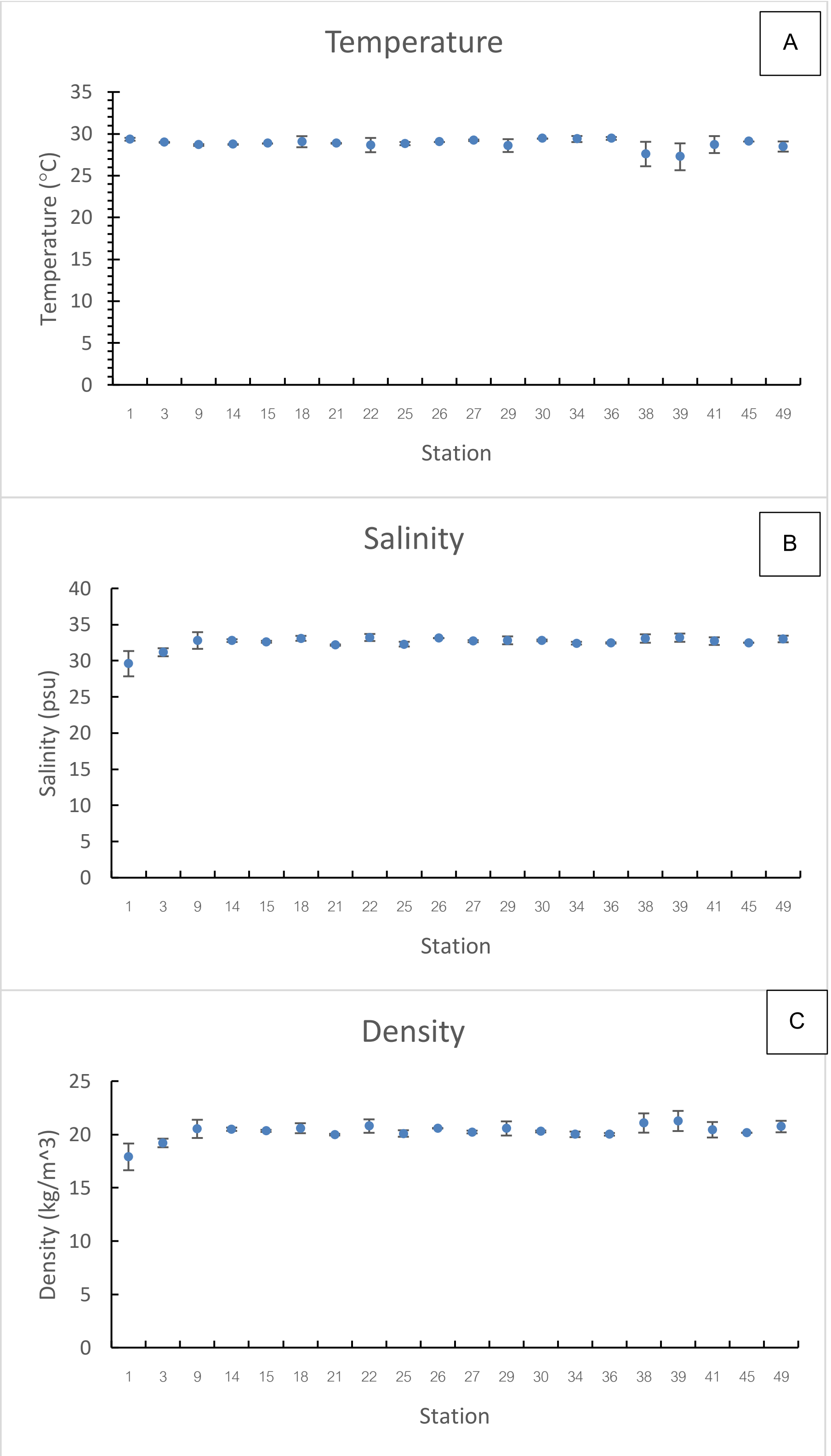
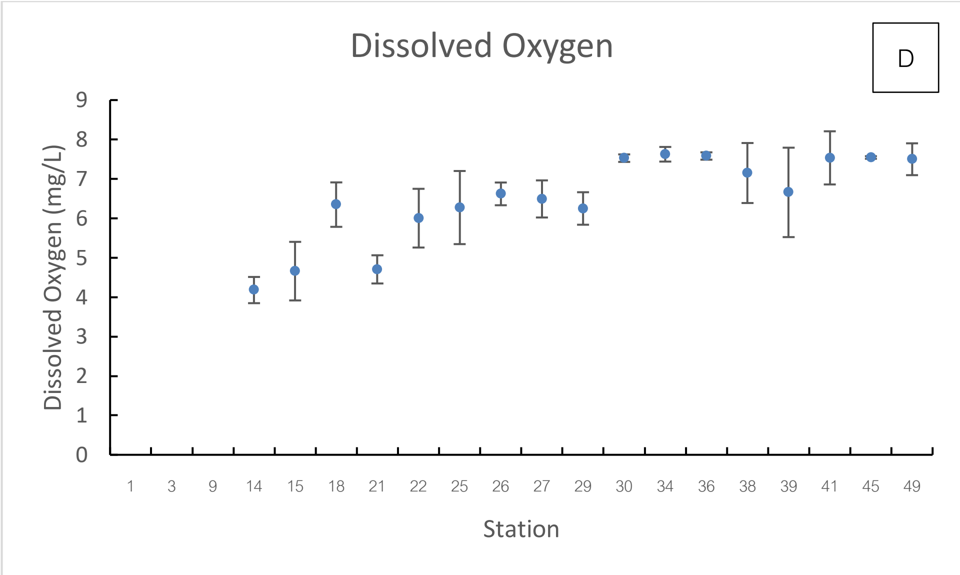


Figure 4.1 Physical parameters of seawater in the Gulf of Thailand. A, Temperature. B, Salinity. C, Seawater density



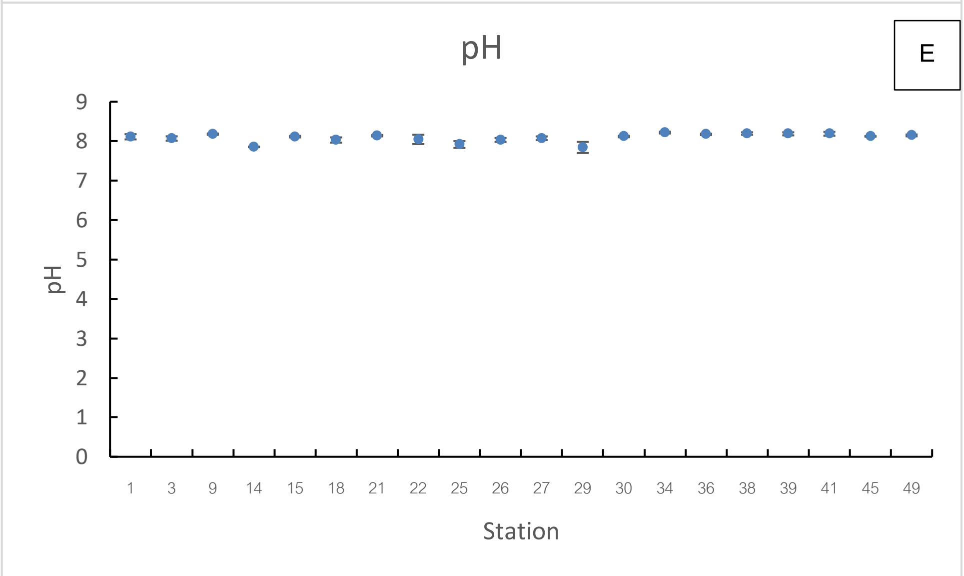


Figure 4.1 (cont.) Physical parameters of seawater in the Gulf of Thailand. D, Dissolved Oxygen. E, pH.

4.2 The Diversity, Abundance and Biovolume of Gelatinous Zooplanktons

4.2.1 The Diversity of Gelatinous Zooplanktons in the Gulf of Thailand

There were 76 species from 8 classes 6 phyla and 32 families found in this study of the diversity of GZ in the Gulf of Thailand. The class with the most GZ species was class Hydrozoa with 57 species (75%) followed by class Thaliacea with 6 species (8%), Appendicularia with 5 species (7%), Gastropoda with 3 species (4%), Sagittoidae with 2 species (3%) and Scyphozoa, Polychaeta and Tentaculata with 1 species (1% each) each (Table 4.1).

The classification of GZ in this study followed Rucker (1962), Kramp (1968), Bone (1997), Boltovsky (1999), Hereu and Suarez-Morales (2012) and Gershwin et al. (2014 a,b,c).. The list of species and their characterstics are as follows.

Table 4.1 Diversity of GZ in the Gulf of Thailand during 17 August 2018 and 11 October 2018

Gelatinous zooplanktons Taxa	Station																			
	1	3	9	14	15	18	21	22	25	26	27	29	30	34	36	38	39	41	45	49
Phylum Cnidaria																				
Class Hydrozoa																				
Order Anthomedusae																				
Family Corynidae																				
1. *Sarsia* sp.1								✓							✓		✓			
2. *Sarsia* sp. 2								✓												
Family Corymorphidae																				
3. *Euphysa* sp.1				✓																
4. Corymorpha bigelowi		✓																		
Family Zancleidae																				
5. *Zanclea* sp.1																			✓	
Family Cyteididae																				
6. *Cytaeis tetrastyla*																			✓	
7. *Cytaeis* sp.1																			✓	
Family Oceanidae																				
8. *Turritopsis nutricula*		✓																		
Family Rathkeidae																				
9. *Podocorynoides* sp.1	✓																			
10. *Lizzia gracilis*																			✓	
Family Bougainvillidae																				
11. *Bougainvillia multitentaculata*		✓																		
12. *Bougainvillia principis*										✓										
13. *Bougainvillia muscus*	✓	✓									✓									

Gelatinous zooplanktons Taxa	Station																			
	1	3	9	14	15	18	21	22	25	26	27	29	30	34	36	38	39	41	45	49
14. *Bougainvillia* sp.1	✓																			
15. *Bougainvillia* sp.2																			✓	
Family Proboscidactylidae																				
16. *Proboscidactyla ornate*										✓										
17. *Proboscidactyla* sp.1			✓																	
Family Protiaridae																				
18. *Protiara tetranema*										✓										
Family Porpitidae																				
19. *Porpita porpita*									✓											
20. Anthomedusa sp.1	✓																			
Order Leptomedusae																				
Family Laodiceidae																				
21. *Laodicea* sp.1																			✓	
22. *Laodicea* sp.2		✓																		
Family Campanulariidae																				
23. *Clytia rangiroae*	✓	✓								✓	✓									
24. Unidentified (*Campanulariidae*) sp.1								✓												
Family Loveneliidae																				
25. *Eucheilota tropica*					✓					✓					✓			✓		
26. *Eucheilota* sp.1	✓																			
Family Phialuciidae																				
27. *Phialucium* sp.1										✓										
Family Malagazziidae																				
28. *Malagazzia carolinae*	✓	✓																		

Gelatinous zooplanktons Taxa	Station																			
	1	3	9	14	15	18	21	22	25	26	27	29	30	34	36	38	39	41	45	49
29. *Octophialucium aphrodite*	✓																			
30. *Octophialucium funerarium*										✓										
31. *Octophialucium* sp.1		✓																		
32. *Octophialucium* sp.2		✓																		
Family Eirinidae																				
33. *Eirene hexanemalis*	✓	✓		✓						✓	✓									
34. *Eirene elliceana*													✓							
Order Trachymedusae																				
Family Phopalonematidae																				
35. *Aglaura hemistoma*			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Order Limnomedusae																				
Family Geryoniidae																				
36. *Liriope tetraphyla*	✓			✓						✓	✓		✓		✓			✓	✓	
Order Narcomedusae																				
Family Solmundaeginidae																				
37. Unidentified (*Solmundaeginidae*) sp.1					✓					✓	✓						✓	✓		
38. *Solmundella bitentaculata*										✓									✓	
Family Cuninidae																				
39. *Cunina octonaria*	✓									✓	✓									
40. *Cunina peregrina*	✓							✓		✓	✓		✓	✓						✓
41. *Cunina* sp. 1																				✓

Gelatinous zooplanktons Taxa	Station																			
	1	3	9	14	15	18	21	22	25	26	27	29	30	34	36	38	39	41	45	49
Order Siphonophorae																				
Suborder Physonectae																				
Family Agalmatidae																				
42. *Agalma elegans*	✓			✓		✓		✓		✓			✓	✓				✓		✓
Family Diphyidae																				
43. *Diphyes bojani*		✓			✓			✓		✓	✓		✓	✓	✓					✓
44. Diphyes dispar		✓						✓		✓	✓		✓							
45. *Diphyes* sp.1				✓	✓	✓		✓		✓	✓		✓						✓	✓
46. *Diphyes* sp.2					✓						✓					✓				✓
47. *Diphyes* sp.3					✓															
48. *Lensia meteori*	✓		✓	✓			✓	✓	✓	✓	✓			✓	✓		✓		✓	
49. *Muggiaea atlantica*		✓			✓	✓				✓	✓		✓		✓					✓
50. *Sulculeolaria monoica*			✓	✓	✓		✓	✓	✓	✓			✓	✓		✓	✓			✓
51. *Sulculeolaria quadrivalvis*	✓					✓	✓	✓		✓		✓			✓		✓			✓
Family Abylidae																				
52. *Abyla haeckeli*																✓		✓		
53. Abyla trigona					✓	✓	✓	✓				✓								✓
54. *Abyla* sp.1					✓	✓	✓		✓			✓								✓
55. *Abylopsis eschscholtzii*				✓																
56. *Bassia bassensis*			✓		✓										✓					
57. *Enneagonum hyalinum*																	✓	✓		✓
Class Scyphozoa																				
Order semaeostomeae																				

Gelatinous zooplanktons Taxa	Station																			
	1	3	9	14	15	18	21	22	25	26	27	29	30	34	36	38	39	41	45	49
Family Pelagiidae																				
58. *Pelagia noctiluca*			✓	✓	✓	✓	✓	✓	✓			✓			✓		✓	✓		✓
Phylum Ctenophora																				
Class Tentaculata																				
Order Cyddipida																				
Family Pleurobranchiidae																				
59. *Hormiphora* sp.1		✓								✓	✓				✓					
Phylum Mollusca																				
Class Gastropoda																				
Order Pteropoda																				
Family Cliidae																				
60. Clio pyramidata										✓										
Family Creseidae																				
61. *Creseis acicula*				✓	✓	✓	✓		✓	✓	✓	✓	✓				✓	✓	✓	✓
62. *Styliola subula*				✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Phylum Annelida																				
Class Polychaeta																				
Order Phyllodocida																				
Family Tomopteridae																				
63. *Tomopteris nationalis*	✓									✓										
Phylum Chaetognatha																				
Class Sagittoidae																				
Order Aphragomorpha																				
Family Sagittidae																				
64. *Aidanosagitta neglecta*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
65. *Flaccisagitta enflata*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Gelatinous zooplanktons Taxa	Station																			
	1	3	9	14	15	18	21	22	25	26	27	29	30	34	36	38	39	41	45	49
Phylum Chordata																				
Class Thaliacea																				
Order Doliolida																				
Family Doliolidae																				
66. *Doliolum nationalis*	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓		✓
Family Salpidae																				
67. *Salpa maxima*		✓												✓						
68. *Salpa* sp.1	✓				✓										✓	✓				
69. *Salpa* sp.2					✓						✓									
70. *Thalia democratica*	✓	✓		✓	✓			✓		✓	✓		✓							
71. *Thalia rhomboides*		✓						✓			✓		✓	✓						
Class Appendicularia																				
Order Copelata																				
Family Fritillariidae																				
72. *Fritillaria pellucida*			✓	✓	✓	✓		✓		✓	✓					✓	✓	✓		✓
73. *Fritillaria borealis sargassi*																	✓			
74. *Oikopleura dioica*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
75. *Oikopleura intermedia*					✓	✓		✓		✓				✓	✓		✓	✓		✓
76. *Oikopleura longicauda*	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

Phylum Cnidaria

Class Hydrozoa

Order Anthomedusae

Family Corynidae

Anthomedusae with a simple cicular mouth, four four radial canals and gonads completely surrounding the manubrium. Two to four hollow tentacles with ocelli on the abaxial side of the tentacle bulbs. (Kramp, 1968)

Genus *Sarsia*

1. *Sarsia* sp.1 (refer to the figure in Appendix B1)
2. *Sarsia* sp.2 (Appendix B2)

Family Corymorphidae

Anthomedusae with a simple cicular mouth with four radial canals. The gonads completely surround the manubrium which does not extend beyond the umbrella margin. Four or fewer marginal tentacles which are usually hollow. No oceilli on marginal bulb. (Kramp, 1968)

Genus *Euphysa*

3. *Euphysa* sp.1 (Appendix B3)

Genus *Corymorpha*

4. *Corymorpha bigelowi* (Maas, 1905) (Appendix B4)

The umbrella is dome shaped with apical pointed projection. There are four spherical radial bulbs on the bell end with four marginal tentacles; one long and three short. The long tentacle has many nematocysts bulbs along the length with a large terminal bulb. The remaining tentacles are short and rudimentary. The manubrium is cylindrical and about as long as the bell with a cicular mouth. (Madkour et al., 2019)

Family Zancleidae

Anthomedusae with simple circular mouth, four radial canals with interradial gonads and two or four hollow marginal tentacles with capsule containing nematocysts or without tentacles (Kramp, 1968).

Genus *Zanclea*

5. *Zanclea* sp.1 (Appendix B5)

Family Cyteididae

Anthomedusae with simple cicular mouth, simple unbranched oral tentacles and interradial gonads, four simple radial canals and four solid marginal tentacles. No ocelli. (Kramp, 1968)

Genus *Cytaeis*

6. *Cytaeis tetrastyla* Eschscholtz, 1829 (Appendix B6)

Very large stomach with numerous medusa buds on upper half. 8-32 oral tentacles with a terminal cluster of nematocysts. Large, pyriform marginal bulbs above the tentacles. (Kramp, 1968)

7. *Cytaeis* sp.1 (Appendix B7)

Family Oceanidae

Anthomedusae with four mouth lips, mouth margin is fringed with a few nematocyst clusters in the shape of spheres. four radial canals present with no centripetal canals. Adults have numerous tentacles that are not grouped with evenly distributed nematocysts. Ocelli are present on adaxial bases of the tentacles. The gonads are on interradial walls of the manubrium. (Schuchert, 2004)

8. Genus *TurritopsisTurritopsis nutricula* McCrady, 1857 (Appendix B8)

Family Rathkeidae

Anthomedusae with four mouth lips, which are elongated to form oral arms with terminal and lateral clusters of nematocysts. four radial canals and eight groups of solid marginal tentacles. No ocelli. (Kramp, 1968)

Genus *Podocorynoides*

9. *Podocorynoides* sp.1 (Appendix B9)

Genus *Lizzia*

10. *Lizzia gracilis* (Mayer, 1900) (Appendix B10)

Domelike shape with a slight apical projection, eight marginal tentacles with big basal bulbs. No prominent lips on mouth which is surrounded by eight oral tentacles. four straight radial canals and ring canals. No ocelli. (Wang et al., 2016)

Family Bougainvillidae

Anthomedusae with simple tubular mouth with simple or dichotomously branching oral tentacles inserted above the mouth opening. four radial canals with gonads at interradial or adradial or completely surrounding stomach. Two, four or more solitary marginal tentacles. four or eight large marginal bulbs each with a group of tentacles. (Kramp, 1968)

Genus *Bougainvillia*

11. *Bougainvillia multitentaculata* Foerster, 1923 (Appendix B11)

Rounded at the top with thick gelatinous substance. Peduce low and broad. Oral tentacles devided six to seven times. Marginal bulbs like a wide, inverted V, each with 50-60 short tentacles. Ocelli brown in a zigzag row. Gonads placed along perradial sides of the stomach. (Kramp, 1968)

12. *Bougainvillia principis* (Steenstrup, 1850) (Appendix B12)

Globular with moderately thick jelly. Manubrium without peduncle. Oral tentacles short and devided five to six times, almost from base. Gonads adradial. Marginal bulbs wide with usually 20-30 tentacles in a single row. Black ocelli on adradial surface of the bulb. (Kramp, 1968)

13. *Bougainvillia muscus* (Allman, 1863) (Appendix B13)

Semiglobular with fairly thick jelly. Short manubrium with oral tentacles devided one to two times. four interradial gonads. Small marginal bulbs with three to five long tentacles. Black, round ocelli. (Kramp, 1968)

14. *Bougainvillia* sp.1 (Appendix B14)

15. *Bougainvillia* sp.2 (Appendix B15)

Family Proboscidactylidae

Anthomedusae with no statocysts nor ocelli. Marginal tentacles are hollow with swollen bases. The gonads surround the manubrium and extends onto gastric lobe. The radial canals are branched. (Bouillon and Boero, 2000)

Genus *Proboscidactyla*

16. *Proboscidactyla ornata* (McCrady, 1859) (Appendix B16)

Medusa with shallow gastric peduncle; four radial canals which can branch out until 16 canals reach the bell margin; Tentacles same number as radial canals. Gonads with smooth surface on the side of the stomach which can extend onto radial canals. (Schuchert, 2009)

17. *Proboscidactyla* sp.1 (Appendix B17)

Family Protiaridae

Anthomedusae with four fully developed marginal tentacles stemming from hollow tentacle bulbs. four simple radial canals, mouth with four lips, gonads are interradial with smooth surface. (Bouillon and Boero, 2000)

Genus *Protiara*

18. *Protiara tetranema* (Péron & Lesueur, 1810) (Appendix B18)

Medusa with a cylindrical bell with four tapering tentacles and a short manubrium with four lips. (Schuchert, 2009)

Family Porpitidae

Genus *Porpita*

19. *Porpita porpita* (Linnaeus, 1758) (Appendix B19)

A hydroid colony without sail with two main structure which are the float and the zooid colony. The float is a firm round slightly convex disc. The zooid colony is bright blue and shoot out from under the disc, each zooid has a specialized function such as digestion, prey capture or reproduction and has multiple branches ending in knots of nemoatocysts. (Marmish et al., 2019)

20. Uidentified Anthomedusa sp.1 (Appendix B20)

Order Leptomedusae

Family Laodiceidae

Leptomedusae with marginal cordyla. Have four to eight or more simple or branched radial canals, with hollow marginal tentacles. (Kramp, 1968)

Genus *Laodicea*

21. *Laodicea* sp.1 (Appendix B21)

22. *Laodicea* sp.2 (Appendix B22)

Family Campanulariidae

Leptomedusae with normal or reduced velum with small stomach, without a peduncle. Normally four simple radial canals and gonads completely surrounding radial canals, separated from stomach. Hollow marginal tentacles without excretory pores. No marginal or lateral cirri, but with closed marginal vesicles. No ocelli. (Kramp, 1968)

Genus *Clytia*

23. *Clytia rangiroae* (Agassiz & Mayer, 1902) (Appendix B23)

Medusae in a shape of a slightly flattened hemisphere. Short manubrium, mouth with five slightly recurved lips. Small, oval gonads situated along the radial canals near umbrella margin. 16-32 well developed tentacles with huge, conical bulbs. (Vervoort and Watson, 2003)

24. Unidentified Campanulariidae sp.1 (Appendix B24)

Family Loveneliidae

Leptomedusae with small stomach with out peduncle, with four simple radial canals. Gonads on radial canals separated fromo stomach. Have hollow marginal tentacles with lateral or marginal cirri. (Kramp, 1968)

Genus *Eucheilota*

25. *Eucheilota tropica* Kramp, 1959 (Appendix B25)

Thick apical jelly with narrow velum. Short manubrium and elongated gonads along almost entire length of radial canals. four large perradial tentacles and in each quadrant up to five rudimentary bulbs. Tentacles and marginal bulbs have one pair of lateral cirri and no black pigmentation. (Kramp, 1968)

26. *Eucheilota* sp.1 (Appendix B26)

Family Phialuciidae

Leptomedusae with small stomach with four to eight simple radial canals without peduncles. Gonads completely surrounding radial canals and separated from stomach. (Kramp, 1968)

Genus *Phialucium*

27. *Phialucium* sp.1 (Appendix B27)

Family Malagazziidae

Leptomedusae with small manubrium without a gastric peduncle. Gonads completely surround radial canals and is separated from the manubrium. Four to eight, sometimes as much as 12 radial canals. No cirri, nor ocelli. (Bouillon and Boero, 2000)

Genus *Malagazzia*

28. *Malagazzia carolinae* (Mayer, 1900) (Appendix B28)

Medusae with a bell-shaped umbrella, the height nearly the same lenth as the width. The manubrium is quadratic with moderately crenulated margin with pointed lips. Typically, with four radial canals. Gonads are on the radial canals. (Júnior and Nascimento, 2018)

Genus *Octophialucium*

29. *Octophialucium aphrodite* (Bigelow, 1928)
(Appendix B29)

Seven to nine radial canals with spindle shaped gonads. Numerous tentacles that are closely crowded. No permanently rudimentary bulbs, more statocysts than tentacles. (Kramp, 1968)

30. *Octophialucium funerarium* (Quoy & Gaimard, 1827)
(Appendix B30)

Lens-shaped medusa with a small stomach with eight small, simple lips. The gonads are on the distal canal, near the margin; 64-128 tentacles with the statocyst beween two tentacles. (Kramp, 1961)

31. Octophialucium sp.1 (Appendix B31)

32. *Octophialucium* sp.2 (Appendix B32)

Family Eirenidae

Leptomedusae with small stomach and a gastric peduncle; four or six simple radial canals, gonads on radial canals restricted to subumbrella; Have hollow marginal tentacles. (Kramp, 1968)

Genus *Eirene*

33. *Eirene hexanemalis* (Goette, 1886) (Appendix B33)

Thick, conical peduncle with a very small stomach. Gonads along less than the distal half of the radial canals; four radial canals in young stages; 30-50 short, slender tentacles with large swollen bulbs with excretory papillae; Three or more rudimentary bulbs; Four statocysts between every two tentacles. (Kramp, 1968)

34. *Eirene elliceana* (Agassiz & Mayer, 1902) (Appendix B34)

Slender peduncle about as long as bell diameter with a broad pyramidal base. Have tentacle bulbs. (Kramp, 1968)

Order Trachymedusae

Hydromedusae with umbrella margin not devided into lobes; with thickened marginal nematocyst ring and with radial canals; gonad usually confined to radial canals; tentacles situated on margin of umbrella. (Kramp, 1968)

Family Rhopalonematidae

Trachymedusae with narrow stomach with or without peduncle; usually eight radial canals and gonad on radial canals; marginal tentacles evenly distributed. (Kramp, 1968)

Genus *Aglaura*

35. *Aglaura hemistoma* Péron & Lesueur, 1810 (Appendix B35)

Thin jelly with flat apex; peduncle shorter than bell-cavity; small stomach, mouth with four simple lips; gonads on peduncle near stomach. (Kramp. 1968)

Order Limnomedusae

Hydromedusa with alternating generations. The sexual generation is a velar medusa with hollow tentacles. Gonads are either on the stomach wall with or without perradial lobes extending along the radial canals. The asexual generation is a sessile polyp. (Kramp, 1968)

Family Geryoniidae

Hydromedusae with gastric peduncle, with 4-6 radial canals. Gonads on radial canals, flattened and leaf-shaped. Have two kinds of marginal tentacles, solid and hollow. (Boltovskoy, 1999)

Genus *Liriope*

36. Liriope Tetraphyla (Chamisso & Eysenhardt, 1821)

(Appendix B36)

Umbrella almost hemispherical with thicker jelly in apical region; velum well developed. Usually four straight radial canals. Mouth with four simple or slightly crenulated lips. Subumbrella portion of radial canals with four flat gondas. Four long, hollow perradial marginal tentacles with nematocyst rings, four small interradial tentacles. (Boltovskoy, 1999)

Order Narcomedusae

Hydromedusae with sides of umbrella devided by peronial grooves so that umbrella margin may be lobed; no radial canals, gonad on stomach walls; solid marginal tentacles leaving umbrella some distance above margin. (Kramp, 1968)

Family Solmundaeginidae

Narcomedusae with interradial devided stomach pouches containing gonads; with primary perradial tentacles leaving umbrella between marginal pouches. (Kramp, 1968)

37. Uidentified Solmundaeginidae sp. (Appendix B37)

Genus *Solmundella*

38. *Solmundella bitentaculata* (Quoy & Gaimard, 1833)

(Appendix B38)

Narcomedusae with the body higher than wide, apical jelly very thick; with broad, rectangular stomach pouches; two opposite, very long tentacles emerging from near the umbrella apex. (Kramp, 1968)

Family Cuninidae

Narcomedusae with perradial and undivided stomach pouches; tentacles leaving umbrella opposite centre of each stomach pouch, equal to the number of pouches; pouches not extending beyond point of origin of tentacles. (Kramp, 1968)

Genus *Cunina*

39. *Cunina octonaria* McCrady, 1859 (Appendix B39)

Narcomedusae with bell somewhat flatter than a hemisphere; seven to nine, but usually eight stomach pouches; stomach pouches broad, square and close together; no peripheral canals; tentacles projecting from midway between margin and apex. (Kramp, 1968)

40. *Cunina peregrina* Bigelow, 1909 (Appendix B40)

Thick jelly with stomach pouches increasing in number with age. In adult, pouches are square or slightly longer than wide with narrow clefts between them; no peripheral canals. (Kramp, 1968)

41. *Cunina* sp.1 (Appendix B41)

Order Siphonophorae

Suborder Physonectae

Siphonophores with both pneumatophore and nectophores.

Family Agalmatidae

Nectostome without tentacles between the nectophores; straight dorsal radial canal on nectosac; siphosome straight, not coiled up to form a sac. (Boltovskoy, 1999)

Genus *Agalma*

42. *Agalma elegans* (Sars, 1846) (Appendix B42)

T-shaped nectosac; Lateral radial canals distinctly looped; apico-lateral ridges of nectophores with distinct notch toward the ostium. (Boltovskoy, 1999)

Suborder Calycophorae

Siphonophores which lack pneumatophore but develop nectophores.

Family Diphyidae

Usually two, occasionally one dissimilar streamlined nectophores; usually the anterior netophore is pointed apically and is positioned directly above the other which is usually apically truncated. The nectosac occupies both nectophores. The hydroecium of the anterior nectophore is small or absent. (Boltovskoy, 1999)

Genus *Diphyes*

43. *Diphyes bojani* (Eschscholtz, 1825) (Appendix B43)

Anterior nectophores with variably serrated ridges. The nectosac gradually narrows toward the apex. Hydroecium extends to about one third of the nectophore; somatocyst extending up from the hydroecium to close to the apex of nectophore. (Boltovskoy, 1999)

44. *Diphyes dispar* Chamisso & Eysenhardt, 1821 (Appendix B44)

Similar to *D. bojani*. Hydroecium extends to half the height of nectophore with somatocyst extending to just above the beginning of the nectosacal caecum. (Boltovskoy, 1999)

45. *Diphyes* sp.1 (Appendix B45)

46. Diphyes sp.2 (Appendix B*46*

47. *Diphyes* sp.3 (Appendix B47)

Genus *Lensia*

48. *Lensia meteori* (Leloup, 1934) (Appendix B48)

Nectophore without any obvious ridges; narrow, almost vertical mouth plate with shallow hydroecium extending above ostial level and open ventrally. Somatocyst expanded laterally with short stalk. (Boltovskoy, 1999)

Genus *Muggiaea*

49. *Muggiaea atlantica* Cunningham, 1892 (Appendix B49)

Anterior nectohpore with five complete, straight longitudinal ridges. Relatively deep hydroecium extending one third of the nectophore. Long, thin somatocyst reaching apex of nectosac. The phyllocyst is club-shaped. (Boltovskoy, 1999)

Genus *Sulculeolaria*

50. *Sulculeolaria monoica* (Chun, 1888) (Appendix B50)

Anterior nectophore with five ostial teeth, three dorsal and two lateral; small somatocyst. (Boltovskoy, 1999)

51. *Sulculeolaria quadrivalvis* de Blainville, 1830
(Appendix B51)

Anterior nectophore with two dorsal and two lateral ostial teeth, sometime reduced or absent; long, sinuous somatocyst reaching one third the height of the nectophore. (Boltovskoy, 1999)

Family Abylidae

Rigid, angular nectophores; posterior nectophore without somatocyst, usually much larger with serrated ridges and teeth. In all but one species the somatocyst of the anterior nectophore has curved over to have a ventral position. (Boltovskoy, 1999)

Genus *Abyla*

52. *Abyla haeckeli* Lens & van Riemsdijk, 1908
(Appendix B52)

Anterior nectophore as wide as long, without wing-like processes; posterior nectophore with up to five teeth on comb. (Boltovskoy, 1999)

53. *Abyla trigona* Quoy & Gaimard, 1827 (Appendix B53)

Anterior nectophore as broad as wide with most ridges heavily, but irregularly serrated; posterior nectophore with 4-11 teeth on comb. (Boltovskoy, 1999)

54. *Abyla* sp.1 (Appendix B54)

Genus *Abylopsis*

55. *Abylopsis eschscholtzii* (Huxley, 1859)
(Appendix B55)

Dorsal and ventral facets of anterior nectophore pentagonal and of nearly equal size; strongly serrated ridges; posterior nectophore less than twice as long as wide. (Boltovskoy, 1999)

Genus *Bassia*

56. *Bassia bassensis* (Quoy & Gaimard, 1833)
(Appendix B56)

Anterior nectophore without an apical diverticulum to the somatocyst, hydroecium not extending below the basal facet; phyllocyst a long tube, swollen apically, without apical-lateral branches. (Boltovskoy, 1999)

Genus *Enneagonum*

57. *Enneagonum hyalinum* Quoy & Gaimard, 1827 (Appendix B57)

Anterior nectophore large and pyramidal. The conical somatocyst is situated above the hydroecium, extending above the nectosac. Bract is cuboidal with slightly concave facets. (Boltovskoy, 1999)

Class Scyphozoa

Order Semaeostomeae

Family Peladiidae

Stomach giving rise to radiating pouches which are separate and unbranched; no ring canal, tentacle appearing from umbrella margin from clefts between lappets; mouth arms long, pointed and much folded. (Boltovskoy, 1999)

Genus *Pelagia*

58. *Pelagia noctiluca* (Forsskål, 1775) (Appendix B58)

The bell is square-hemispherical with numerous warts; mouth arms also with numerous warts; mouth arms can be five times bell height; 16 marginal tentacles. (Boltovskoy, 1999)

Phylum Ctenophora

Class Tentaculata

Order Cyddipida

Family Pleurobrachiidae

The body is spherical, ovoid or cylindrical. The tentacle sheaths open aborally, close to apical sense organ; tentacles with tentilla. (Boltovskoy, 1999)

Genus *Hormiphora*

59. *Hormiphora* sp.1 (Appendix B59)

Phylum Mollusca

Class Gastropoda

Order Pteropoda

Family Cliidae

Thin and transparent triangular shell with clear difference between ventral and dorsal side. Visceral mass can be seen through the shell. (Lishchka and Ossenbrügger, 2017)

Genus *Clio*

60. *Clio pyramidata* Linnaeus, 1767 (Appendix B60)

Triangular test with three pronounced ridges on dorsal side of the test. The diameter of the shell increases consistently. (Bhuttacharjee, 2000)

Family Creseidae

Long, straight, narrow needle shaped shell with a round cross section. The surface of the shell is smooth or with faint transverse striations. Visceral mass can be seen through the shell. (Lishchka and Ossenbrügger, 2017)

Genus *Creseis*

61. *Creseis acicula* (Rang, 1828) (Appendix B61)

The test is elongated, progressively increasing in diameter with a circular aperture. White in colour, but the posterior part is less white and opaque. (Bhuttacharjee, 2000)

Genus *Styliola*

62. *Styliola subula* (Quoy & Gaimard, 1827) (Appendix B62)

Conical test with a circular aperture. The test is elongated and the diameter increases gradually. There is a longitudinal groove running along the long axis of the test. (Bhuttacharjee, 2000)

Phylum Annelida

Class Polychaeta

Order Phyllodocida

Family Tomopteridae

The body is broad, dorsoventrally flat and transparent. Prostomium with one pair of antennae and a simple pair of eyes. Parapodia are biramous without chaetae and modified for swimming into membranous structures. (Castellani and Camp, 2017)

Genus *Tomopteris*

63. *Tomopteris nationalis* Apstein, 1900 (Appendix B63)

Small size with long tail, the anterior cirri can be as long as the prostomial horns. Rosettes are present near the tip of the rami in mid body region and on the trunks of the first two pairs of parapodia which are on the ventral side at the base of the ventral rami. (Dales, 1957)

Phylum Chaetognatha

Class Sagittoidae

Order Aphragomorpha

Family Sagittidae

Transverse musculature absent. The body is either firm or flaccid. Head with 3-12 hooks and two rows of teeth. Have two paris of lateral fin. (Pierrit-Bults, 2017)

Genus *Aidanosagitta*

64. *Aidanosagitta neglecta* (Aida, 1897) (Appendix B64)

Body is firm and opaque. The head is narrow with hooks that are not serrated. No fin bridge. Anterior fins medium length, round and fully rayed. Posterior fin medium length, round and fully rayed. Has long and narrow collarette (Al-Yamani et al., 2011)

Genus *Flaccisagitta*

65. *Flaccisagitta enflata* (Grassi, 1881) (Appendix B65)

The body is flaccid and transparent. The head is of medium width with hooks that are not serrated. No fin bridge. Aterior fins very short and round, partially rayed. Posterior fin short and round, also partially rayed. Seminal vesicle round and touching the tail fin, but separated from posterior fins. Ovaries short with large ova, reaching the middle of posterior fins. (Al-Yamani et al., 2011)

Phylum Chordata

Class Thaliacea

Order Doliolida

Family Doliolidae

Musculature normally complete cicular bands surrounding the body (nine bands in oozoids and nurses, eight bands in phorozooids and gonozooids). Pharyngeal cavity large, occupying anterior half of the body or more, with gill slits in the posterior part. (Boltovskoy, 1999)

Genus *Doliolum*

66. *Doliolum nationalis* Borgert, 1893 (Appendix B66)

Gastrozooid with few gill-slits and a U-shaped digestive tract. Gonozooid and phorozooid with short endostyle from MII to MIV. Gill septum strongly arched, extending dorsally to MII and ventrally to MV. (Boltovskoy, 1999)

Order Salpida

Family Salpidae

Covered with a transparent test. Body muscle usually interrupted ventrally, sometimes also dorsally, or forming complete bands. Gill bar extending from the antero-dorsal surface to the esophagus located postero-ventrally. (Boltovskoy, 1999)

Genus *Salpa*

67. *Salpa maxima* Forskål, 1775 (Appendix B67)

Solitary zooid: Test entirely smooth, all the body muscles are dorsally parallel. Dorsal tubercle resemgling letter G.

Aggregate zooid: Test entirely smooth. MI and MII, MIII and MIV fused dorsally, MII and MIII meeting in the mid-dorsal region. MIV and MV converging but not fused laterally. (Boltovskoy, 1999)

68. *Salpa* sp.1 (Appendix B68)

69. *Salpa* sp.2 (Appendix B69)

Genus *Thalia*

70. *Thalia democratica* (Forskål, 1775)

Solitary zooid: Test smooth, all projections are echinate. MI and MIII, MIV and MV are contiguous or fused dorsally over a short distance. 37-86 muscular fibers.

Aggregate zooid: Nucleus bearing a posterior projection. 15-17 muscular fibers. (Boltovskoy, 1999)

71. *Thalia rhomboides* (Quoy & Gaimard, 1824)
(Appendix B70)

Solitary zooid: Body elongated, cylindrical. All test echinate. Lateral projections well developed. Body muscle thick.

Aggregate zooid: Body pentagonal shaped. Test relatively hard, and nucleus oval. (Kim *et al*., 2011)

Class Appendicularia

Order Copelata

Family Fritillariidae

Trunk usually elongated and dorso-ventrally flattened. The mouth is elongated, the endostyle is curved upwards at the end. The tail is short and rarely longer than the trunk. (Boltovskoy, 1999)

Genus *Fritillaria*

72. *Fritillaria pellucida* (Busch, 1851) (Appendix B72)

Trunk up to 2.2 mm long with a protruding upper lip. Two amphichordal cell with ejective ducts on each side of the broad tail musculature. The testis on the right side of the body, ovary on the left. (Boltovskoy, 1999)

73. *Fritillaria borealis sargassi* Lohmann, 1896
(Appendix B73)

Trunk is elongate and up to 1.4 mm long. Gonads assymetrically arranged and tail musculature is broad. (Boltovskoy, 1999)

Family Oikopleuridae

The trunk is compact and generally pear-shaped, sometimes it is laterally compressed or dorsoventrally depressed. Has a straight endostyle, and the tail is several times longer that th trunk. (Boltovskoy, 1999)

Genus *Oikopleura*

74. *Oikopleura (Vexillaria) dioica* Fol, 1872
(Appendix B74)

Trunk compact, up to 1.3 mm long; tail with two spindle-shpaed subchordal cells arranged in a line, musculature narrow dioecious. (Boltovskoy, 1999)

75. *Oikopleura (Coecaria) intermedia* Lohmann, 1896 (Appendix B75)

Trunk up to 2.5 mm long, wide bay between the genital parts of left and right lobes of the stomach; gonads arising between the stomach lobes; tail musculature broad. (Boltovskoy, 1999)

76. *Oikopleura (Coecaria) longicauda* (Vogt, 1854) (Appendix B76)

Trunk compact, up to 1.4 mm long; tail musculature broad. (Boltovskoy ,1999)

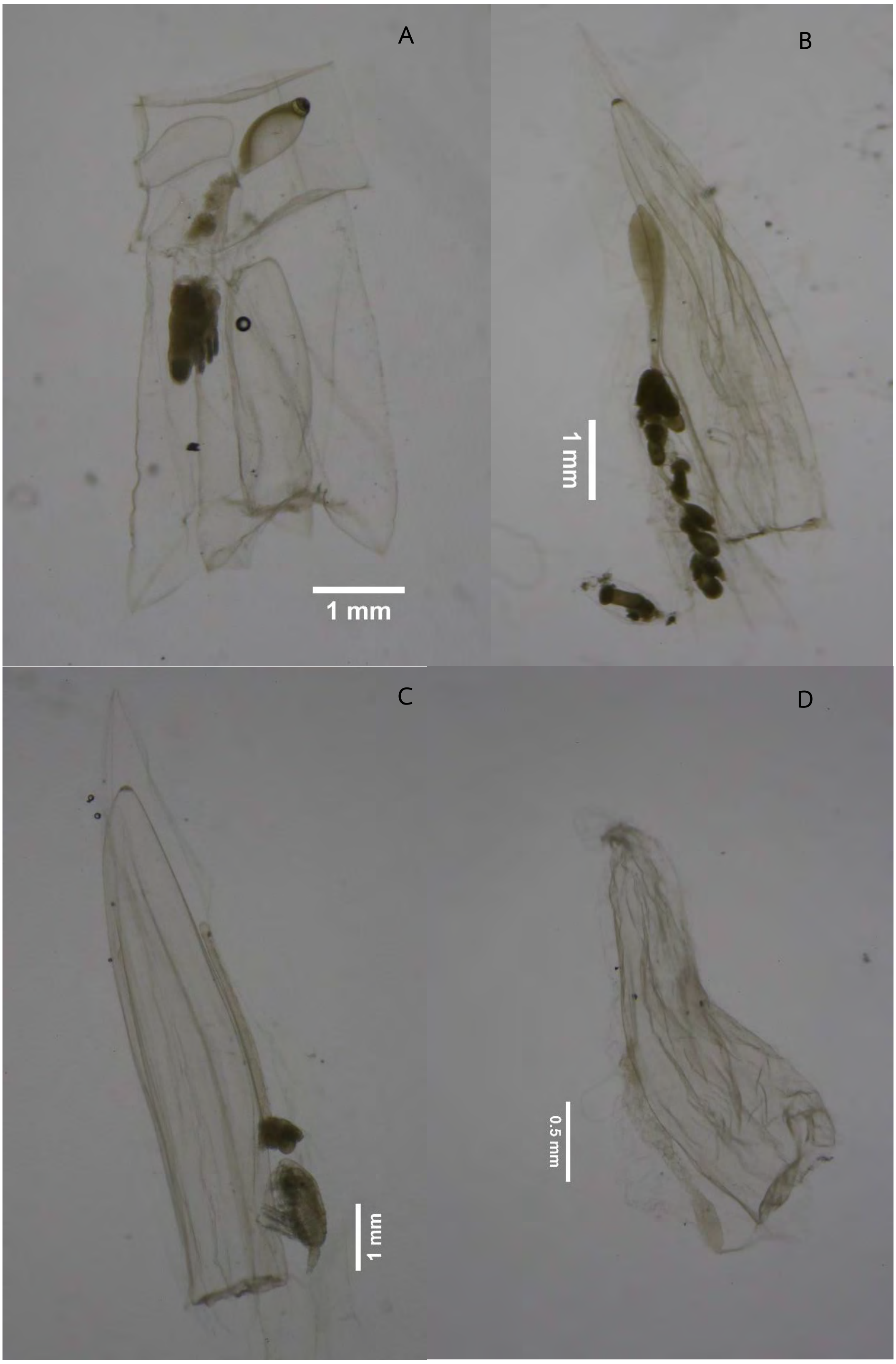


Figure 4.2 Examples of Siphonophore from this study. A, *Bassia bassensis*. B, *Diphyes dispar*. C, *Muggiaea atlantica*. D, *Sulculeolaria quadrivalvis*.

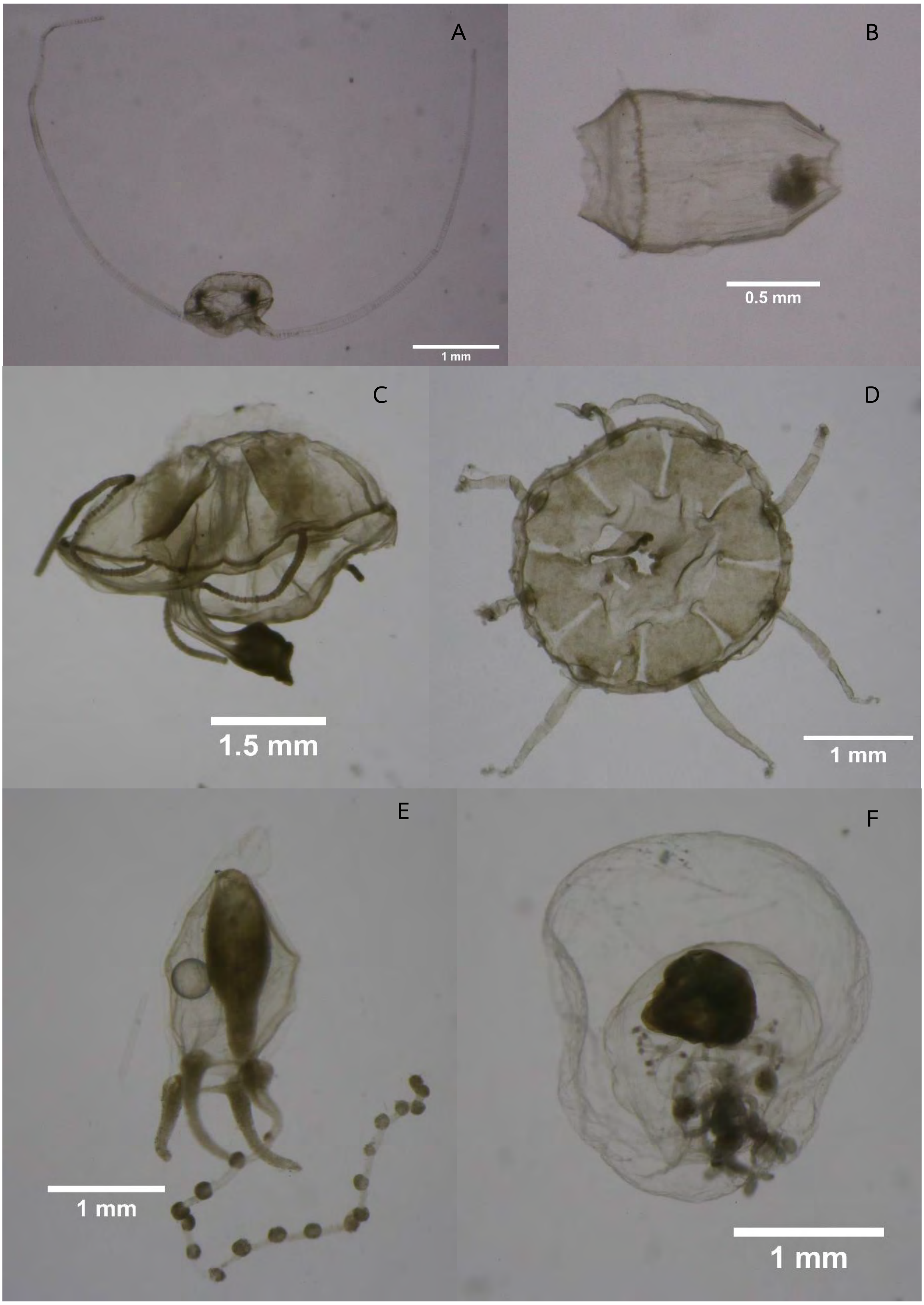


Figure 4.3 Examples of Hydromedusae from this study. A, *Solmundella bitentaculata*. B, *Aglaura hemistomata*. C, *Liriope tetraphyla*. D, *Cunina octonaria*. E, *Corymorpha bigelowi*. D, *Bougainvillia principis*.

Figure 4.4 Examples of Ctenophore, Gastropods and arrowworms from this study. A, *Hormiphora* sp. B, *Styliola subula*. C, *Creseis clava*. D, *Tomopteris nationalis*. E, *Flaccisagitta enflata*. F, *Aidanosagitta neglecta*.

Figure 4.5 Examples of Thaliaceas and Appendicularians from this study. A, *Doliolid nationalis*. B, *Thalia democratica*. C, *Fritillaria pelucida.* D, *Oikopleura dioica.*

4.2.2 Shannon-Weiner Index and Evenness Index of Gelatinous Zooplanktons in the Gulf of Thailand

The highest value of the Shannon-Weiner Index was found at station 15 (2.850) followed by station 49 (2.593) (Figure 4.6). The lowest value of the Shannon-Weiner Index was at station 1 (0.924). The highest value of the Evenness index was also found at station 15 (0.865) followed by station 25 (0.853). The lowest value was found at station 1 (0.291). Interestingly, the lowest values of both the Shannon-Weiner Index and the Evenness Index were found in the upper Gulf of Thailand.

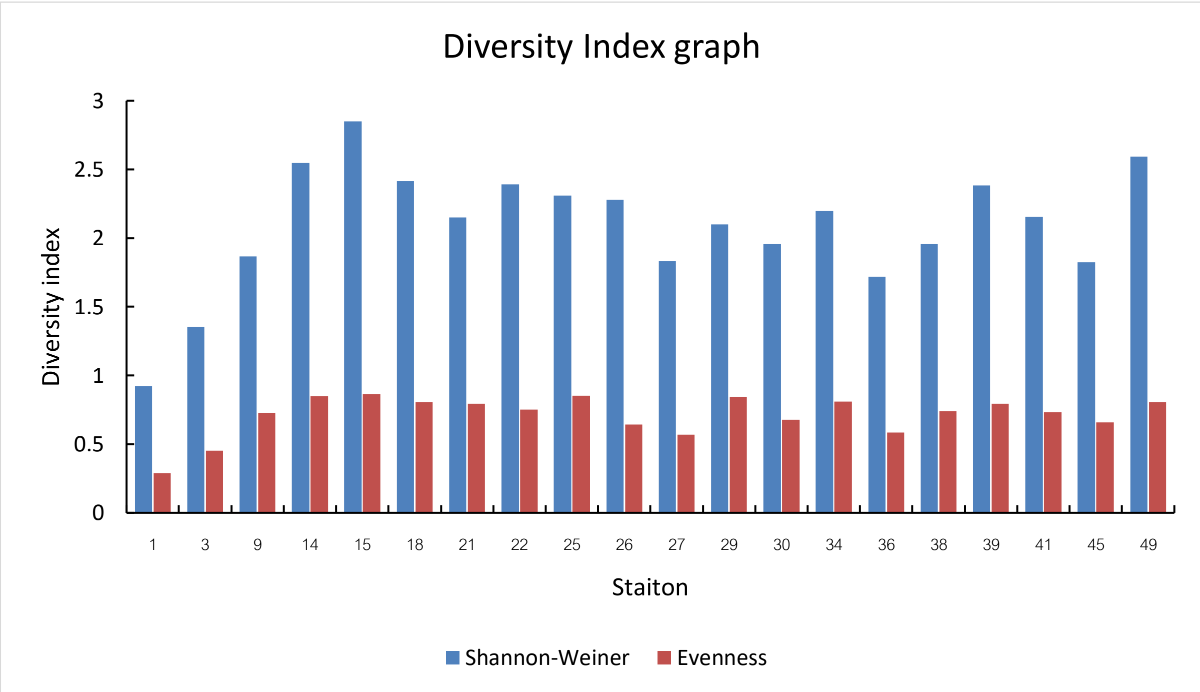


Figure 4.6 Shannon-Weiner index and Evenness index of GZ in the Gulf of Thailand

4.2.3 The Abundance and Biovolume of Gelatinous Zooplanktons in the Gulf of Thailand

The abundance of GZ in the Gulf of Thailand (Figure 4.7) was found to be the highest at station 1 with 113,365 individuals/100m^3 and the lowest at station 29 with 1,753 individuals/100m^3. The abundance of GZ tended to be higher near shore (station 1, 3, 22, 26, 27, 36, 45) than off shore (21, 25, 29) with a few exceptions (station 38, 39). The highest biovolume (Figure 4.7) was found at station 3 with 3.26 ml/m^3 and the lowest at station 34 with 0.04 ml/m^3. High biovolume at station 3 in the inner Gulf of Thailand was due to the high number of salps found. Salps have a bulky shape) leading to the high biovolume.

The abundance and biovolume of the GZ were significantly correlated ($p<0.01$). It was noted that the upper Gulf of Thailand had the highest average abundance and biovolume, followed by the middle part of the Gulf of Thailand and the lower Gulf of Thailand having the lowest value for both.

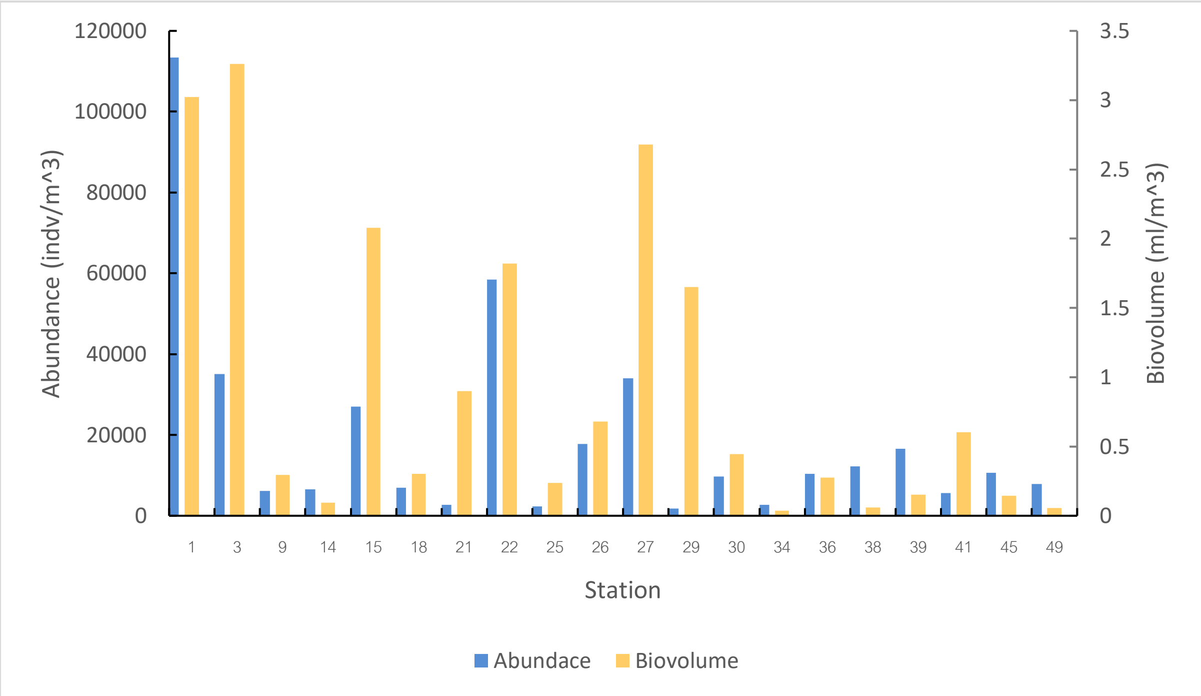


Figure 4.7 Abundance and Biovolume of GZ in the Gulf of Thailand collected during 17 August 2018 and 11 October 2018.

Gennerally, Hydrozoa, Sagittidae and Appendicularians were common groups of GZ that found at every station (Figure 4.8). Sagittidae had the highest abundance in almost all the stations followed by Appendicularians and Hydromedusae. The dominant GZ species (Table 4.2) was an arrow worm *Flaccisagitta enflata*, having the highest abundance in 14 out of the 20 stations followed by an arrow worm *Aidanosagitta neglecta* and an Appendicularian *Oikopleura longicauda* which were in the top 3 abundant species in most stations. However, *Salpa* sp.1 was the dominant species in station 1.

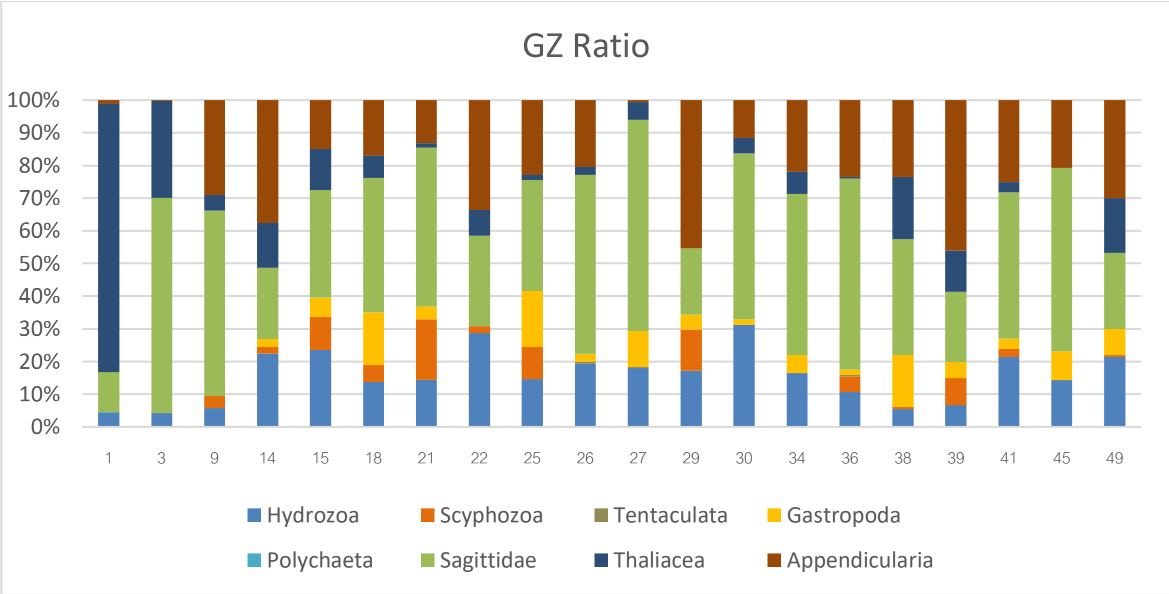


Figure 4.8 Composition of GZ abundance in the Gulf of Thailand

Table 4.2 First three dominant species of GZ at each station in the Gulf of Thailand

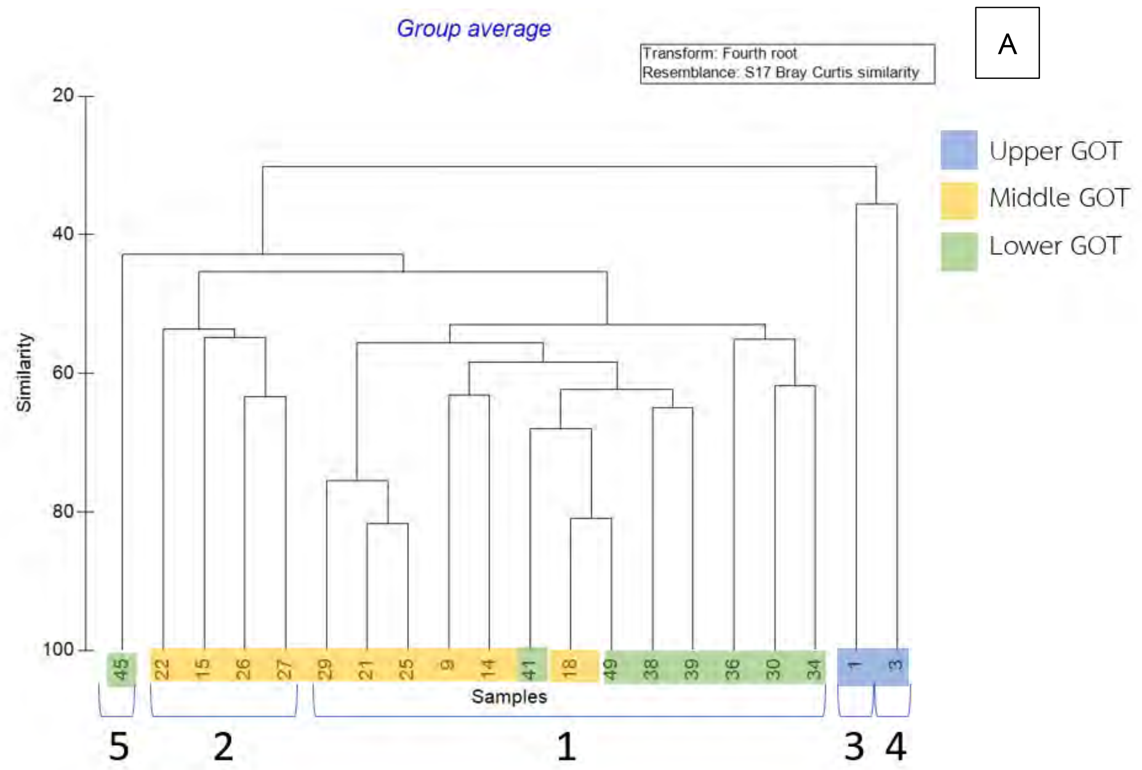
	Dominant Species (proportion of abundance in sample, %)		
Station	1st	2nd	3rd
1	*Salpa* sp.1 (79%)	*Flaccisagitta enflata* (11%)	Unidentified Doliolid (2%)
3	*Flaccisagitta enflata* (61%)	*Thalia democratica* (17%)	*Salpa maxima* (9%)
9	*Flaccisagitta enflata* (33%)	*Aidanosagitta neglecta* (24%)	*Oikopleura longicauda* (19%)
14	*Fritillaria pelucida* (16%)	*Oikopleura dioica* (14%)	*Aidanosagitta neglecta* (11%)
15	*Flaccisagitta enflata* (18%)	*Aidanosagitta neglecta* (15%)	*Doliolum nationalis* (7%)
18	*Flaccisagitta enflata* (29%)	*Styliola subula* (13%)	*Aidanosagitta neglecta* (12%)
21	*Aidanosagitta neglecta* (32%)	*Flaccisagitta enflata* (17%)	*Pelagic noctiluca* (14%)
22	*Oikopleura dioica* (24%)	*Flaccisagitta enflata* (19%)	*Aglaura hemistoma* (12%)
25	*Flaccisagitta enflata* (22%)	*Oikopleura longicauda* (15%)	*Creseis clava* (13%)
26	*Flaccisagitta enflata* (34%)	*Aidanosagitta neglecta* (21%)	*Fritillaria pelucida* (9%)
27	*Flaccisagitta enflata* (36%)	*Aidanosagitta neglecta* (29%)	*Diphyes bojani* (10%)
29	*Oikopleura dioica* (25%)	*Oikopleura longicauda* (20%)	*Aidanosagitta neglecta* (17%)
30	*Flaccisagitta enflata* (39%)	*Diphyes bojani* (20%)	*Aidanosagitta neglecta* (12%)
34	*Flaccisagitta enflata* (33%)	*Aidanosagitta neglecta* (16%)	*Oikopleura dioica* (10%)
36	*Flaccisagitta enflata* (48%)	*Oikopleura longicauda* (21%)	*Aidanosagitta neglecta* (11%)
38	*Flaccisagitta enflata* (26%)	*Oikopleura dioica* (19%)	*Doliolum nationalis* (18%)
39	*Flaccisagitta enflata* (19%)	*Oikopleura longicauda* (18%)	*Doliolum nationalis* (12%)
41	*Flaccisagitta enflata* (35%)	*Aglaura hemistoma* (15%)	*Aidanosagitta neglecta,* (9%) *Oikopleura longicauda* (9%)
45	*Flaccisagitta enflata* (35%)	*Aidanosagitta neglecta* (22%)	*Oikopleura longicauda* (21%)
49	*Oikopleura longicauda* (19%)	*Doliolum nationalis* (13%)	*Aidanosagitta neglecta* (12%)

4.2.4 The Community Structure of Gelatinous Zooplankton in the Gulf of Thailand

Non-metric multidimensional scaling showed that GZ communities were divided into 5 groups (Figure 4.9). The first group is the biggest group formed by GZ from the middle and lower part of the GOT including stations 9, 14, 18, 21, 25, 29, 30, 34, 36, 38, 39, 41 and 49. This group has a similarity of more than 50%. This group has a relatively low abundance (1,753-16,613 individuals/100m^3) and is dominated by arrowworms *Flaccisaggita enflata* and *Aidanosagitta neglecta*, an appendicularian *Oikopleura dioica* and a hydromedusa *Aglaura hemistoma*.

The second group are GZ from near shore in the middle part of the GOT including stations 15, 22, 26, 27. This group is characterized by high abundance (17,744-58,399 individuals/100m^3) and dominated by arrow worms *Flaccisagita enflata* and *Aidanosagitta neglecta,* appendicularians *Oikopleura longicauda,* and *Oikopleura dioica*. This group also has a similarity of more than 50%.

The third, fourth and fifth groups are station 1, 3 and 45 respectively. Each group consists of a single station from upper GOT and lower GOT that had different dominant species. Dominant GZ in station 1 are thaliaceans *Salpa* sp.1, old nurse of Doliolid, *Thalia democratica* and an arrow worm *Flaccisagitta enflata*. For station 3, the dominant species are arrowworms *Flaccisagitta enflata* and *Aidanosagitta neglecta* and thaliaceans *Thalia democratica* and *Salpa maxima*. Finally, for station 45 the dominant species are arrow worms *Flaccisagitta enflata* and *Aidanosagitta neglecta*, an appendicularian *Oikopleura longicauda* and a pteropod *Creseis clava*. Station 45 has a similarity with stations 1 and 3 of less than 45%, moreover, station 1 and 3 have a similarity of less than 40%.



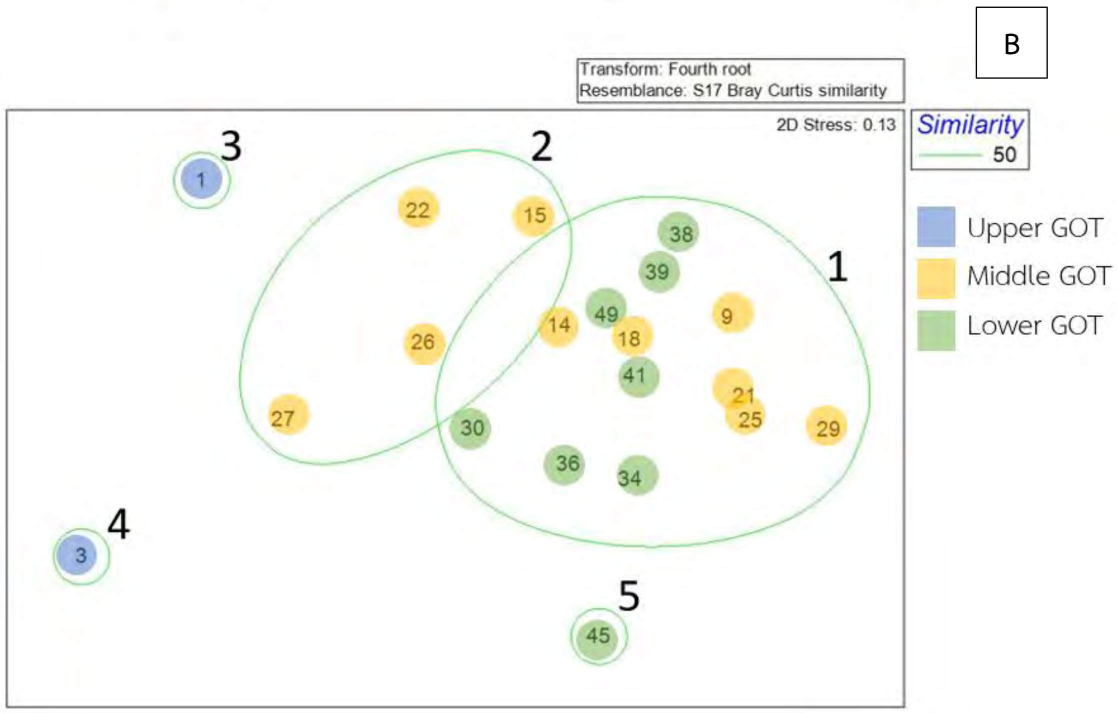


Figure 4.9 A: Similarity dendogram of GZ in the Gulf of Thailand collected during 17 August 2018 until 11 October 2018. B: GZ plankton community in GOT using Non-metric multidimensional scaling analysis by PRIMER V6 program.

4.2.5 Correlation between Shannon-Weiner Index and Abundance of Gelatinous Zooplankton with Physical Parameter

The number of species had no significant correlation with physical parametes (Table 4.3). However, the Shannon-Weiner index and the Evenness index were significantly positively correlated with salinity and seawater denisity ($p<0.01$), but negatively correlated with DO ($p<0.05$). On the other hand, GZ abundance and biovolume were significantly negatively correlated with salinity and seawater density ($p<0.01$).

Table 4.3 Pearson Correlation Coefficient between Shannon-Weiner index, Evenness index, Species number, GZ abundance and GZ biovolume and physical parameters (Temperature, Salinity, pH, sea water density and Dissolved Oxygen)

	Temperature	Salinity	Seawater Density	DO	pH
Species Number	0.156	-0.007	-0.066	-0.136	-0.020
Shannon-Weiner Index	-0.333	0.760**	0.748**	-0.558*	-0.192
Evenness Index	-0.394	0.745**	0.758**	-0.501*	-0.221
GZ Abundance	0.180	-0.700**	-0.665**	-0.162	0.049
GZ Biovolume	0.271	-0.603**	-0.603**	-0.373	-0.165

* Correlation is significant at $p< 0.05$

** Correlation is significant at $p< 0.01$

4.3 Discussion

4.3.1 The Diversity and Abundance of Gelatinous Zooplanktons in the Gulf of Thailand

In this study, a total number of 76 species from 8 classes and 6 phyla of GZ were reported in the Gulf of Thailand. Comparing this to the studies of Jitrapat (2018) and Chaiburin (2007) who studied the diversity of GZ as well as Phongphattarawat (2013) and Wuttichareonmonkol (2004) who studied Hydrozoas in the upper Gulf of Thailand, I found 24 new records that have never been reported in previous studies (Table 4.4). The 24 newly reported species include Hydrozoa such as *Sarsia* sp., *Euphysa* sp. *Zanclea* sp., *Podocoryne* sp., *Lizzia gracilis*, *Bougainvillia multitentaculata, Protiara tetranema, Clytia rangiroae,* *Eucheilota tropica, Phialucium* sp., *Octophialucium Aphrodite, Eirene elliceana*, *Lensia meteori, Muggiaea atlantica, Sulculeolaria monoica, Abyla haecklei*. For Appendicularia these include *Oikopleura dioica, Oikopleura intermedia, Fritillara peullucida,* and Thaliceas such as *Doliolum nationalis, Salpa maxima, Thalia rhomboides* and finally the Gastropods which are *Styliola subula* and *Clio pyramidata.* This is not surprising because this study was conducted in the entire Gulf of Thailand, while the previous studies were limited in the upper Gulf of Thailand.

However, there are 32 species that have been reported in the upper Gulf of Thailand in previous works, but were not found in this study (Table 4.4). This is likely due to my study obtained samples from only one season during August until October 2018, but others were conduct more than one season in a year. For example, Chaiburin (2007) obtained samples in December (2005) and May (2006); Phongphattarawat (2013) collected samples in February (2012) and November (2012); Jittrapat (2018) analyzed GZ samples collected in June, October (2017), and April (2018), and Wuttijaroenmongkol (2004) collected samples 5 times in Jan, Mar, May, Jul, Sep (2000).

Hydrozoans, Sagittidae and Appendicularians were found in all stations in this study. The dominant GZ species were arrow worms*Flaccisagitta enflata* and *Aidanosagitta neglecta,* and appendicularian *Oikopleura longicauda*. *F. enflata* was reported as one of the dominant species in the upper GOT (Jittrapat, 2018) and a coastal of Andaman Sea (Punnarak, 2004), whaereas *A. neglecta* was second domiant arrow worm after *F. enflata* in the Andaman Sea (Punnarak, 2004). However, *O. longicauda* has not been documented as a dominant species in other studies in Thailand. In contrast to other studies on GZ in Thailand (Chaiburin 2007; Jittrapat 2018), no species of hydrozoan was considered as a dominant species in this study.

Comparing the abundance of hydrozoans from the same location in the same season from this study (4,904 individual/100m^3) with previous studies by Wuttichareonmonkol (2004) in 2000 (4.54 individal/100m^3) and Phongphattarawat in 2013 (<2000 individaul/100m^3), the abundance of hydrozoans have increased in the past 18 years. The area with high abundance was found in the upper and middle Gulf of Thailand. Near shore stations had higher abundance than those further from shore agreeing with the result of Jittrapat (2018). From calculating the correlation between physical parameters and abundance, it was found that the abundance of GZ had a negative correlation with salinity ($p<0.01$) and seawater density ($p<0.01$) which is in accordance with the studies of Wuttijaroenmongkol (2004), Chaiburin (2007) and Jittrapat (2018). This means that the abundance of GZ will have a high value when the salinity and sea water density have a low value and vice versa. The salinity and seawater density in the upper Gulf of Thailand had the lowest values, whereas the lower Gulf of Thailand had relatively high values. A study of GZ in the Belgian part of the North Sea and the adjacent estuary by Vansteenbrugge and coleagues (2015) reported that salinity was the main parameter explaining the spatial distribution of the GZ. They explained that highest densities and diversity was found in the coast and lower estuary locations where presumably there is low salinity, these locations have high nutrient inputs leading to high primary production thus becoming an optimum site for GZ to grow and reproduce.

Table 4.4 Diversity of gelatinous zooplanktons in Thailand

No.	Phylum	Species	Previous studies		This study
			Upper GoT[1,2,3,4,5,6,7]	Andaman[7,8]	
1	Cnidaria	*Sarsia sp.*			✓
2		*Corymorpha nutans*	✓		
3		*Corymorpha bigelowi*	✓		✓
4		*Corymorpha forbesii*	✓		
5		*Euphysa* sp.			✓
6		*Halocoryne orientalis*	✓		
7		*Zanclea* sp.			✓
8		*Cytaeis tetrastyla*	✓		✓
9		*Turritopsis nutricula*	✓		✓
10		*Podocorynoides* sp.			✓
11		*Lizzia gracilis*			✓
12		*Bougainvillia britannica*	✓		
13		*Bougainvillia muscus*	✓		✓
14		*Bougainvillia platygaster*	✓		
15		*Bougainvillia principis*	✓		✓
16		*Bougainvillia ramosa*	✓		
17		*Bougainvillia muscoides*	✓		
18		*Bougainvillia multitentaculata*			✓
19		*Kollikerina fasciculata*	✓		
20		*Pandeopsis ikarii*	✓		
21		*Proboscidactyla ornata*	✓		✓

No.	Phylum	Species	Previous studies		This study
			Upper GoT[1,2,3,4,5,6,7]	Andaman[7,8]	
22	Cnidaria	*Hydractinia apicata*	✓		
23		*Hydractinia carnea*	✓		
24		*Steenstrupia nutans*	✓		
25		*Euphysora bigelowi*	✓		
26		*Hybocodon* sp.	✓		
27		*Halitiara formosa*	✓		
28		*Protiara tetranema*			✓
29		*Physalia physalis*			
30		*Porpita porpita*	✓	✓	✓
31		*Laodicea indica*	✓		
32		*Laodicea miniscula*	✓		
33		*Laodicea undulata*	✓		
34		*Obelia* sp.	✓		
35		*Clytia uchidai*	✓		
36		*Clytia rangiroae*			✓
37		*Phialidium malayense*	✓		
38		*Phialidium uchida*	✓		
39		*Eucheilota menoni*	✓		
40		*Eucheilota paradoxica*	✓		
41		*Eucheilota comata*	✓		
42		*Eucheilota tropica*			✓
43		*Phialucium* sp.			✓
44		*Malagazzia carolinae*	✓		✓
45		*Octophialucium multitentaculatum*	✓		
46		*Octophialucium medium*	✓		
47		*Octophialucium indicum*	✓		
48		*Octophialucium funerarium*	✓		✓
49		*Octophialucium aphrodite*			✓
50		*Eirene brevigona*	✓		
51		*Eirene ceylonensis*	✓		
52		*Eirene hexanemalis*	✓		✓

No.	Phylum	Species	Previous studies		This study
			Upper GoT[1,2,3,4,5,6,7]	Andaman[7,8]	
53	Cnidaria	*Eirene menoni*	✓		
54		*Eirene palkensis*	✓		
55		*Eirene viridula*	✓		
56		*Eirene elliceana*			✓
57		*Eutima orientalis*	✓		
58		*Eutima curva*	✓		
59		*Eutima gracilis*	✓		
60		*Helgicirrha malayensis*	✓		
61		*Helgicirrha schuzei*	✓		
62		*Aequorea conica*	✓		
63		*Aequorea macrodacyla*	✓		
64		*Aequorea pencilis*	✓		
65		*Aequorea globosa*	✓		
66		*Aequorea parva*	✓	✓	
67		*Zygocanna* sp.	✓	✓	
68		*Liriope tetraphylla*	✓		✓
69		*Amphogona apicata*	✓		
70		*Aglaura hemistoma*	✓		✓
71		*Solmundella bitentaculata*	✓		✓
72		*Cunina octonaria*	✓		✓
73		*Cunina duplicata*	✓		
74		*Cunina tenella*	✓		
75		*Cunina peregrina*	✓		✓
76		*Agalma elegans*	✓		✓
77		*Agalma okeni*	✓		
78		*Diphyes chamissonis*	✓		
79		*Diphyes bojani*	✓		✓
80		*Diphyes dispar*	✓		✓
81		*Lensia subtilis*	✓		
82		*Lensia subtiloides*	✓		
83		*Lensia campanella*	✓		
84		*Lensia gnanamulthui*	✓		

No.	Phylum	Species	Previous studies		This study
			Upper GoT[1,2,3,4,5,6,7]	Andaman[7,8]	
85	Cnidaria	*Lensia meteori*			✓
86		*Muggiaea atlantica*			✓
87		*Chelophyes contorta*	✓		
88		*Sulculeolaria quadrivalvis*	✓		✓
89		*Sulculeolaria monoica*			✓
90		*Sphaeronectes koellikeri*	✓		
91		*Ceratosymba leuckarti*	✓		
92		*Abyla trigona*	✓		✓
93		*Abyla haeckeli*			✓
94		*Abylopsis eschsholtzi*	✓		✓
95		*Abylopsis tetragona*	✓		
96		*Bassia bassensis*	✓		✓
97		*Enneagonum hyalinum*	✓		✓
98		*Physalia physalis*	✓	✓	
99		*Morbakka* sp.	✓	✓	
101		*Chiropsoides buitendijki*		✓	
104		*Tripedalia cystophora*		✓	
106		*Pelagia* sp.	✓	✓	✓
107		*Chrysaora* sp.	✓	✓	
108		*Cephea cephea*		✓	
109		*Cyanea buitendijki*		✓	
110		*Aurelia aurita*	✓	✓	
111		*Cassiopea andromeda*	✓		
112		*Cassiopea ornata*		✓	
113		*Acromitus flagellatus*	✓	✓	
114		*Acromitus hardenbergi*	✓		
115		*Catostylus townsendi*	✓	✓	
116		*Crambione* sp.		✓	
117		*Lobonema smithii*	✓		
118		*Lobonemoides* sp.	✓	✓	
120		*Lynchnorhiza malayensis*		✓	
121		*Phyllorhiza punctata*	✓	✓	

No.	Phylum	Species	Previous studies		This study
			Upper GoT[1,2,3,4,5,6,7]	Andaman[7,8]	
122	Cnidaria	*Rhopilema hispidum*	✓	✓	
123		*Thysanostoma* sp.		✓	
124		*Versuriga anadyomene*	✓	✓	
125	Ctenophora	*Hormiphora* sp.	✓		✓
126		*Beroe* sp.	✓		
127	Annelida	*Tomopteris nationalis*	✓		✓
128	Mollusca	*Creseis acicula*	✓		✓
129		*Styliola subula*			✓
130		*Diacavolinia longirostris*	✓		
131		*Clio pyramidata*			✓
132		*Clione* sp.	✓		
133		*Pneumoderma* sp.	✓		
134		*Atlanta* sp.	✓		
135	Chaetognatha	*Aidanosagitta neglecta*	✓	✓	✓
136		*Ferosagitta ferox*		✓	
137		*Flaccisagitta enflata*	✓	✓	✓
138		*Flccisagitta hexaptera*	✓		
139		*Zonsagitta bedoti*		✓	
140	Chordata	*Oikopleura longicauda*	✓		✓
141		*Oikopleura (Vexillaria) dioica*			✓
142		*Oikopleura (Coecaria) intermedia*			✓
143		*Fritillaria borealis*	✓		✓
144		*Fritillaria pellucida*			✓
145		*Doliolum* sp.	✓		
146		*Doliolum nationalis*			✓
147		*Dolioloides* spp.	✓		
148		*Iasis cylindrica*	✓		
149		*Salpa maxima*			✓
150		*Thalia democratica*	✓		✓
151		*Thalia rhomboides*			✓

1 – Tandavanij (2001), 2 - Narawisut (2002), 3 - Wuttijaroenmongkol (2004), 4 - Chaiburin (2007), 5 - Phonphattarawat (2013) 6-Jittrapat (2018), 7- DMCR (2019), 8 – Porntep (2004),

4.3.2 The Importance of Gelatinous Zooplanktons in the Gulf of Thailand

GZ play an important role in the marine foodweb. Doliolids and appendicularians are important filter feeding (Anderson, 1998; Gorsky and Fenaux, 1998), whereas ctenophores, medusae and chaetognaths are significant predators in the food web (Licandro et al., 2017b,c; Pierrot-Bults, 2017;). Fecal pellets produced by these zooplankton and death bodies in form of marine snow are the important sources of nutrients transferring to sea floor for the benthic community (Diebel, 1998; Gorsky and Fenaux, 1998; Sweetman and Chapman, 2015).

From this study, we have seen that the Gulf of Thailand is home to a diverse group of GZ including dominant predators, the arrow worms *F. enflata* and *A. neglecta*, different species of hydromedusae and siphonophores as well as suspension feeders such as the larvacean *O. dioica*, *O. longicauda* salps and doliolids. They all play an important role in transferring energy to different trophic levels. The suspension feeders graze on phytoplankton and the microbial ecosystem (Anderson 1998; Gorsky and Fenaux 1998) transferring this energy to higher trophic levels such as copepods, fish or other carnivorous GZ, or this energy can be transported to the benthic ecosystem through faecal pellets (Gorsky and Fenaux 1998). However, when these GZ bloom, the high efficiency grazing may have a negative indirect impact on the growth of commercial aquatic animals by competition for phytoplankton. Predators like the arrow worm, hydromedusae and siphonophore prey on zooplanktons, primarily copepods, (Feigenbaum 1991; Licandro, et al. 2017a; Licandro, et al. 2017b) and may be competitors for food against fish who have the same diet such as the indian mackerel (Nath et al., 2015).

Impacts on human can also occur when there is a rapid increase in number, or bloom, of GZ. Thailand is famous for its beaches and every year tourists flock to enjoy a sunny day at the seashore. Therefore, it can be a problem when cnidarians such as *Pelagia* sp. bloom because they can injure and harm these tourists. Also, blooms of carnivorous GZ offshore can have an impact on fisheries by depleting the fish stock (Lynam et al., 2005; Shiganova and Bulgakova, 2000).

With the global temperature on the rise and developing of the coastal areas, the GZ will also be impacted by this change. Hence, in my opinion we should continuously study the diversity and abundance of GZ in the Gulf of Thailand for us to be able to monitor the change and be ready to take action in case of problems arising from GZ.

Chapter 5

Conclusion

5.1 Conclusion

Seventy-six species from 32 families, 6 phyla were reported in this study where class Hydrozoa was the most diverse group of GZ. Of these 76 species, 24 species were reported for the first time in Thailand. The dominant GZ were arrow worms *Flaccisagitta enflata* and *Aidanosagitta neglecta,* and an appendicularian *Oikopleura dioica*. The abundance of the GZ in the GOT was between 1,753 – 113,365 individuals/m^3 where the upper GOT had the highest abundance of 35,084 – 113,365 individuals/m^3 followed by the middle GOT and the lower GOT with abundaces of 1,753 – 58,399 individuals/m^3 and 2,685 – 16,616 individuals/m^3 respectively. The biovolume had a value between 0.04 ml/m^3 and 3.26 ml/m^3. The biovolume was correlated with the abundance thus had the highest value in the upper GOT followed by middle and lower GOT.

The GZ in the GOT were devided into five groups based on abundance and dominant species. The biggest group is formed by GZ from the middle and lower GOT characterized by their low abundance. *Flaccisaggita enflata*, *Aidanosagitta neglecta*, *Oikopleura dioica* and *Aglaura hemistoma* were the dominant species in this group. The second largest group is formed by GZ from the middle GOT and had a high abundance with *Flaccisagita enflata, Oikopleura longicauda, Aidanosagitta neglecta* and *Oikopleura dioica* as the dominant species.

The Shannon-Weiner index was high in the middle GOT and low in the upper GOT. Salinity, seawater density and DO were found to be major influencers of the abundance, biovolume and diversity of GZ

5.2 Suggestions

1. GZ identification should be done the earlier the better after sample collection because their bodies are very delicate and can disfigure when left in formalin solution for a long time. Conducting the identification process with a recently collected sample would be much easier and much more accurate.

2. Photography of GZ should be done in formalin solution or water and not in an alcohol solution. The reason being once GZ are put into an alcohol solution, the water inside their body is pulled out and their body shrinks.

3. There should be more studies conducted on the abundance and diversity of GZ in the Gulf of Thailand in different seasons and areas for the future in order to compare results and improve our understanding of the GZ community in the Gulf of Thailand.

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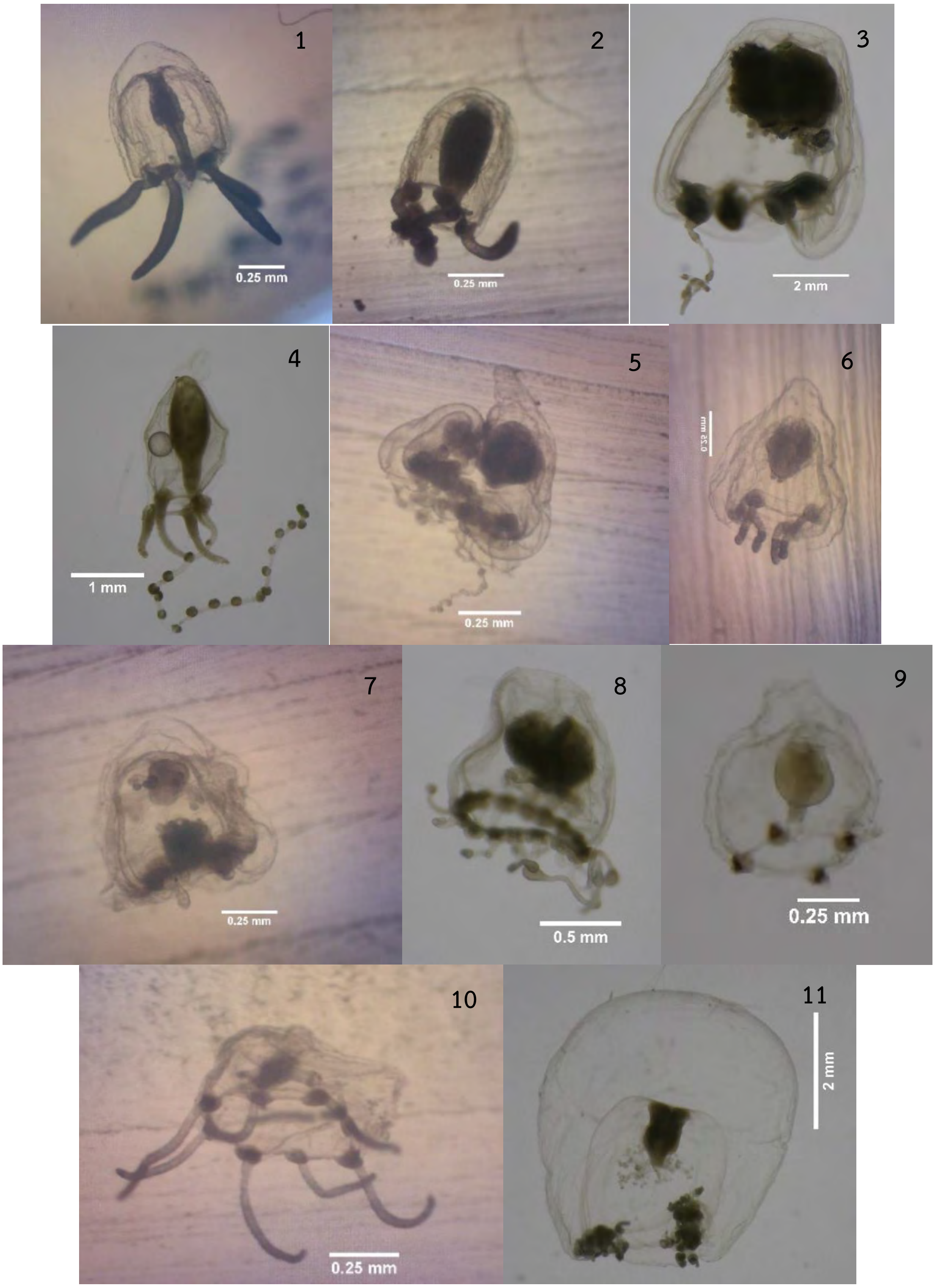
APPENDIX

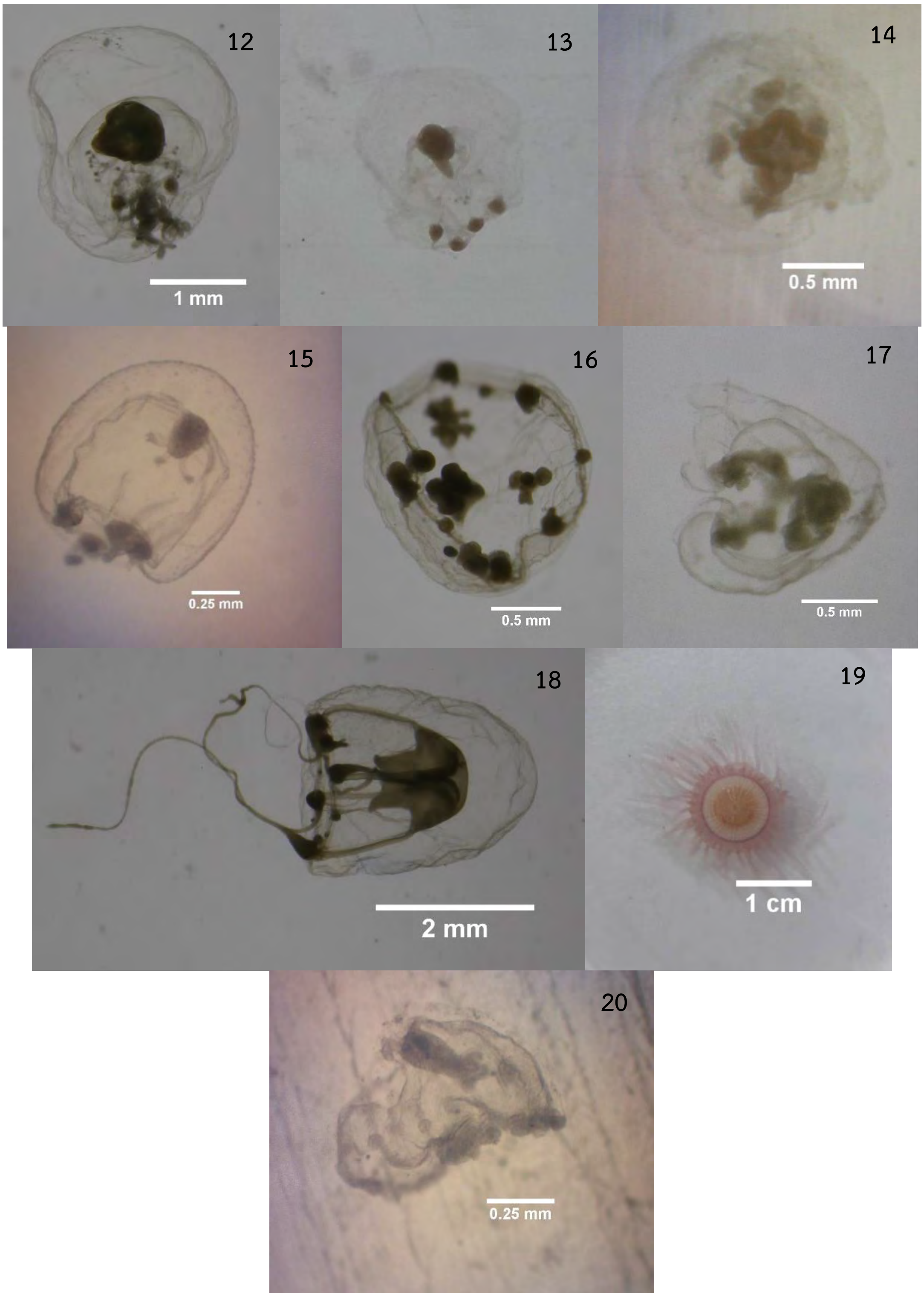
Appendix A Physcial parameter in the Gulf of Thailand during August until October 2018

	Station	Depth (m)	Average Temp (°C)	Average Salinity (PSU)	Average pH	Density (Kg/m^3)	Oxygen (mg/l)
Inner GOT	1	16	29.35	29.59	8.11	17.89	-
	3	20	28.98	31.17	8.07	19.20	-
Middle GOT	9	35	28.66	32.79	8.18	20.52	-
	14	37	28.73	32.78	7.86	20.49	4.18
	15	46	28.84	32.62	8.12	20.33	4.66
	18	42	29.06	33.10	8.03	20.58	6.35
	21	61	28.87	32.17	8.14	19.98	4.71
	22	42	28.66	33.21	8.04	20.78	6.00
	25	65	28.83	32.29	7.92	20.09	6.27
	26	22	29.02	33.12	8.03	20.58	6.62
	27	25	29.22	32.70	8.07	20.23	6.49
	29	60	28.59	32.82	7.84	20.56	6.25
Lower GOT	30	25	29.43	32.81	8.12	20.28	7.53
	34	30	29.38	32.42	8.22	20.01	7.63
	36	23	29.45	32.46	8.17	20.01	7.58
	38	55	27.58	33.07	8.19	21.07	7.15
	39	69	27.25	33.18	8.19	21.26	6.66
	41	44	28.72	32.71	8.19	20.44	7.53
	45	16	29.08	32.49	8.12	20.16	7.54
	49	45	28.48	33.01	8.15	20.74	7.50
	Average	38.9	28.81	32.53	8.09	20.26	6.51
	Max	69	29.45	33.21	8.22	21.26	7.63
	Min	16	27.25	29.59	7.84	17.89	4.18

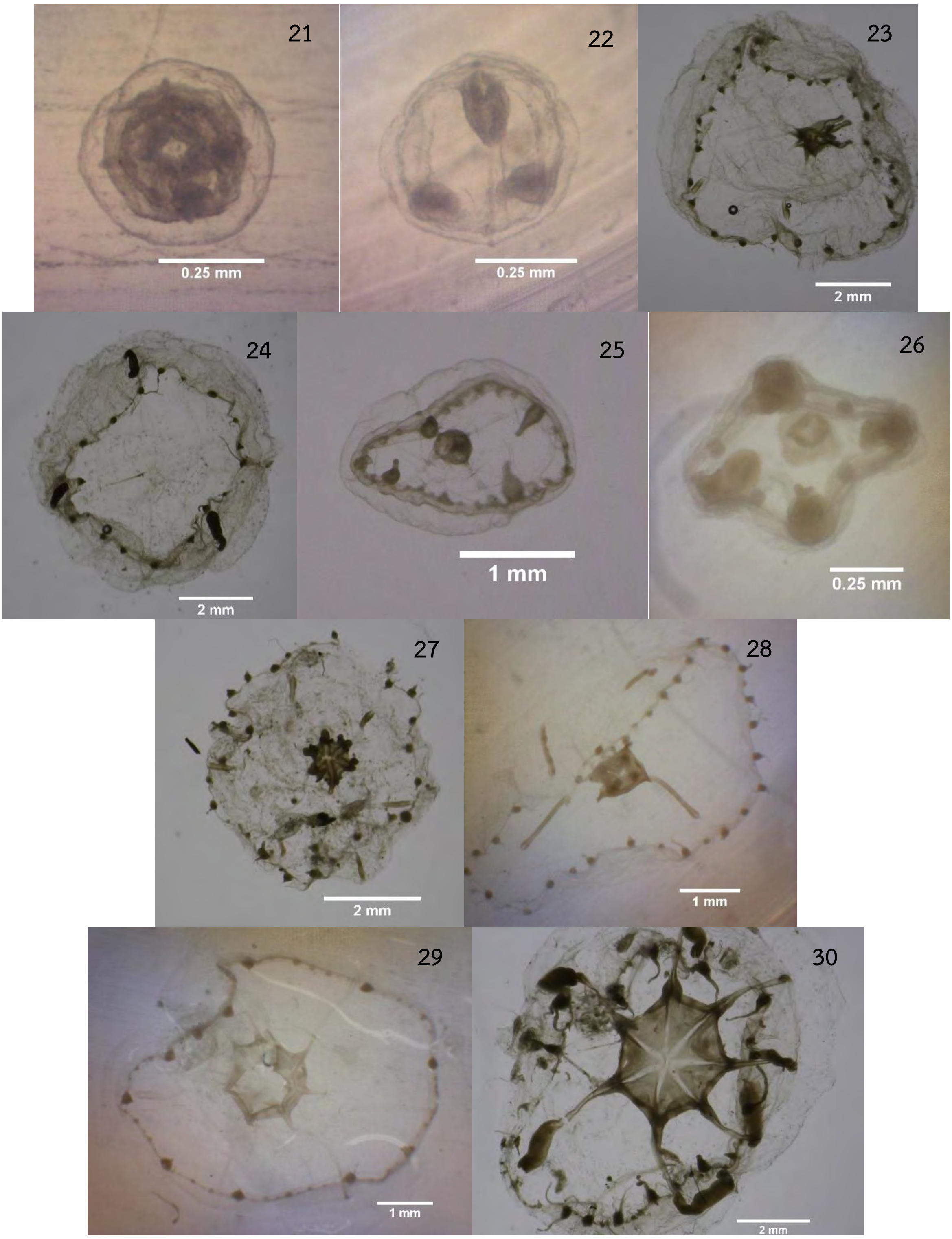
Appendix B Pictures of GZ found in this study



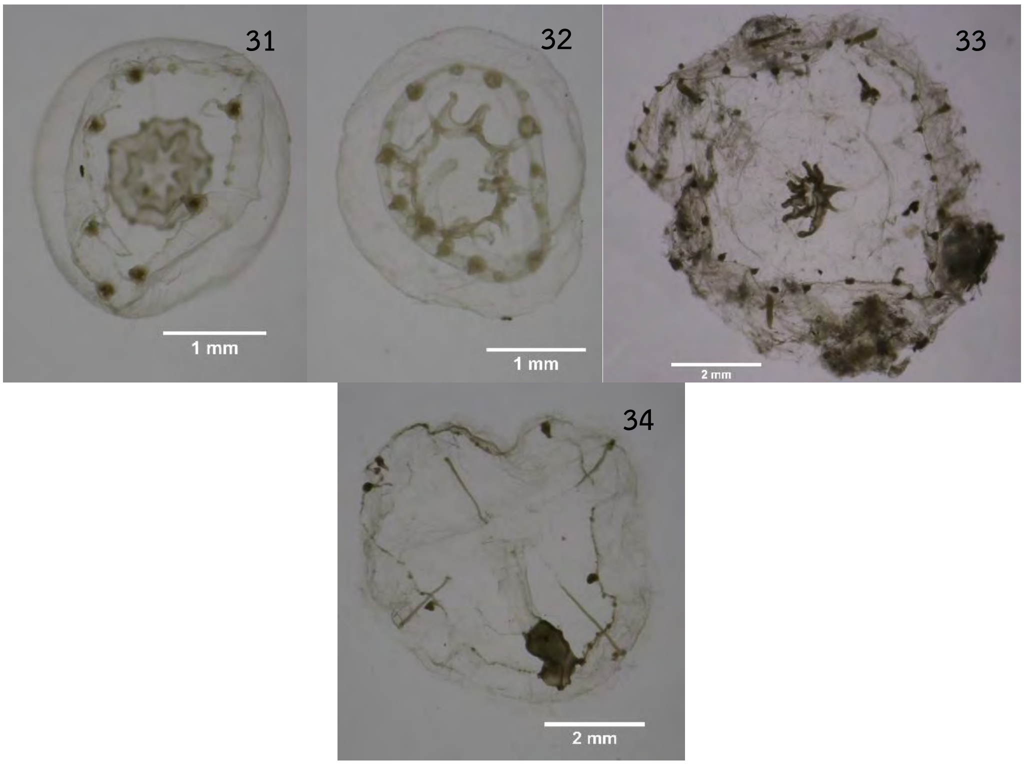
Anthomedusae from this study. 1, *Sarsia* sp.1. 2, *Sarsia* sp.2. 3, *Euphysa* sp.1. 4, *Corymorpha bigelowi*. 5, *Zanclea* sp.1. 6, *Cytaeis tetrastyla*. 7, *Cytaeis* sp.1. 8, *Turritopsis nutricula*. 9, *Podocorynoides* sp.1. 10, *Lizzia gracilis*. 11, *Bougainvillia multitentaculata*.



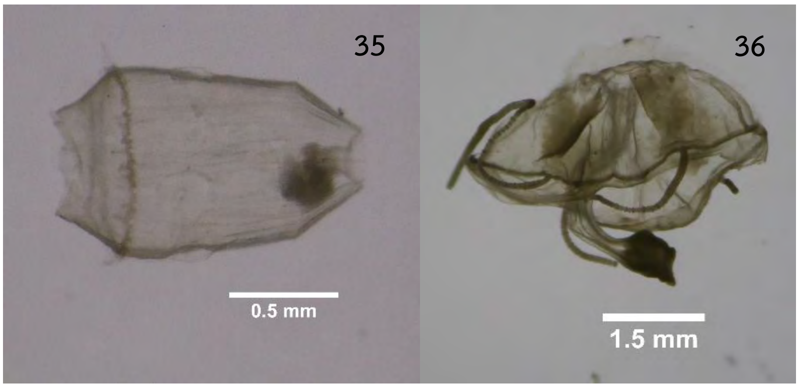
Anthomedusae from this study. 12, *Bougainvillia principis*, 13, *Bougainvillia muscus*. 14, *Bougainvillia* sp.1. 15, *Bougainvillia* sp.2. 16, *Proboscidactyla ornata*. 17, *Proboscidactyla* sp.1. 18, *Protiara tetranema*. 19, *Porpita porpita*. 20, Anthomedusa sp.1



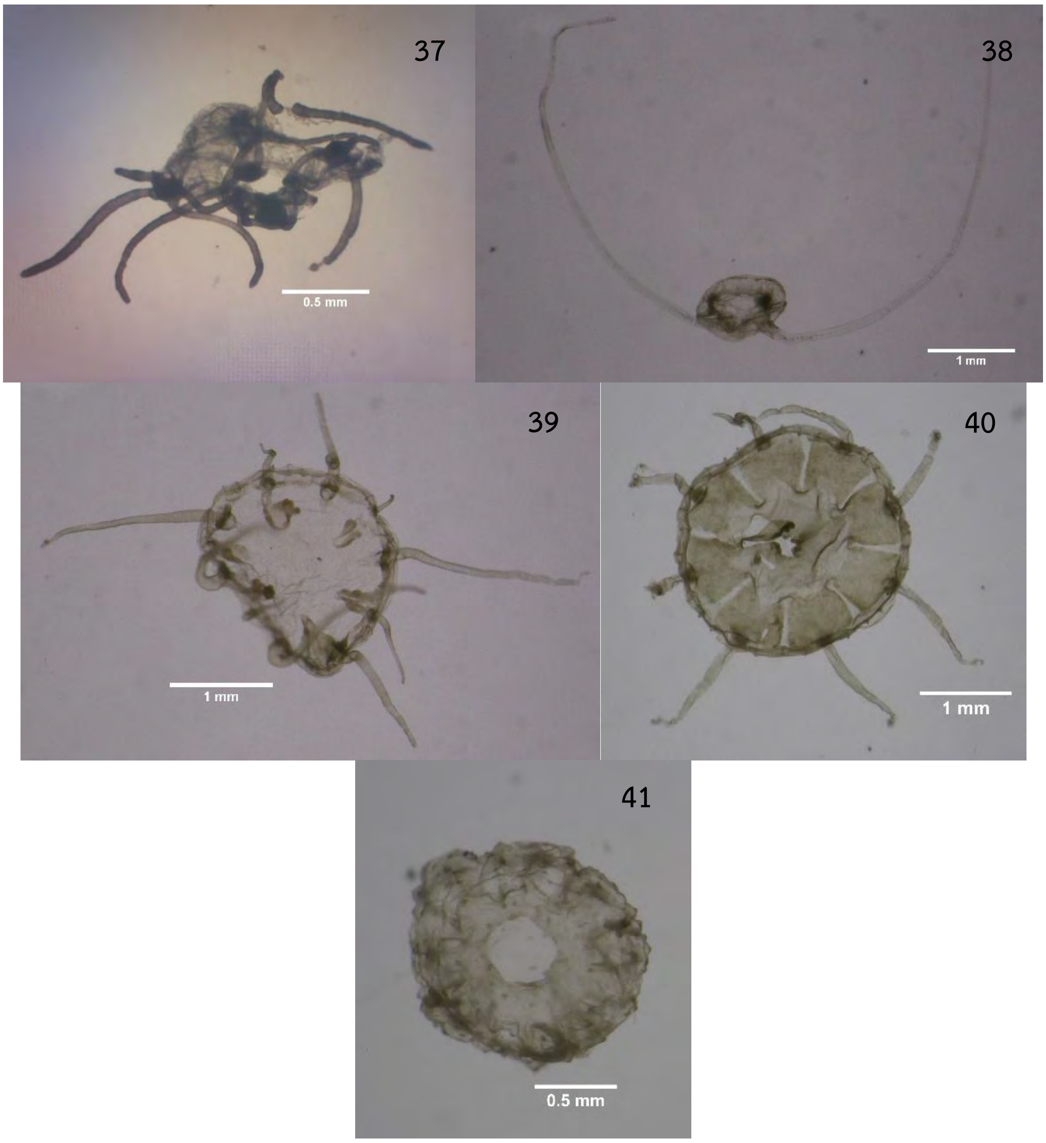
Leptomedusae from this study. 21, *Laodicea* sp.1.22, *Laodicea* sp.2. 23, *Clytia rangiroae.* 24, Unidentified (C*ampanulariidae*) sp.1. 25, *Eucheilota tropica*. 26, *Eucheilota* sp.1. 27, *Phialucium* sp.1. 28, *Malagazzia carolinae*. 29, *Octophialucium aphrodite*. 30, *Octophialucium funerarium*.



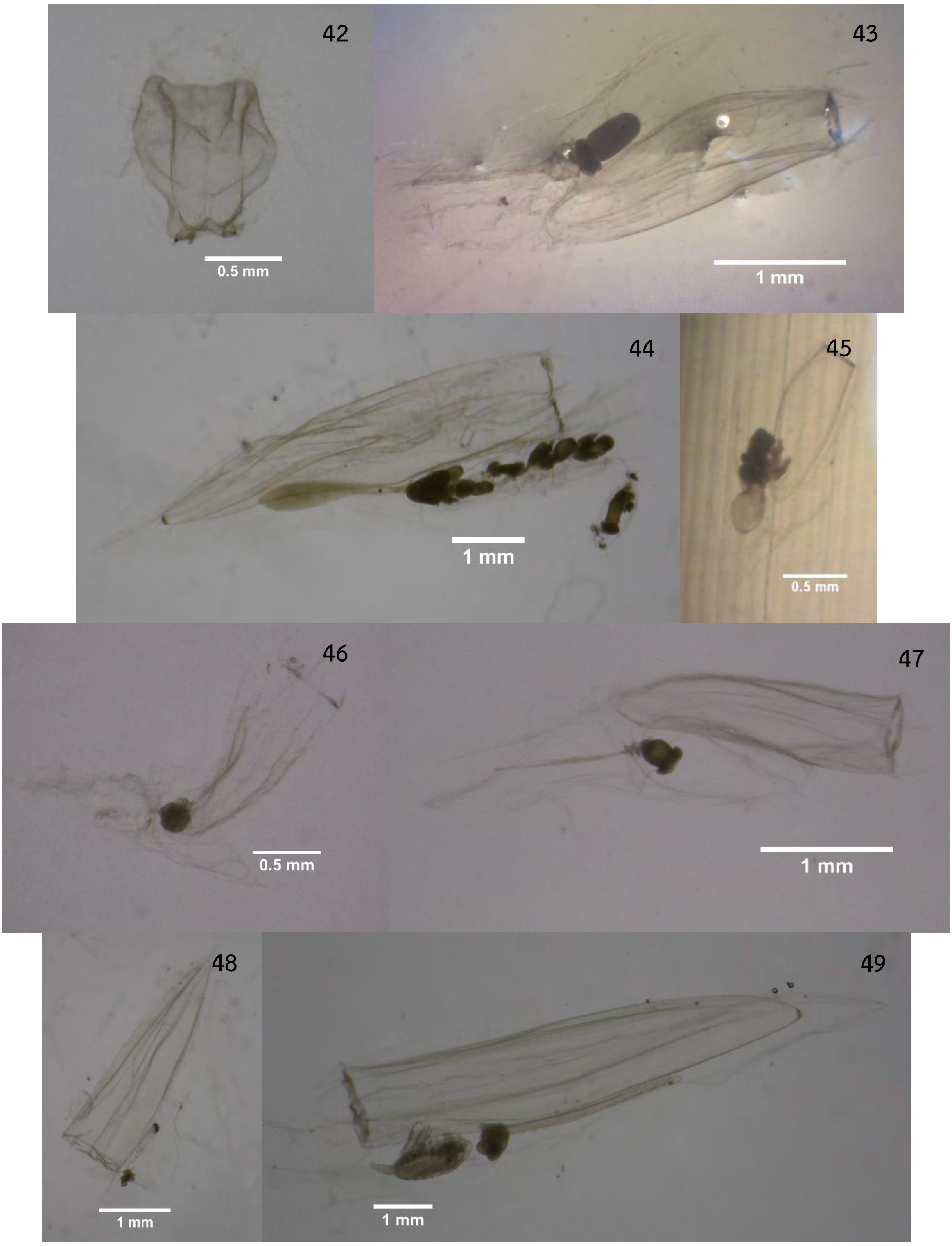
Leptomedusae from this study. 31, *Octophialucium* sp.1. 32, *Octophialucium* sp.2.
33, *Eirene hexanemalis*. 34, *Eirene elliceana*.



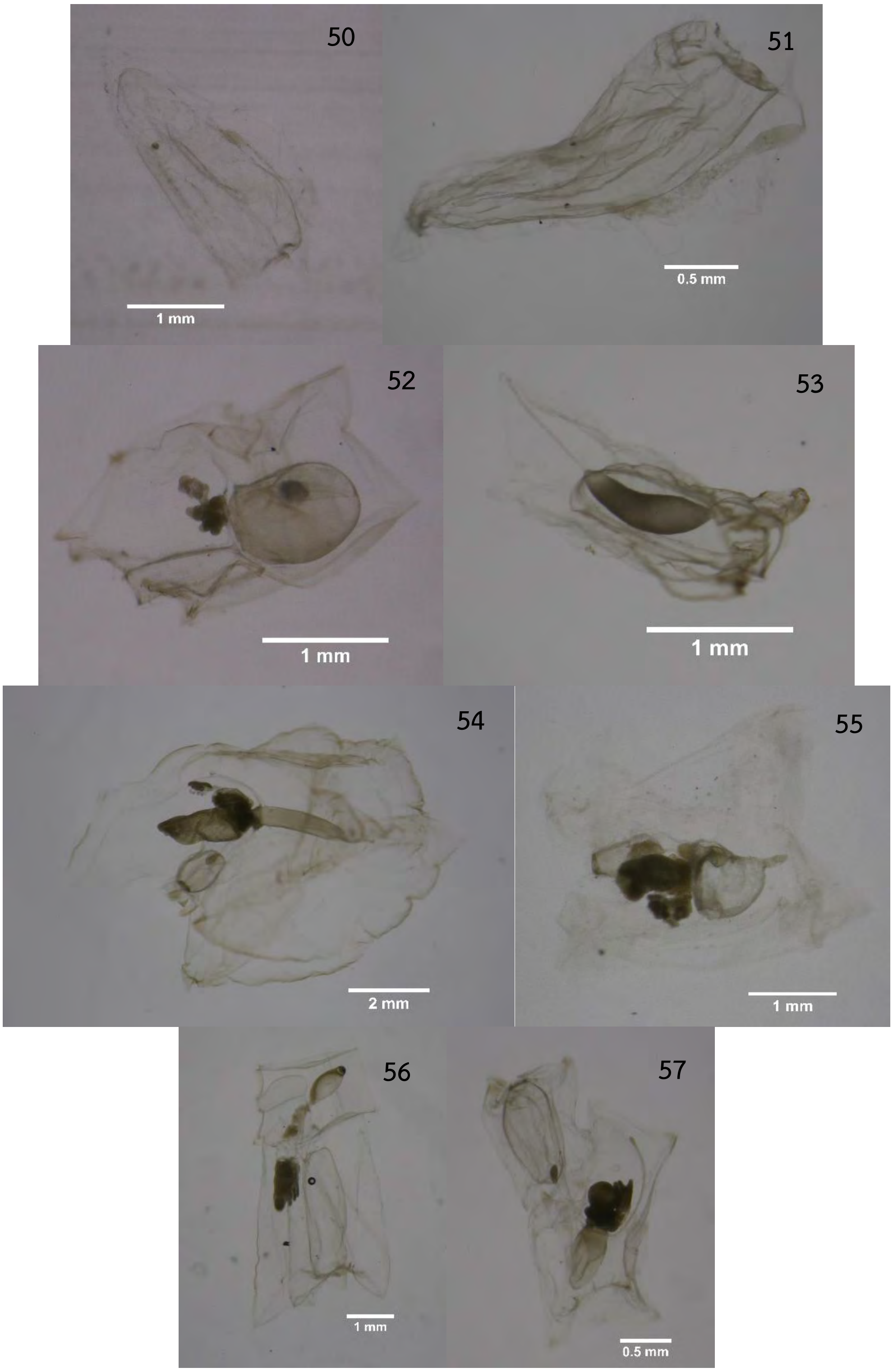
35, Trachymedusa from this study, *Aglaura hemistoma.*
36, Limnomedusa from this study, *Liriope tetraphylla.*



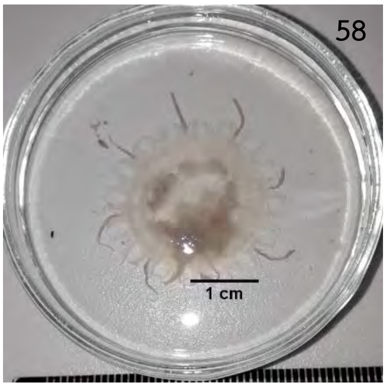
Narcomedusae from this study. 37, Unidentified *(Solmundaeginidae)* sp.1.
38, *Solmundella bitentaculata*. 39, *Cunina octonaria*. 40, *Cunina peregrina*. 41, *Cunina* sp.1.



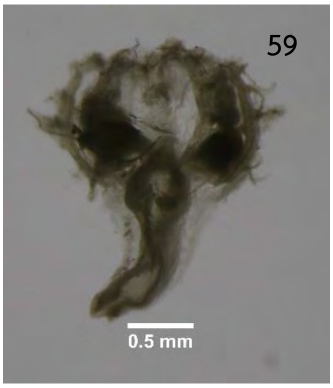
Siphonophore from this study. 42, *Agalma elegans*. 43, *Diphyes bojani*. 44, *Diphyes dispar.* 45, *Diphyes* sp.1. 46, *Diphyes* sp.2. 47, *Diphyes* sp.3. 48, *Lensia meteori.* 49, *Muggiaea atlantica*



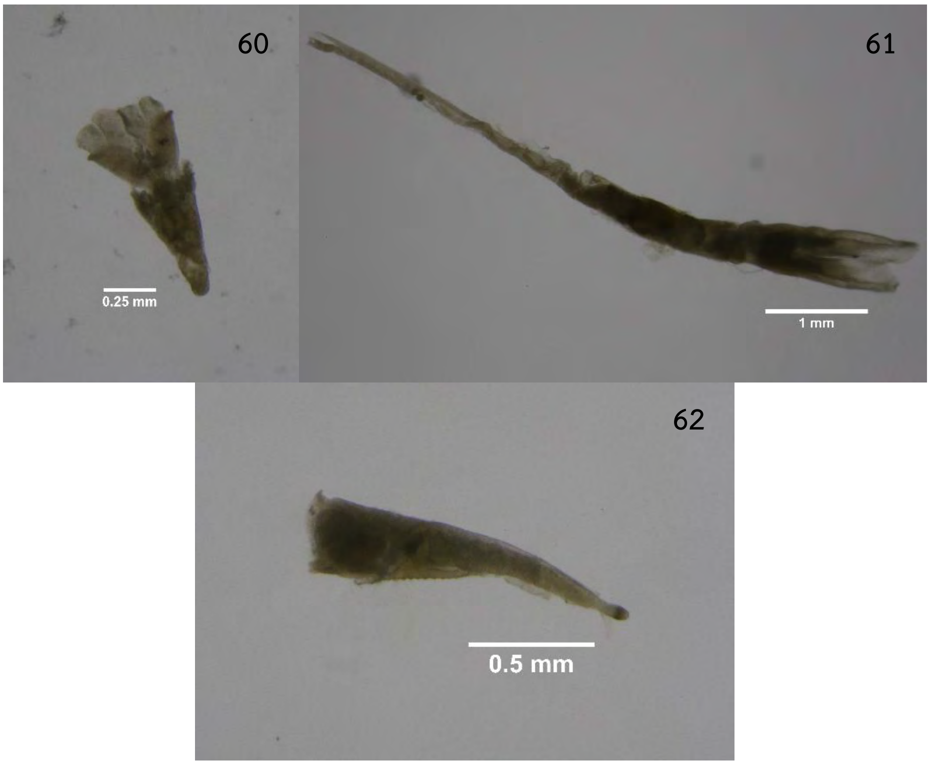
Siphonophore from this study. 50, *Sulculeolaria monoica*. 51, *Sulculeolaria quadrivalvis*. 52, *Abyla haeckeli*. 53, *Abyla trigona*. 54, *Abyla* sp.1. 55, *Abylopsis eschscholtzii*. 56, *Bassia bassensis.* 57, *Enneagonum hyalinum*



58, Scyphozoa from this study, *Pelagia noctiluca.*



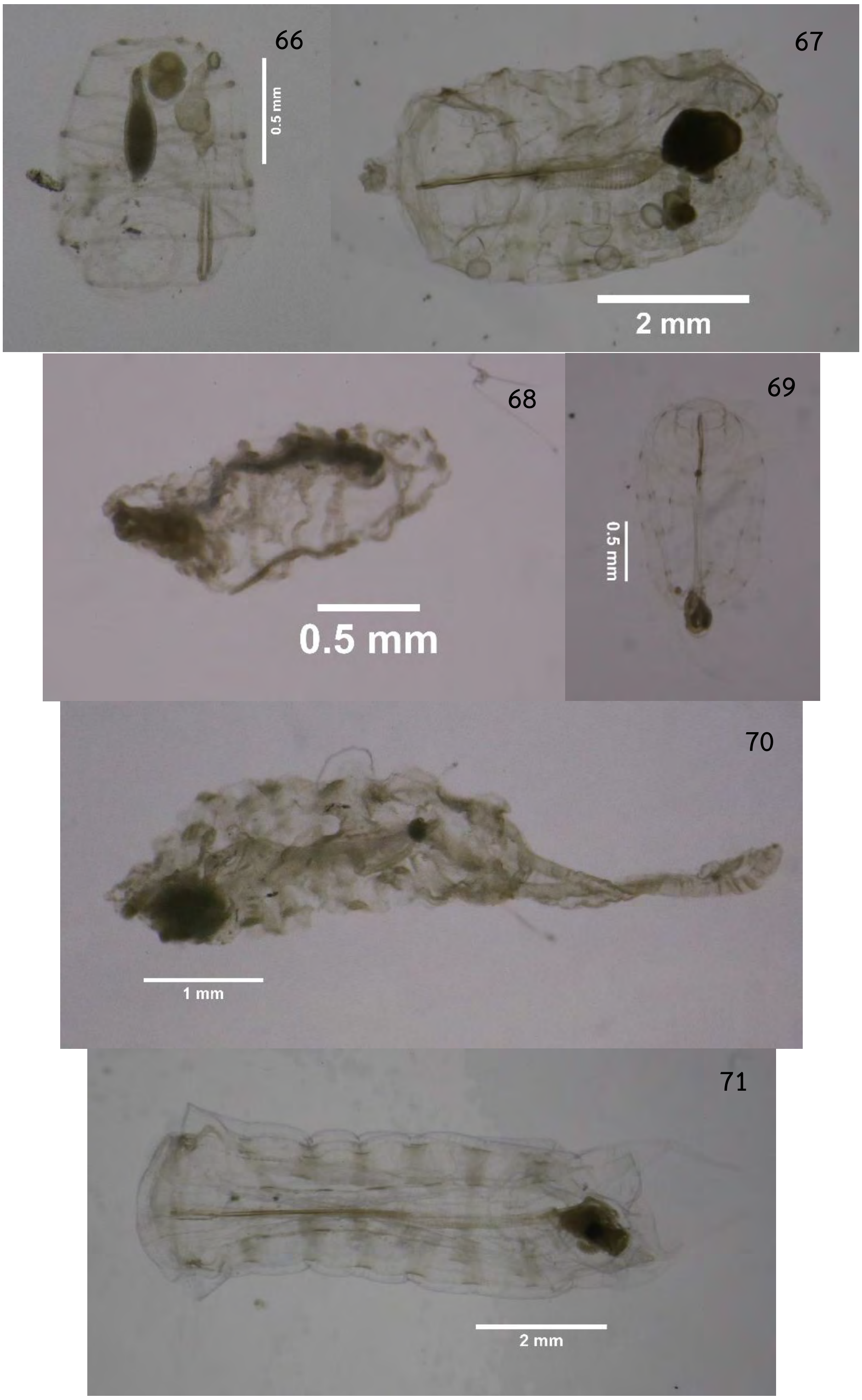
59, Ctenophora from this study, *Hormiphora* sp.1



Molluscs from this study. 60, *Clio pyramidata*. 61, *Creseis acicula.* 62, *Styliola subula.*

63, Annelid from this study, *Tomopteris nationalis.*

Chaetognaths from this study, 64, *Aidanosagitta neglecta*. 65, *Flaccisagitta enflata.*



Thaliacean from this study. 66, *Doliolum nationalis.* 67, *Salpa maxima.* 68, *Salpa* sp.1. 69, *Thalia democratica*. 70, *Salpa* sp.2. 71, *Thalia rhomboides.*

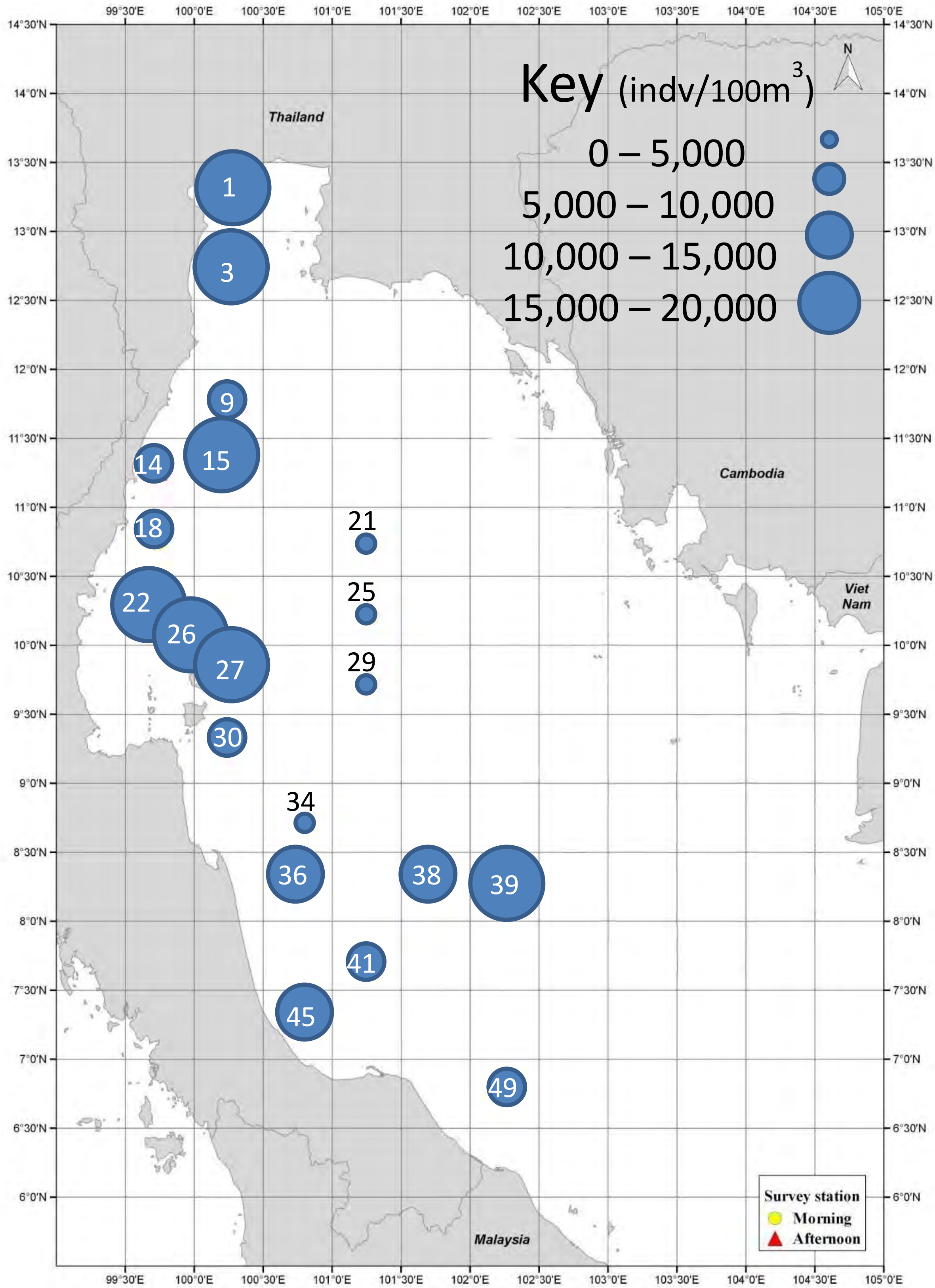
Appendicularian from this study. 72, *Fritillaria pellucida*. 73, *Fritillaria borealis sargassi.* 74, *Oikopleura dioica*. 75, *Oikopleura intermedia*. 76, *Oikopleura longicauda.*

Appendix C Shannon-Weiner Index and Evenness Index for each station in the Gulf of Thailand (GOT).

	Station	Shannon Weiner Index	Evenness
Upper GOT	1	0.92	0.29
	3	1.35	0.45
Middle GOT	9	1.87	0.73
	14	2.55	0.85
	15	2.85	0.86
	18	2.41	0.81
	21	2.15	0.79
	22	2.39	0.75
	25	2.31	0.85
	26	2.28	0.64
	27	1.83	0.57
	29	2.10	0.85
Lower GOT	30	1.95	0.68
	34	2.20	0.81
	36	1.72	0.58
	38	1.96	0.74
	39	2.38	0.80
	41	2.16	0.73
	45	1.83	0.66
	49	2.59	0.81
	Average	2.09	0.71
	Max	2.85	0.86
	Min	0.92	0.29

Appendix D Abundance of GZ in each station in the Gulf of Thailand (individual/m^3)

Station	Hydrozoa	Scyphozoa	Tentaculata	Gastopoda	Polychaeta	Sagittoidae	Thaliacea	Appendicularia	Total Abundance
1	4904	0	0	0	189	13770	93182	1320	113365
3	1415	0	71	0	0	23131	10398	71	35085
9	354	212	0	0	0	3466	283	1768	6083
14	1460	133	0	166	0	1427	896	2455	6536
15	6350	2702	0	1621	0	8917	3378	4053	27022
18	959	354	0	1126	0	2877	480	1189	6985
21	390	496	0	106	0	1311	35	354	2692
22	16754	1197	0	0	0	16275	4547	19626	58399
25	333	222	0	389	0	778	37	519	2278
26	3429	0	111	401	22	9729	445	3607	17745
27	6140	0	65	3723	0	22012	1829	196	33965
29	301	219	0	82	0	356	0	795	1753
30	3050	0	0	161	0	4954	459	1124	9747
34	441	0	0	147	0	1324	184	589	2685
36	1102	485	44	176	0	6040	44	2425	10317
38	669	67	0	1940	0	4347	2341	2876	12239
39	1081	1401	0	801	0	3603	2082	7646	16614
41	1194	140	0	176	0	2494	176	1405	5585
45	1523	0	0	934	0	5994	0	2211	10662
49	1692	38	0	639	0	1843	1316	2369	7897
Total	53542	7667	291	12587	211	134648	122112	56597	387655



Appendix E Total abundance of GZ at each station in the Gulf of Thailand during August until October 2018. The numbers indicate station.