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**FULL NAME**

**Thesis Submitted in Fulfilment of the Requirement for the**

**Doctor of Philosophy of Science**

**in the Institute of Oceanography and Environment**

**Universiti Malaysia Terengganu**

**MAY 2021**



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DEDICATION

*Dedicated this thesis to:*

*My all: Abah & Mak.*

*My anchor throughout the storm & turbulence:*

*Shahrul, Kak Ain, Shahira, Shahila, Shahiqa, Muhammad & Aishah*

*I owe you guys, big time*

*Thanks a lot*

*May Allah bless*

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfillment of the requirements for the degree of Doctor of Philosophy

**TITLE**

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**MAY 2021**

**Main Supervisor : Professor Zainudin Bachok, Ph.D**

**Co-Supervisor : Izwandy Idris, Ph.D**

**School/Institute : Institute of Oceanography and Environment**

Fouling polychaetes from genus *Ficopomatus* are known to give adverse impacts to human activities through fouling on the man-made structures such as ship hulls, seawater intake pipes and aquaculture platforms. Various study on fouling pattern of the fouling species has been done worldwide because some of thespecies are estuarine invaders, thus become a pest to the environment.

.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

**TAJUK**

**NAMA PENUH**

**MEI 2021**

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**Penyelia Bersama : Izwandy Idris, Ph.D**

**Pusat Pengajian/Institut : Institut Oseanografi dan Sekitaran**

Poliket fouling dari genus *Ficopomatus* diketahui memberi kesan buruk kepada aktiviti manusia melalui fouling pada struktur buatan manusia seperti kapal kapal, saluran pengambilan air laut dan platform akuakultur. Pelbagai kajian tentang corak fouling bagi perspex fouling telah dilakukan di seluruh dunia kerana sesetengah perspex adalah penceroboh muara sehingga menjadi perosak kepada alam sekitar.

ACKNOWLEDGEMENTS

Alhamdulillah thanks to Allah S.W.T for giving blessings, good health and strength to complete my study. Millions of thanks to my beloved parents for their understanding, endless love, courage, financial support and everything. My gratitude and special appreciation goes to my supervisor and co-supervisor for their guidelines, advice, support, patience, unlimited creative ideas and constructive criticism. Special thanks to INOS staffs for corresponding sincerely, tolerating with my requests and provide facilities during laboratory work periods to smoothen my journey in completing this study. I would also like to thank my laboratory mates as well as the rest of INOS postgraduate students who helped me in many ways and encouraged me throughout this project. May Allah’s blessings always with them. Thank you

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(External Examiner 2)

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Professor/ Director

Institute of Oceanography and Environment

Universiti Malaysia Terengganu

Date

This thesis has been accepted by the Senate of Universiti Malaysia Terengganu in fulfilment of the requirement for the degree of Master of Science.

**MOHD FADZIL MOHD AKHIR,**

**Ph.D**

Professor/ Director

Institute of Oceanography and Environment

Universiti Malaysia Terengganu

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UMT or other institutions.

FULL NAME

Date:

TABLE OF CONTENTS

|  |  |
| --- | --- |
|  | **Page** |
| **DEDICATION** | ii |
| **ABSTRACT** | iii |
| **ABSTRAK** | iv |
| **ACKNOWLEDGEMENTS** | v |
| **APPROVALS** | vi |
| **DECLARATION** | viii |
| **LIST OF TABLES** | xi |
| **LIST OF FIGURES** | xii |
| **LIST OF ABBREVIATIONS** | xiii |
| **LIST OF FORMULAS** | xix |
| **LIST OF APPENDICES** | xv |
|  |
| **CHAPTER** |  |
| **1** | **INTRODUCTION** | 1 |
|  | 1.1 Background of the Study | 1 |
|  | 1.2 Problem Statement and Justification | 1 |
|  | 1.3 Research Questions | 2 |
|  | 1.3 Objectives | 2 |
|  | 1.4 Hypothesis  | 3 |
|  |  |
| **2** | **LITERATURE REVIEW** | 4 |
|  | 2.1 Fouling Polychaetes | 4 |
|  | 2.2 Family Serpulidae Fafinesque, 1815 | 4 |
|  |  | 2.2.1 Taxonomic Classification | 4 |
|  |  | 2.2.2 Morphology of Serpulids | 5 |
|  |
| **3** | **METHODOLOGY** | 6 |
|  | 3.1 Overview of the Methodology | 6 |
|  | 3.2 Study Location | 6 |
|  | 3.3 Field Sampling | 9 |
|  | 3.4 Data Analysis | 9 |
|  |  |
| **4** | **RESULTS** | 10 |
|  | 4.1 Diversity of Fouling Polychaetes | 10 |
|  | 4.2 Distribution of Fouling Polychaetes | 10 |
|  |  | 4.2.1 Spatial Distribution | 10 |
|  |  | 4.2.2 Temporal Distribution | 11 |
|  |
| **5** | **DISCUSSION** | 12 |
|  | 5.1 Diversity and Distribution of Fouling Polychaetes | 12 |
|  | 5.2 Reproductive Biology and Ecological Resilience of Serpulids | 12 |
|  |  |  |
| **6** | **CONCLUSION AND RECOMMENDATIONS** | 13 |
|  |
| **REFERENCES** | 14 |
| **APPENDICES** | 15 |
| **BIODATA OF AUTHOR** | 17 |

LIST OF TABLES

|  |  |  |
| --- | --- | --- |
| Table |  | **Page** |
| 1.1 | Text should begin here. Text should begin here.  | 5 |
| 2.1 | Text should begin here. Text should begin here.  | 10 |
| 3.1 | Text should begin here. Text should begin here. | 15 |
| 4.1 | Text should begin here. Text should begin here. | 20 |

LIST OF FIGURES

|  |  |  |
| --- | --- | --- |
| Figure |  | **Page** |
| 1.1 | Text should begin here. Text should begin here.  | 5 |
| 2.1 | Text should begin here. Text should begin here.  | 10 |
| 3.1 | Text should begin here. Text should begin here. | 15 |
| 4.1 | Text should begin here. Text should begin here. | 20 |

LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| ANOSIM | Analysis of similarities |
| ANOVA | One-way analysis of variance |
| PRIMER | Plymouth Routines in Multivariate Ecological Research |
| SCS | South China Sea |
| SIMPER | Similarity percentage |
| spp. | species |
| SPSS | Statistical Package for the Social Sciences |
| ° | degree |
| < | less than |
| > | more than |
| % | percentage |
| ± | plus minus |
|  |  |

LIST OF FORMULAS

|  |  |  |
| --- | --- | --- |
| Equation |  | **Page** |
| 1 | Shannon Diversity Index, *H’* =  | 34 |
| 2 | *pi* = | 34 |
| 3 | Pielou’s evenness index, *J’* =  | 34 |

LIST OF APPENDICES

|  |  |  |
| --- | --- | --- |
| Appendix |  | Page |
| 1 | SIMPER analysis from Primer-6 according to group. | 100 |
| 2 | Non-parametric test (diversity index) for fouling polychaete. | 101 |
| 3 | Non-parametric test (evenness index) for fouling polychaete. | 102 |

# INTRODUCTION

## Background of the Study

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

## Problem Statement and Justification

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

## Research Questions

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## Objectives

This study specifically embarks to:-

1. Objective 1
	1. Sub-objective
	2. Sub-objective
2. Objective 2
	1. Sub-objective
	2. Sub-objective
	3. Sub-objective
3. Objective 3
	1. Sub-objective
	2. Sub-objective
	3. Sub-objective
4. Objective 4
	1. Sub-objective
	2. Sub-objective
	3. Sub-objective

## Hypothesis

1. Hypothesis 1
2. Hypothesis 2
3. Hypothesis 3
4. Hypothesis 4
5. Hypothesis 5

# LITERATURE REVIEW

## Fouling Polychaetes

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

## Family Serpulidae Fafinesque, 1815

### Taxonomic Classification

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid).

### Morphology of Serpulids

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

# METHODOLOGY

## Overview of the Methodology

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

## Study Location

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

Table 3.1 Position (latitude and longitude) of 5 sampling stations and vegetation/man-made structure in the lagoon area of Setiu Wetlands. RA: *Rhizophora apiculata*; NF: *Nypa fruticans*; CC: cage culture; ACC: Abounded cage culture; J: Jetty; W: Wharf.

|  |  |  |
| --- | --- | --- |
| **Station** | **Coordinate** | **Vegetation / man-made structure** |
| **Latitude** | **Longitude** |
|  ST 1 | 5°43'00.24"N | 102°40'31.57"E | RA |
| ST 2 | 5°42'38.69"N | 102°40'49.78"E | NF |
| ST 3 | 5°42'06.45"N | 102°41'26.71"E | CC |
| ST 4 | 5°41'42.84"N | 102°41'51.77"E | ACC |
| ST 5 | 5°41'11.32"N | 102°42'22.74"E | W |

Table 3.2 Position (latitude and longitude) of 3 sampling stations.

|  |  |
| --- | --- |
| **Station** | **Coordinate** |
| **Latitude** | **Longitude** |
|  ST 10 | 5°43'00.24"N | 102°40'31.57"E |
| ST 11 | 5°41'42.84"N | 102°41'51.77"E |
| ST 12 | 5°41'11.32"N | 102°42'22.74"E |

Figure 3.1 Sampling stations at the lagoon area of Setiu Wetlands.

## Field Sampling

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013).

Figure 3.2 Fouling polychaete collection on the man-made structure and natural habitat in the lagoon area of Setiu Wetlands.

## Data Analysis

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013).

# RESULTS

## Diversity of Fouling Polychaetes

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013).

## Distribution of Fouling Polychaetes

### Spatial Distribution

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013).

### Temporal Distribution

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013).

# DISCUSSION

## Diversity and Distribution of Fouling Polychaetes

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

## Reproductive Biology and Ecological Resilience of Serpulids

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010).

# CONCLUSION AND RECOMMENDATIONS

The unwanted accumulation of microorganisms, plants, algae and animals on submerged structures is known as fouling (IMO, 2017), which is a global issue happened all over the world. Several example of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes (Bloecher *et al*., 2013). Two types of fouling polychaete are the tubeworms (sabellid and serpulid) and burrowers (spionid and terebellid) but the most important component of fouling community are the serpulids (Lewis, 1982; Madin, 2010; Bloecher *et al*., 2013; Bastida-Zavala *et al*., 2017).

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APPENDICES

Appendix 1

SIMPER analysis from Primer-6 according to group

Appendix 2

Non-parametric test (diversity index) for fouling polychaete

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