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SOME EFFECTS OF SUBSEA WATER PIPELINE CONSTRUCTION ON SESSILE BENTHIC COMMUNITY STRUCTURE OF REDANG ISLAND, MALAYSIA

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By

HAMID REZAI-MARNANI

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Science and Environmental Studies Universiti Putra Malaysia

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He let forth the two seas that meet together.

Between them a barrier they do not overpass.

O which of your Lord's bounties you and you deny?

From them come forth the pearl and the coral...

O which of your Lord's bounties you and you deny?

Lovely as rubies, beautiful as coral-

The *Quran* Chapter 55*, Verses 19...58*

Dedicated to the memory of my father who no longer accompany us on these rocky shores.

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LIST OF ABBREVIATIONS

A	Abundance
AB	Abiotics
AL	Algae
CI	Condition Index
Cs	Jaccard's Coefficient of Similarity
S	Number of Species
DC	Dead Corals
DI	Development Index
HC	Hard Corals
HDPE	High Density Polyethylene
H'	Shannon Diversity Index
LC	Live Corals
Md	Median
NS	Not Significant
OF	Other Fauna
SCUBA	Self Contained Underwater Breathing Apparatus
S_o	Sorting Coefficient
SC	Soft Corals
SI	Succession Index
TSS	Total Suspended Solids

Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the Degree of Master of Science.

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HAMID REZAI-MARNANI

December 1998

Chairman: Professor Mohd.Ibrahim Hj.Mohamed., Ph.D.

Faculty: Faculty of Science and Environmental Studies

A pipeline system, constructed in 1997-1998, to provide water to Redang Island, traverses an area covered with coral reefs. Biological studies were conducted before and following the construction to monitor changes in habitat and biota at selected sites. Pre-construction studies consisted of conducting inventories of predominant marine life, and evaluating sites for their sensitivity to construction, whilst, post-construction studies involved assessment of disturbed areas and monitoring the pattern of re-colonization by marine life. Marine environmental impact associated with the pipeline-crossing was monitored in the vicinity of the Island for one year. Evidence of the pipeline impact was assessed mainly by values concerning the abundance of zoobenthic community (including corals) and species diversity indices. Annelids and Arthropods were the most dominant phyla

numerically during both study periods, being greater in pre-construction period. Student t-test and One-way ANOVA analyses revealed that there was no significant differences between total abundance of sessile macroinvertebrates during pre and post-construction periods. Student t-test revealed a significant difference between the means of live coral coverage during pre and post-construction periods. There was no apparent change in total number of macro-invertebrates as a result of pipeline construction. Results indicated that impacts arising from marine-crossing were short-term and non-residual.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi syarat untuk mendapat ijazah Master Sains

BEBERAPA KESAN PEMBINAAN SALURAN PAIP DASAR LAUT KEATAS STRUKTUR KOMUNITI SESIL BENTIK DI PULAU REDANG, MALAYSIA

OLEH

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Satu sistem saluran paip telah dibina pada 1997-1998, untuk membekalkan air ke Pulau Redang, merentangi satu kawasan yang diliputi oleh terumbu karang. Kajian biologi telah dijalankan sebelum dan selepas pembinaan untuk memerhati perubahan di dalam habitat dan biota pada lokasi yang dipilih. Kajian pra-pembinaan merangkumi penentuan inventori hidupan marin yang paling dominan dan menilai sensitiviti tapak-tapak kepada pembinaan, sementara, kajian selepas pembinaan melibatkan penilaian kawasan tapak yang terganggu dan pemerhatian corak pengkolonisasi semula hidupan marin. Kesan persekitaran marin berhubung saluran paip telah diperhatikan di sekitar pulau tersebut selama setahun. Bukti kesan saluran paip tersebut telah dinilai terutamanya dengan nilai-tapak yang melibatkan kehadiran komuniti zoobentik dengan banyaknya (termasuk karang) dan indeks kepelbagaian spesis. Annelida dan Arthropoda adalah filum yang paling

banyak pada masa sebelum pembinaan. Ujian 'student-t' dan analisis ANOVA sehala menunjukan bahawa tidak terdapat perbezaan yang bermakna di antara jumlah kehadiran sesil makroinvertebrat sebelum dan selepas masa pembinaan. Ujian 'student-t' menunjukkan bahawa terdapatnya perbezaan yang kuat di antara purata karang hidup pada masa sebelum dan selepas pembinaan. Tidak terdapat perubahan yang jelas dalam jumlah keseluruhan makroinvertebrat akibat daripada pembinaan saluran paip. Keputusan menunjukkan bahawa kesan daripada laluan paip marin bersifat jangka pendek dan tidak berpanjangan.

CHAPTER I

INTRODUCTION

The construction of Redang Island's subsea water pipeline from Penarik to Redang Island, Terengganu, offered an opportunity to monitor and determine the effects of pipeline construction on benthic macroinvertebrate communities of Redang Island.

The Redang submarine water pipeline project will supply water from Penarik in Setiu to Redang Island, a distance of about 28 km. The project, would enable residents as well as Island's hospitality industry at Redang Island to receive fresh water supply from the mainland via the high density polyethylene submarine pipeline. It can supply one million gallons of fresh water per day (Anon, 1997). But based on the current need, only 400,000 gallons will be supplied.

Coral reefs and their associated marine life are one of the greatest natural treasure of Redang Island. Both their quality and quantity are impressive. Coral reefs form the core of the livelihood for hundreds of Redang subsistence fishermen. Redang Island is known for its crystal clear blue water and rich diversity of beautiful corals and associated ecosystem that fringe the smaller peripheral islands.

Not only are the coral reefs a source of food, but also provide a natural barrier against wave erosion, thereby protecting coastal dwellings, and tourism beaches. They are a potential source of foreign exchange from divers and other marine tourists. In addition, because of their unique biodiversity, they are of great interest to scientists, students, pharmaceutical companies, and others. These and many other functions give coral reef an important and growing value (Erdman and Pet-Soede, 1996). The pathway in which the pipeline system traverses is an area covered with coral reefs and possibly undulations along ridges resulting in widely varying water depths. Hence, the corals are vulnerable to physical destruction caused by the pipeline construction.

The gazetting of Redang Island as a Fisheries Protected Area in 1988 as a precursor to its subsequent gazetting as a Marine Park in 1994 has brought about tremendous development for this island famous for her crystal clear waters and beautiful unexploited coral reef gardens.

Background of the Study

Previously, several studies have been undertaken on Redang Island. These include a general survey carried out (Green, 1978: Green *et al.*, 1979) under the auspices of WWF Malaysia. Coral mapping with the aide of remotely sensed imagery was completed by Schwamborn (1993). The area was briefly investigated by White (1986) and De Silva (1979) reported the destruction some reefs by the Crown-of-Thorn sea star, *Acanthaster planci*. Othman *et al.* (1990) studied the soft bottom communities of Redang Island and gave a detailed account of the benthos in the area.

Those studies by Ibrahim *et al.* (1992,1993), and more recently Japar *et al.* (1997) were concerned primarily on monitoring the coastal environment related to the development of Redang Island. The latter authors reported that the decrease in live coral cover in some of their sites may have been attributed to several factors resulting from human activities including landfilling, dredging, boating, shipping, anchor damage, diver-related damage and natural phenomena such as crown-of-thorns attack and invasion of macroalgae growth. These studies brought about some light to the pollution effects due to the development of the Island.

There have been few publications on the effects of subsea pipeline to the benthic communities. Such examples were those of the North Sea. Most of these studies concentrated on the effects of oil/gas pipeline on marine communities. These include studies by De Groot (1982), Haldane (1992), Pranesh and Kumar (1993), Tillinghast *et al.* (1987), and the work of Tsui and McCart (1981). These studies had revealed short term and long-term damages to the marine benthic communities, and consequently to the fisheries.

Importance of the Study

The construction of a freshwater pipeline made from HDPE (high density polyethylene) and its impact on benthic community is one of its kind in Malaysia. However, benthic communities may respond differently to the disturbances in tropical waters where there are far more hard coral assemblages than in the temperate regions. The study of the effects of subsea pipeline construction is important because at present there is no record on the physical and mechanical disturbances to the benthic community in Redang Island.

Some habitat disturbances due to the construction was anticipated but whether these disturbances could affect the corals in the short and long term, and their impacts on other benthic lifeforms remains to be seen. This study highlights the importance of benthic communities as tool to monitor the effects of pipeline construction.

Benthic Invertebrates as Monitoring Tool

Benthic invertebrate community structure is an important tool for evaluating ecosystem stress induced by anthropogenic perturbations. The benthic invertebrates were chosen due to their important role in the food chain and rapid responses to changes in physical and chemical environments, such as the potential impact of pipeline construction and operation on the Island. The benthos may serve as food for some fish, which again attract larger fishes.

In terms of output, percentage cover of live and dead coral cannot provide more than a significant outlook of reef status. From an economic point of view, the data collection in this study takes a significant amount of time and money , but only a small part of this information is used for management. Therefore, a more efficient way is to use what are required, or try to maximize the use of the present information at its full potential.

The status of a reef does not only depend on how much coral or the amount of live and dead coral but needs to include the other components of the reef. In fact, sand and other components can contribute to the status of the reef. The use of live and dead coral data may be limited or could mislead the management decision (Manthachitra, 1994).

Objectives

Since the laying of a pipeline can induce a significant impact upon its surrounding environment, the purpose of this study was to determine the effect of water pipeline construction on:

(i) the changes in benthic macroinvertebrate community structure following construction

(ii) the effects of construction on coral community

(iii) the colonization of the pipeline by the benthos after the construction.

The aim of reef monitoring was to determine the health of reef and to monitor changes in these reefs after the pipeline construction. Healthy reefs are generally able to survive natural stress, while unhealthy reefs are more likely to suffer cumulative degradation and a possible reduction in species diversity and density.

CHAPTER II

LITERATURE REVIEW

From the beginning of the oil and gas exploration in the North Sea, the impact of offshore installation, especially pipelines, on the fishery has been thoroughly discussed and investigated (MacLennan and Strange, 1979; Moshagen and Kjeldsen, 1980; Lange, 1995). De Groot (1982) gives a comprehensive review of the impact of laying of offshore pipelines on the marine environment and the North Sea Fisheries.

Submarine pipelines are used for the marine transportation of oil, water and gas from offshore places to the mainland or visa versa. These pipelines are laid on the seabed with soil support on the route selected after surveying. The uneven surface areas such as rocky outcrops are covered by the sediments, which are transported from one place to another.

These pipelines are placed either to rest directly on the seabed or in a trench or on saddles depending on the bottom topography of the seabed along their routes. When placed in a hostile environment such as the oceans, the pipelines are subjected to various environmental loads due to waves, currents, etc. It has been established by many researchers in the area of wave-pipeline interaction problem that the effect of the gap between the pipeline and ocean bottom would play a dominant role in the evaluation of the hydrodynamic forces on marine pipelines (Subbiah *et al.*, 1990).

Laying of Submarine Pipelines

Various methods are available to lay pipelines at sea. The following methods are the most used, the bottom-pull method, the lay-barge method and the reel-barge method (Lous, 1978). In Redang Island, the lay-barge method was used. The lay-barge or semi-submersible acts as a pipeline factory where the pipe sections are welded together at welding stations, X-rayed and the joints coated. Each time a section of pipe is completely added to the pipeline, the anchored barge pulls itself ahead with its anchor winches. With this method pipelines can be laid at depths to about 200 m (De Groot, 1982). If the pipe is properly laid, it will rest on a flat bottom without residual curvature due to yielding. Carstens (1980) and Richardson (1980) reviewed experiences from the contractor's point of view with the navigation and positioning of lay-barges (semi-submersibles) in the northern North Sea from 1975 to 1979.

In due course the corrosion or scouring of the sea floor which supports the pipeline will take place leading to the loss of support and thereby some parts of pipeline are made to rest on the elevated obstructions. This causes additional stresses in the pipeline depending on site conditions such as height of obstruction, pipeline span, the unsupported span, and the soil properties (Pranesh and Johnson, 1993).

Pipeline Burial

Submarine pipelines are generally buried to provide greater assurance of protection against the forces in the surf zone, the hazards of ship anchors and general sea bottom environment. However, this procedure is not always feasible particularly on a moveable seabed (Ozturk *et al.*, 1994). Pipelines laid in trenches should be backfilled with suitable materials, rather than relying on natural processes to provide sediment cover (Herbich, 1981). When a pipeline trench is formed by a plough, soil spoils are formed on either side of the trench. Backfill blades are attached to the plough, which when redeployed and towed along the trench, guide the spoil back into the pre-cut trench and covers the pipeline (Haldane *et al.*, 1992). The actual depth of burial depends on several factors, including storm frequency, sediment erosion, and environmental consequences of pipeline failures.

In depths of less than 61 m, the pipeline is usually laid in a trench of 0.9 m deep unless it is in area congested with pipelines, or the bottom is rocky and the disturbance due to trenching is expected to be greater than laying the pipe on the surface with some rip rap cover (Boesch and Robilliard, 1990). Trenching is accomplished by hydraulic jetting or cutting a trench under the pipe after it has been laid on the seafloor. Typically the trench is not backfilled by the operators, but will usually fill up with sediment due to wave and sediment action. As water depth increases, natural backfilling may not occur as fast because of the decrease in the influence of surface waves and bottom current velocity (Anon, 1983)

If shore approaches are coral or solid rock, a trench can be blasted through the wave breaking zone to provide lateral stability and protection from floating