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ESRF-025/047
EFFECTS OF PIPELINES/GATHERING LINES ON SNOW CRAB AND LOBSTER

FINAL REPORT

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PROPRIETARY NOTICE

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EXECUTIVE SUMMARY

After completion of the ExxonMobil natural gas pipeline, the fishing community in the vicinity of the pipeline landfall in Goldboro, Nova Scotia, expressed concern that lobster may either avoid the pipeline region or exhibit other behavioural changes resulting from its presence, and therefore affect the catch. This study was initiated to address this overall concern with the implementation of four main study components: a) field studies to measure underwater noise in the region possibly associated with the operational gas pipeline; b) determination of the electromagnetic (EM) fields generated by the presence of a pipeline in the region with creation of a numerical model for results presentation; c) a lobster catch-and-release field program to measure the catch of lobster - concentrating sampling around the Goldboro pipeline landfall and using two reference sites; and d) a separate lab-based study to determine the scaling/climbing ability of lobsters over simulated 32” and 48” (external diameter) gas pipelines with simulated smooth and rough surface texture protective coatings. The ExxonMobil pipeline is buried in the nearshore but offshore sections are either partially or fully exposed above the seafloor. Lab-based scaling experiments, using two diameters of pipeline representing both present and proposed pipeline installations, were conducted to study the potential effects of unburied pipelines creating a barrier to lobster movement.

The results are:

- The acoustic surveys conducted in July and November 2003 show peaks (tonals) of low frequency sound (34, 41, 50, 67, 84 and 100 Hz – within the hearing range of lobster) in the vicinity of the pipeline. These tonals were measured at least 200 m on either side of the pipeline but not at the three reference sites which were between two and two and half kilometres distant (located on both sides of the pipeline).

- The electromagnetic survey and resulting numerical model indicates that the pipeline creates a very narrow magnetic field that affects an area only two to three metres wide on either side of the pipeline. This field produces a field strength up to one third (1/3) as strong as that of the earth’s background magnetic field.

- The lobster “catch and release” study program showed no statistically significant variation of catches between the pipeline locale and the two reference sites.

Thus, while there is a clearly measurable low intensity, but highly localized, magnetic field about the pipeline (extending some two to three metres outwards) and the acoustic measurements show low frequency tonals (within the hearing range of lobster) that appear to emanate from the pipeline, the buried pipeline in Goldboro had no effect on the experimental lobster catch near the pipeline as compared to the reference sites.

The ability of lobsters to successfully scale an exposed undersea pipeline structure was studied as a function of pipeline diameter, exposure height above the seafloor and the surface roughness of the outer protective coating. In the laboratory testing, a rough surface outer protection coating was found to be a clear advantage in scaling ability as compared to a smooth surface coating and is particularly evident at pipelines which are more than half exposed. Overall the 32” diameter pipeline was more readily scaled than the 48” diameter pipeline. At up to ½ height exposure, with a rough surface coating, both the 32” and 48” pipeline were quite readily scaleable. Testing of the smooth surfaces showed that the 32” pipeline was readily scaleable at up to ½ height exposure but the 48” smooth surface testing indicated difficulties at the ½ height exposure.

SOMMAIRE

Après l'achèvement du gazoduc d'ExxonMobil, la communauté de pêcheurs située à proximité du point d'arrivée à terre de Goldboro, en Nouvelle-Écosse, s'est montrée préoccupée par le fait que les homards puissent soit éviter la région du gazoduc, soit adopter de nouveaux comportements qui, en bout de ligne, auraient une incidence sur les prises. La présente étude traite de cette préoccupation d'ordre général par l'entremise de quatre composantes principales : a) études sur le terrain pour mesurer le bruit sous-marin éventuellement associé à l'exploitation du gazoduc dans la région; b) détermination des champs électromagnétiques produits par le gazoduc et création d'un modèle numérique pour présenter les résultats; c) programme de remise à l'eau des homards pour évaluer les prises (concentration de l'échantillonnage autour du point d'arrivée à terre, à Goldboro, et à deux sites de référence); d) étude distincte en laboratoire pour déterminer la capacité des homards à franchir des conduites de 32 pouces et de 48 pouces (diamètre extérieur) revêtues d'un enduit protecteur à surface lisse ou rugueuse. Le gazoduc d'ExxonMobil est enterré dans le littoral, mais des sections au large émergent partiellement ou entièrement du plancher océanique. On a mené des expériences de franchissement en laboratoire avec des conduites de deux diamètres différents (qui représentent à la fois le gazoduc actuel et celui qui est proposé) afin d'étudier si l'exposition du gazoduc entravait les mouvements des homards.

Les résultats sont les suivants.

- Les relevés acoustiques menés en juillet et en novembre 2003 montrent des crêtes tonales basse fréquence (34, 41, 50, 67, 84 et 100 hertz – fréquences audibles par le homard) à proximité du gazoduc. Ces niveaux de bruit ont été mesurés à au moins 200 m de chaque côté du gazoduc, mais non aux trois sites de référence qui étaient situés de deux à deux kilomètres et demi de chaque côté du gazoduc.

- Le relevé électromagnétique et le modèle numérique connexe indiquent que le gazoduc crée un champ magnétique très étroit qui irradie sur une zone de seulement deux à trois mètres de part et d'autre du gazoduc. L'intensité du champ équivaut au tiers (maximum) de celui du champ magnétique naturel de la Terre.

- Le programme de remise à l'eau des homards n'a révélé aucun écart statistique important des prises entre la région du gazoduc et les deux sites de référence.

En conséquence, bien qu'on détecte clairement un champ magnétique de faible intensité, mais fortement concentré autour du gazoduc (qui irradie jusqu'à environ deux à trois mètres), et que les mesures acoustiques révèlent des basses fréquences audibles par le homard qui semblent provenir du gazoduc, la section du gazoduc enfouie à Goldboro n'a pas eu d'effet sur les prises de homards, en comparaison avec les prises constatées aux sites de référence.

La capacité des homards à franchir avec succès une conduite sous-marine exposée a été étudiée en fonction du diamètre, de la hauteur au-dessus du plancher océanique et de la rugosité de l'enduit protecteur de la conduite. Au cours de l'essai en laboratoire, on a constaté qu'un enduit rugueux facilitait le franchissement par rapport à un enduit lisse, et ce, particulièrement dans le cas des conduites à demi enfouies. De façon générale, la conduite de 32 pouces de diamètre était plus aisément franchissable que la conduite de 48 pouces. Jusqu'à un enfouissement à mi-hauteur, les conduites de 32 pouces et de 48 pouces de diamètre dont la surface était rugueuse ont été assez faciles à franchir. L'essai avec des surfaces lisses montre que la conduite de 32 pouces était facile à franchir jusqu'à un enfouissement à mi-hauteur, mais que dans les mêmes conditions, la conduite de 48 pouces était difficile à franchir.

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1.0 INTRODUCTION

The lobster industry is a valuable commercial fishery in the nearshore waters in the Goldboro, Nova Scotia area where they are fished in shallow, rocky bottoms usually associated with kelp beds. Five local lobster fishermen use this immediate area where the ExxonMobil (formally Sable Offshore Energy Incorporated ~ SOEI) Sable Offshore Energy Project pipeline makes landfall.

After completion of the natural gas pipeline, the Goldboro fishing community expressed concern that lobster may either avoid the pipeline or exhibit other behavioural changes resulting from it, affecting catch. This study was aimed at addressing this concern.

A recent research paper (Pye and Watson, 2004) has concluded that immature lobsters can detect sounds in the range of 20–1000 Hz while sexually mature lobsters exhibit two distinct peaks in their acoustic sensitivity (20–300 Hz and 1000–5000 Hz). Lobsters produce a buzzing vibration when grasped with larger lobsters (120–149 mm in carapace length) vibrating most consistently. The greater tendency for sound production in the larger lobsters may indicate a role in mating behavior. Prior to study commencement, a preliminary calculation indicated that the ExxonMobil gas pipeline might be capable of emitting low frequency sounds given its size and gas pressures/flow rates.

Lohmann et al. (1995), suggest that spiny lobsters (*Panulinus* sp.) are able to determine their location via the Earth's magnetic fields and may migrate using this ability. Although the spiny lobster is considered a distant relative of the American lobster (*Homarus americanus*) this discovery was deemed of interest to this study. To the best of our knowledge this type of research has not been carried out with the American lobster but provided the impetus behind the electromagnetic studies.

The overall study is comprised of four main study areas:

1. An acoustic survey in the region of the marine pipeline to establish pipeline emitted sounds.

2. A survey in the region of the marine pipeline to establish the electromagnetic (EM) signatures. A numerical model of the field strengths was created based on the field measurements to facilitate interpretation of the results.

3. A lobster catch study for the pipeline landfall and two reference sites in Country Harbour.

4. A laboratory program examining whether lobster can scale a simulated 32" and 48" pipeline with 'rough' and 'smooth' surface textures. These mobility experiments, more directly related to unburied pipelines, were deemed to be important to the overall objectives of the study, i.e. the effects of pipelines on lobster, particularly with other Nova Scotia proposed offshore pipelines in the planning stages.

Finally, this report combines both the first and second funding phases of the overall study into one cohesive document. For the purpose of record, the second phase permitted further lobster scalability testing using the larger 48” mock-up pipeline and measurement of a second set of electromagnetic and acoustic field data. The second set of EM measurements permitted generation of a numerical simulation model to better understand the EM fields.

The overall report format is designed to be understandable to the layman reader and presents the study and outcomes in a straightforward manner. The more technical aspects of the study have been included as appendices for the reader who wishes to examine the study in more detail.

2.0 OBJECTIVES

The objectives of the project were to study the effect of operational pipelines/gathering lines on the lobster fishery. As per study specifications, we were seeking to answer the following global questions:

- Does an operational gas pipeline cause lobsters to avoid the area near the pipeline?
- Is the catch of lobsters reduced near the gas pipeline?
- Does the pipeline modify behaviour so that catch decreases? If so, what might cause this movement or behavioural change (heat, noise/vibration, electromagnetic or other)?
- What is the potential for an unburied gas pipeline to pose a barrier to the movement of lobster or snow crab and is there potential for any resultant effect on a population and the fishery?

The first three questions were targeted by studies including three different field measurement programs in the vicinity of the ExxonMobil submarine pipeline while the latter involved a laboratory study of lobster climbing behavior near exposed simulated pipelines in a controlled/tank environment.

2.1 STUDY LOCATIONS

As mentioned previously, the existing Sable Offshore Energy Project (SOEP) marine pipeline from the Sable Island region passes through Country Harbour to a landfall near Goldboro, Nova Scotia (see Figure 2-1 below). The fieldwork was carried out in Country Harbour concentrating in the nearshore pipeline route (from shoreline out to a distance of approximately 1 kilometre). The laboratory work, examining lobster scaling/climbing capabilities over a mock-up pipeline, was conducted in a large tank facility in the biology department at St. Francis Xavier University, Antigonish, Nova Scotia.

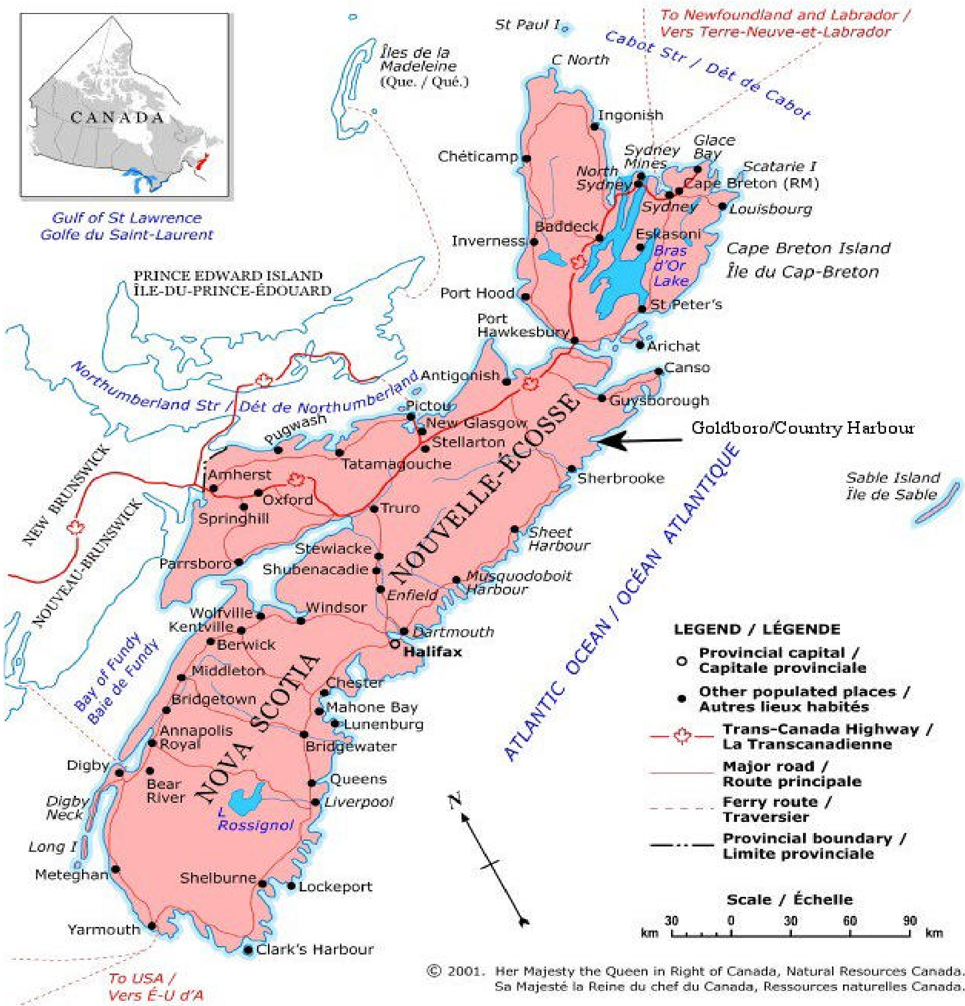


Figure 2.1: Illustration of Goldboro/Country Harbour in Relation to the Province of Nova Scotia

This map was taken from The Atlas of Canada web site. http://atlas.gc.ca

Original produced in full colour.

3.0 FIELD PROGRAM SCHEDULE AND RELATED BACKGROUND DATA

3.1 FIELD PROGRAM SCHEDULES

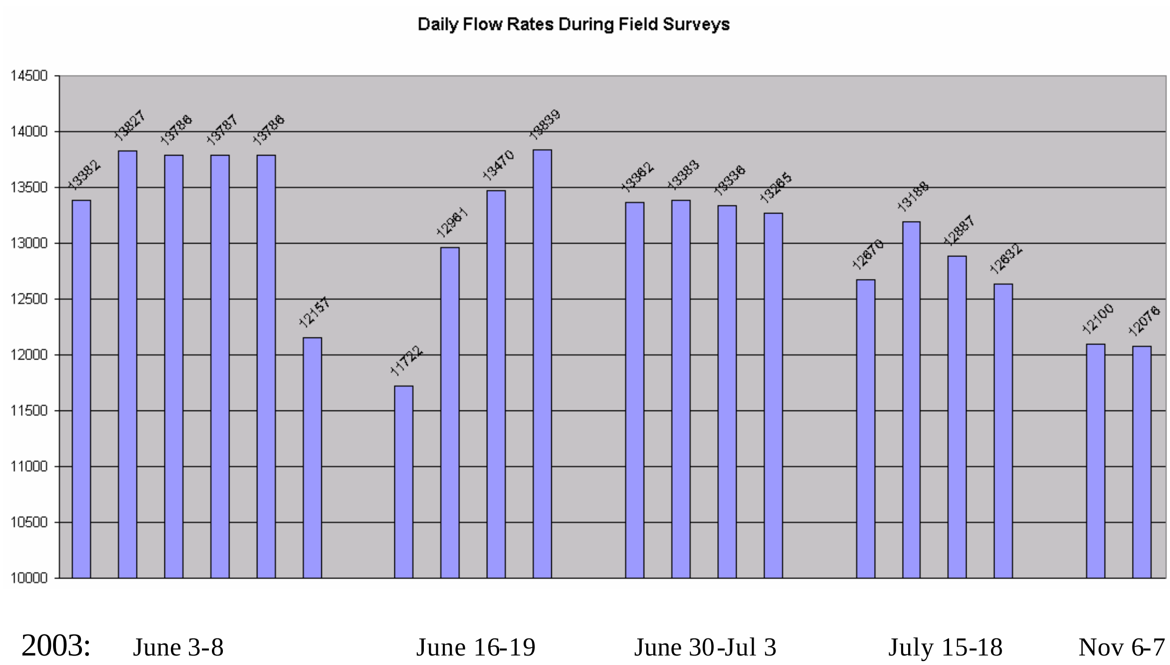
Three trapping periods were used to gather the lobster catch data, two within the regular lobster season [Canadian Department of Fisheries and Oceans area 31B, (which includes the study area) which extended from April 19 to June 20 in 2003], and one outside this period to avoid potential competition from regular traps set in the locale. The acoustics and magnetic surveys were carried out after the lobster trapping periods, because of logistical concerns and the towed/submerged field equipment interfering (entanglement with the lobster gear) with the lobster trapping programs.

The field program dates were:

Date (2003)	Field Program	Comments
June 3 – June 8	Lobster I	In Season
June 16 – June 19	Lobster II	In Season
June 30 – July 3	Lobster III	Out of Season
July 15 – July 18	Acoustics and Magnetics I	Out of Season
Nov 6 and Nov 7	Acoustics and Magnetics II	Out of Season

3.2 FLOW RATES

The pipeline flow data, courtesy of ExxonMobil Canada Corporation, is shown below (see Figure 3.1) for the periods of the field programs. According to ExxonMobil sources, these are typical of the daily flow rates of the pipeline.



Average Flow Rate During Fieldwork Days = 13.1E6 M^3/Day, St. Dev. = 655E6 M^3/Day

Figure 3.1: Average Flow Rate During Fieldwork Days

3.3 TEMPERATURE

A temperature gauge was placed inside one of the lobster traps during each of the three lobster catch study periods. Temperatures ranged from approximately three to six degrees Celsius during the first catch period (early June) and six to ten degrees in the second and third study periods (mid-June and early July, respectively).

Plots of the temperature data are included in Appendix A.

4.0 ACOUSTIC SURVEYS

4.1 INTRODUCTION

Two acoustic surveys were performed as part of the study to establish whether the pipeline emits significant above-ambient noise. Ambient underwater noise related to wind is caused primarily by wave action and spray with the level of wind-generated noise influenced by many factors including speed, fetch, duration, water depths, seafloor topography, and the proximity to the coastline. Wind is the major contributor to noise between ~100Hz and 30kHz, while wave generated noise is a significant contributor in the range of 1 to 20Hz (which is below the normal human hearing range). Surf noise is specific to coastal locations. Combined wind and wave generated noise covers a broadband range of 1Hz to 7kHz. As mentioned earlier lobsters can detect sounds in the range of 20–5000 Hz well within the frequencies of natural occurring sound.

The first survey was conducted in July 2003 and involved deploying a tripod-mounted hydrophone to perform noise measurements in locations both close to and remote from the pipeline to determine if the pipeline produces significant above-ambient noise.

The second survey was performed in November 2003, in the same time period as the second electromagnetic survey (see Section 5), and was used to provide further insight into the findings from the first survey.

Summary results from the combined acoustic surveys are presented in this section, with complete documentation included as Appendix B.

4.2 METHODOLOGY

In the first survey, a hydrophone mounted in a tripod assembly (see Figure 4.3) was lowered to the seafloor at the twenty-five locations as shown in Figure 4.1 and data recorded at each site for subsequent analysis. During these spot measurements, the data sets collected were typically for a one-minute duration.

In the second survey two hydrophone assemblies were lowered into the water at locations shown in Figure 4.2. Shore-based stations were used to record the data. Unfortunately, weather curtailed the desired 6-hour planned deployment to approximately 1½ hours. Nonetheless, sufficient data was gathered to support the findings of the first survey (see Appendix B).

4.3 PRINCIPAL RESULTS (COMBINED SURVEYS)

Sound levels were recorded at various frequency ranges from 0-200 Hz to 0-12800 Hz with efforts focusing on the lower frequencies where gas pipeline noise might be expected. Baseline measurements taken at locations both away from and near to the pipeline showed varying results. There was no clear trend with respect to sound level for the highest frequency bands, however, there did appear to be a significant sound level increase in the 0-400 Hz range along with the appearance of some tonal lines (peaks in sound level at discrete frequencies). Further examination of points both along the pipeline and perpendicular to the pipeline showed little correlation between sound levels and distance from the pipeline. Analysis of the lower frequency ranges did show the presence of several tones, which were not readily visible at the reference sites. These tones occurred at 34 Hz, 41 Hz, 50 Hz, 67 Hz, 84 Hz, and 100 Hz. It is presumed that these tones were a result of flow in the pipeline.

Following a close review of the measurements made in the frequency range 0 – 200Hz, it was evident that at the two reference sites the tones were not particularly visible, while they are clearly visible at all transect locations across the pipeline. This was a strong indication that the tones originated in the pipeline.

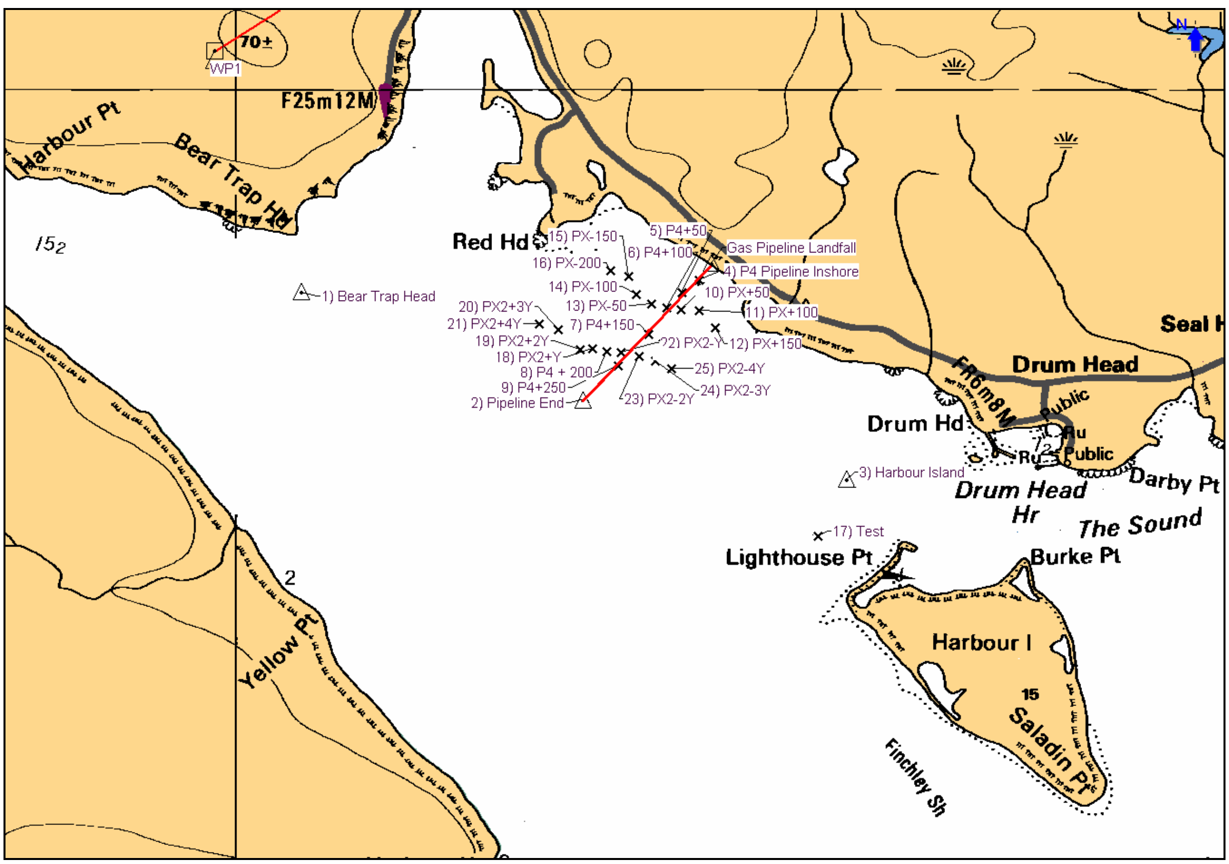


Figure 4.1: First Acoustic Field Survey Measurement Locations

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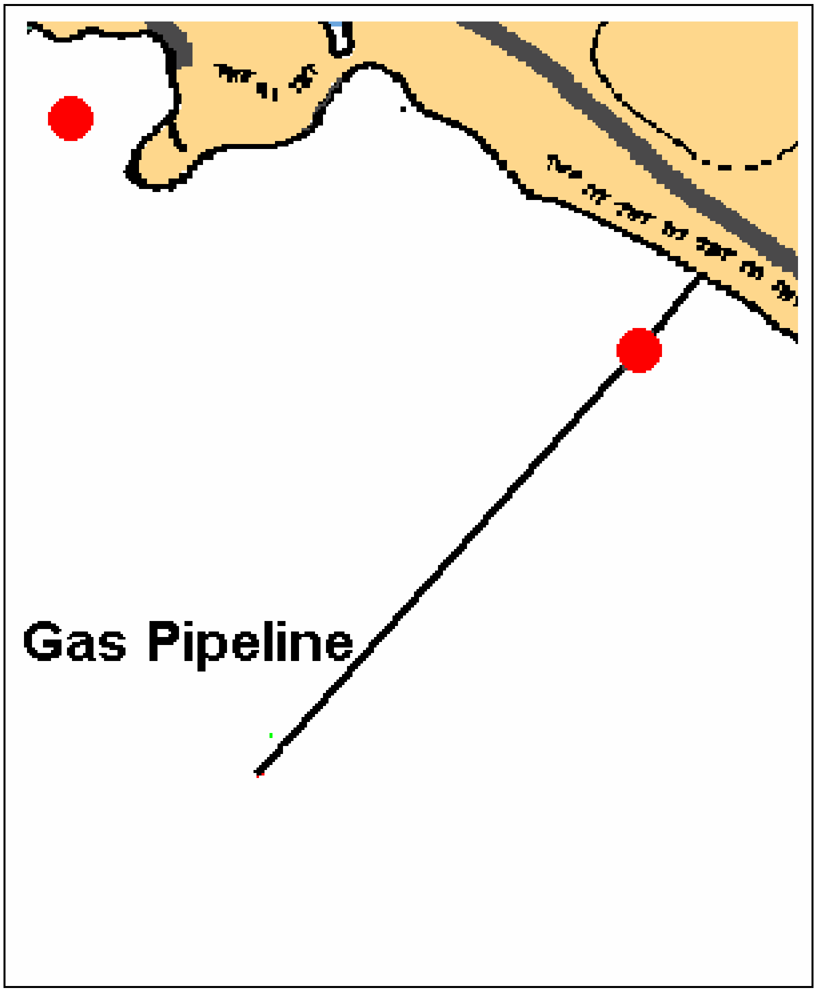

Figure 4.2: Second Acoustic Survey Locations (Red Circles)

Original produced in full colour.

4.4 CONCLUSIONS

For most of the acoustic measurements, there was a fairly significant variation of sound level within a single measurement band/frequency. At some locations the identified tones were clearly visible above the background noise, and at others, it was difficult to distinguish them from the background noise without prior knowledge of what to identify. Thus, while it appears likely that the flow in the pipeline is producing detectable noise, it is not clear that the level is significant, unless the particular tonal frequencies are an issue.

These low frequency tonals of 34, 41, 50, 67, 84 and 100 Hz appear to be emitted from the pipeline and were measurable, with little reduction in strength, at the outer limits of the field measurements adjacent to the pipeline (approximately 200 m on either side of the pipeline). The sound levels decay to background levels (based on the reference site measurements) at an undetermined distance from the pipeline but beyond the 200 m outer acoustic measurement boundaries either side of the pipeline. Measurements at the reference sites (Bear Trap Head, Harbour Island and a Cove on the northern shore of Harbour Island) do not exhibit any of these tonals above background levels. There is likely only a limited decay extending to the outer lobster trapping line approximately 400 m west of the pipeline. The tonals were not easily recognizable at the reference sites located 2 to 2-½ kilometres from the pipeline. The tonals as measured in the vicinity of the pipeline are in the order of 10 db higher than background levels (a factor of approximately 3 times).

First Survey Photos

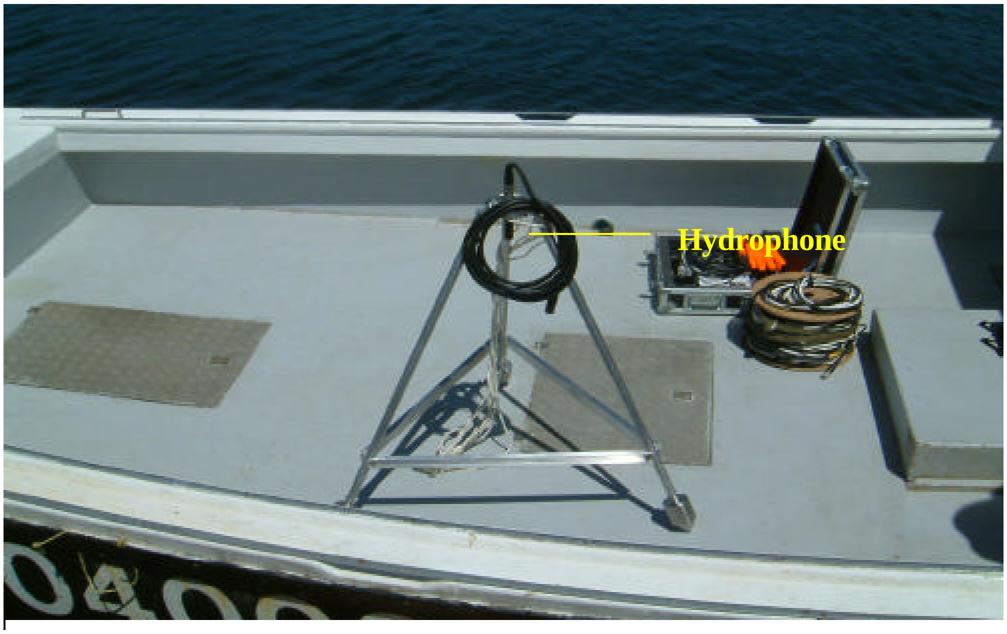

Figure 4.3: Hydrophone Assembly (Lowered to Sea Floor)

Figure 4.4: Spectrum Analyser and Amplifier

Originals produced in full colour.

Figure 4.5: Shore Based Stations Used in the Second Acoustic Survey

Originals produced in full colour.

5.0 ELECTROMAGNETIC SURVEYS

5.1 BACKGROUND

To better understand the magnetic anomalies that can be attributed to pipelines, it is useful to make some fundamental observations about the earth's magnetic field. The origin of the field is not well understood, but thought to be due to currents in a fluid conductive core. In simple terms, the earth's magnetic field resembles the field of a large bar magnet. The field, or flux, lines of the earth are vertical at the north and south magnetic poles, and horizontal at the magnetic equator. Anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Induced magnetic anomalies are the result of secondary magnetization induced in a ferrous body, in our case the pipeline, by the earth's magnetic field. The shape and amplitude of an induced magnetic anomaly is a function of the orientation, geometry, size, depth, and magnetic permeability (or susceptibility) of the body as well as the intensity and inclination of the earth's magnetic field in the survey area. Induced magnetic anomalies over buried objects such as drums, pipes, and tanks generally exhibit an asymmetrical, south up/north down signature (positive response south of the object and negative response to the north). The remanent or permanent magnetization is often the predominant magnetization (relative to the induced magnetization). Permanent magnetization depends upon the metallurgical properties and the thermal, mechanical and magnetic history of the body, and is independent of the field in which it is measured. High values of permanent magnetization are related to the effects of heating. For pipelines, significant in this regard are hot rolling fabrication processes as well as welding. The results of the electromagnetic surveys were processed to quantify the total magnetic fields introduced by the presence of the pipeline.

The first of the electromagnetic surveys were completed the week of July 14, 2003. The surveys were performed by towing a 10 m (approx.) length of instrument laden PVC pipe back and forth over the pipeline (see Figure 5.1 below). This MK I system of PVC pipe (Figure 5.2) housed two three-axis magnetometers (for magnetic field measurements) and two single-axis electric-field sensor pairs. A reference magnetometer system to measure the Earth’s background electromagnetic signature was installed on-shore a few kilometres from the pipeline location. This background level was then subtracted from the data collected in the pipeline vicinity to isolate the electromagnetic fields due to the pipeline. The first survey showed easily detectable electric and magnetic signals in the vicinity of the pipeline at spot locations. It was decided that a numerical (computer) model of these fields would be useful to predict a continuous signature along the pipeline and that a second survey was required to gather more precise data for calibration of the numerical model.

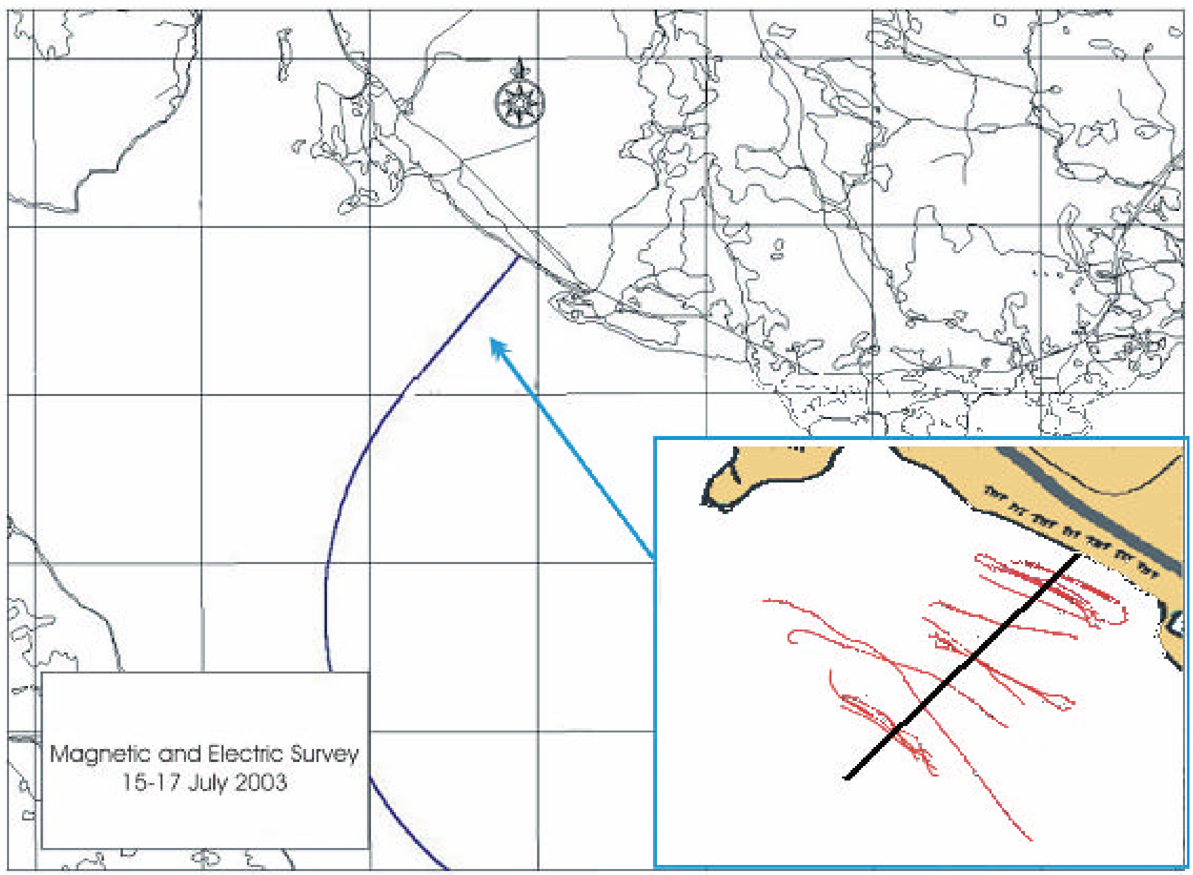

Figure 5.1: First Survey Transects

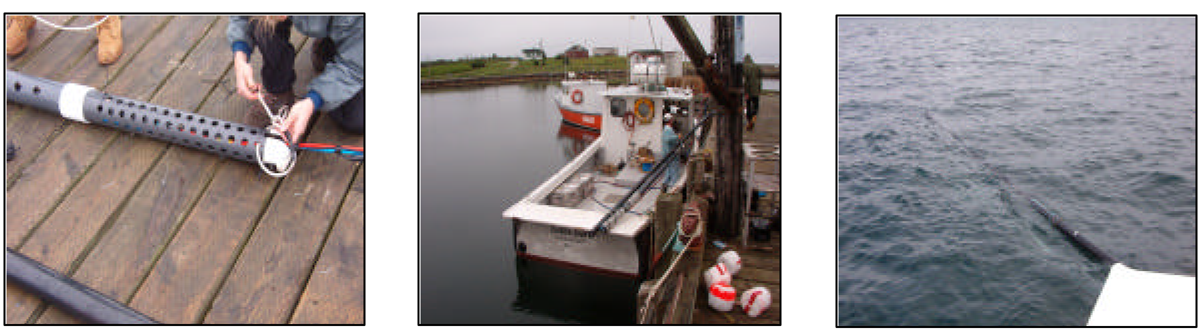

Figure 5.2: Photo of the MK I Electromagnetic Detection System

Originals produced in full colour.

5.2 SECOND ELECTROMAGNETIC SURVEY

A second survey, using an improved MK III electromagnetic system was used in late November 2003 (an intermediate EM MK II system was used internally for DND purposes). The second survey was used to gather improved EM data for the calibration of the EM numerical model (further acoustic data was also collected during this survey). The EM measurements obtained on this second survey were greatly superior to those of the first survey and were exclusively for model calibration.

The MK III system (Figure 5.3) comprises of 3 triaxial magnetometers, triaxial electric sensors, and an on-board Differential Global Positioning System (DGPS), assembled into a compact and rigid stable floating platform. The topside recording instrumentation is shown on the lower right.

This system was towed as illustrated in Figures 5.4 and 5.5 and the results used to calibrate the computer model.

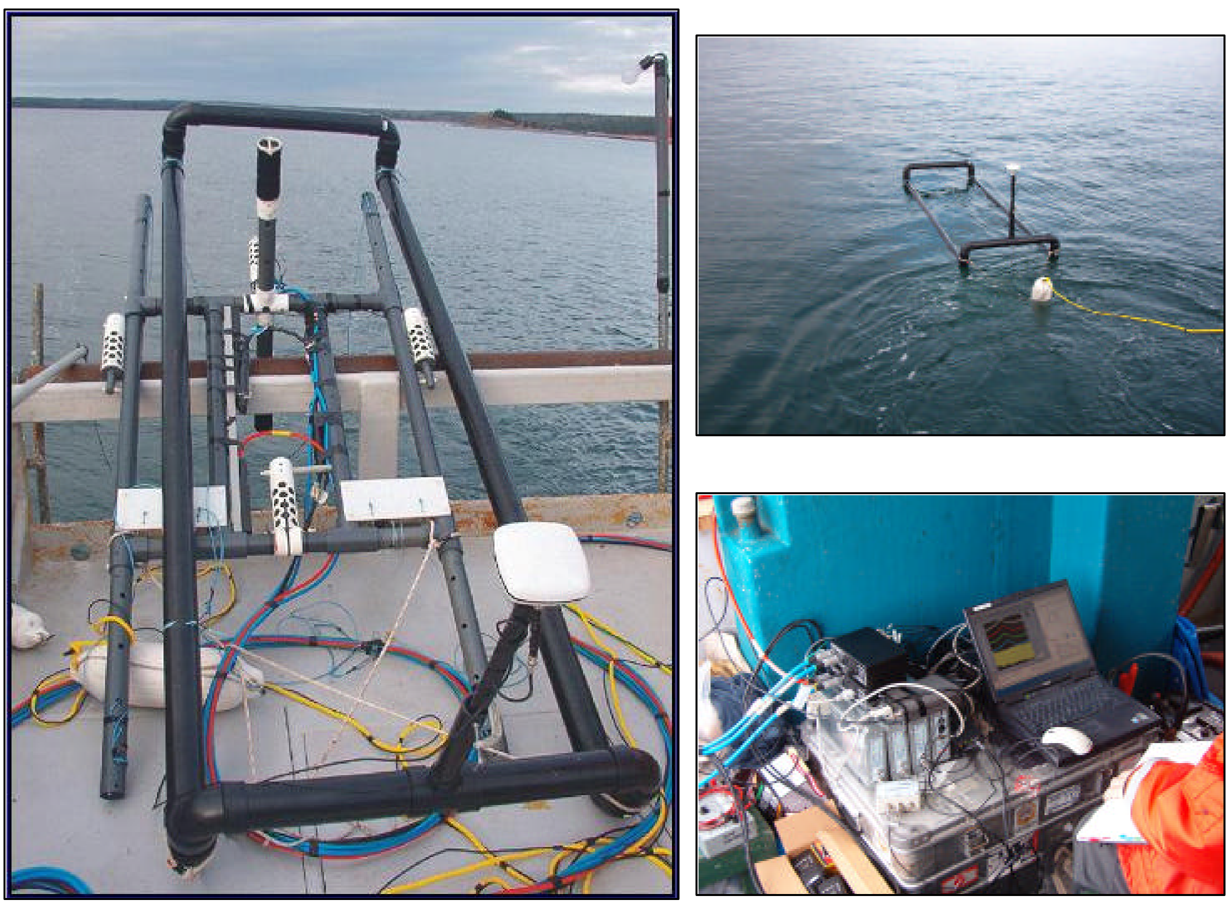

Figure 5.3: Photo of the MK III Electromagnetic Detection System

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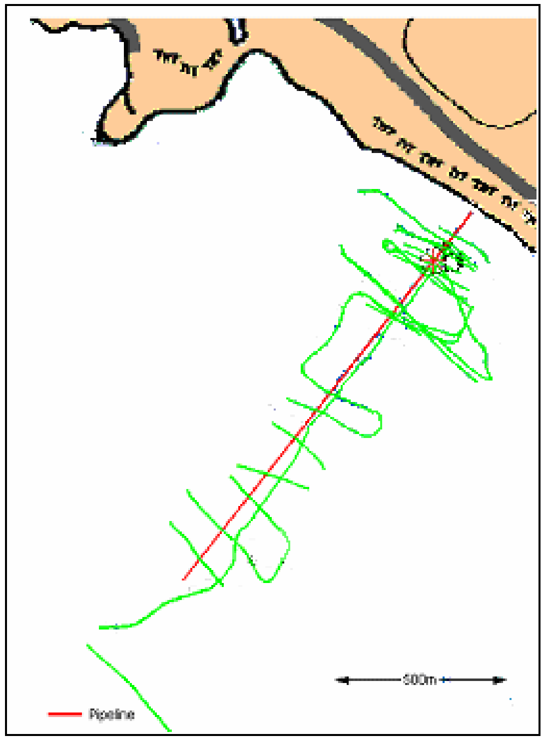


Figure 5.4: Second Electromagnetic Survey Tracks

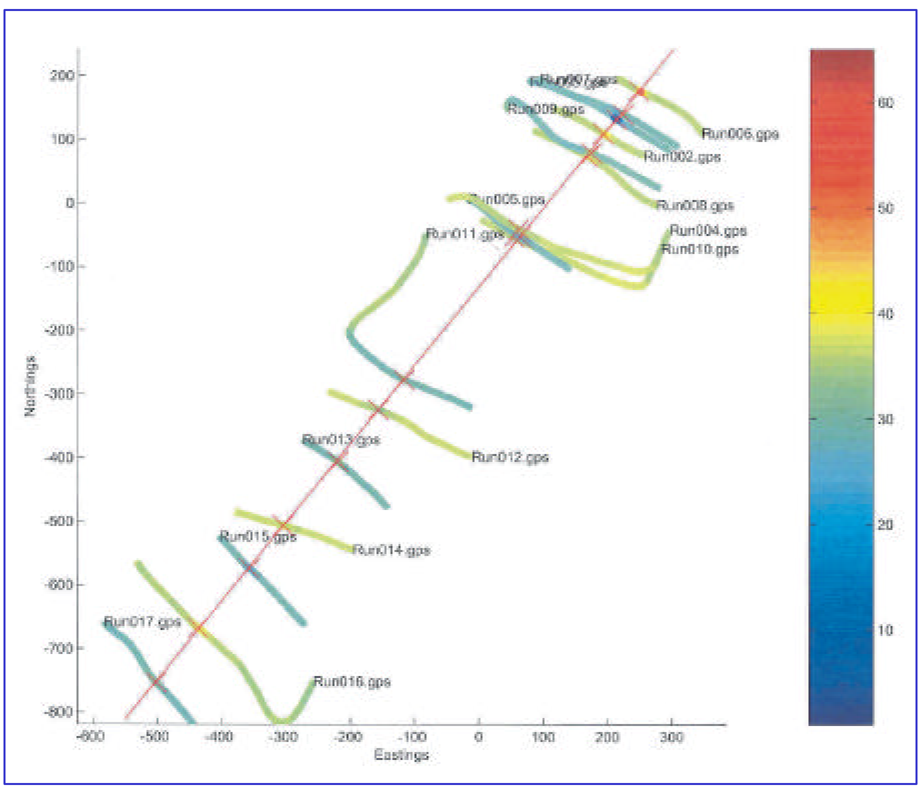


Figure 5.5: Second Electromagnetic Survey Results along the Tracks

(Pipeline route in red; results used to calibrate numerical model)

Originals produced in full colour.

The numerical model was used to predict the magnetic effects as experienced on the seafloor based on the surface measurements as recorded by the instruments. As shown in the following graph (Fig 5.6 - depicting surface observed versus surface computer modelled), a very good correlation between measured and predicted field strengths at the surface was achieved.

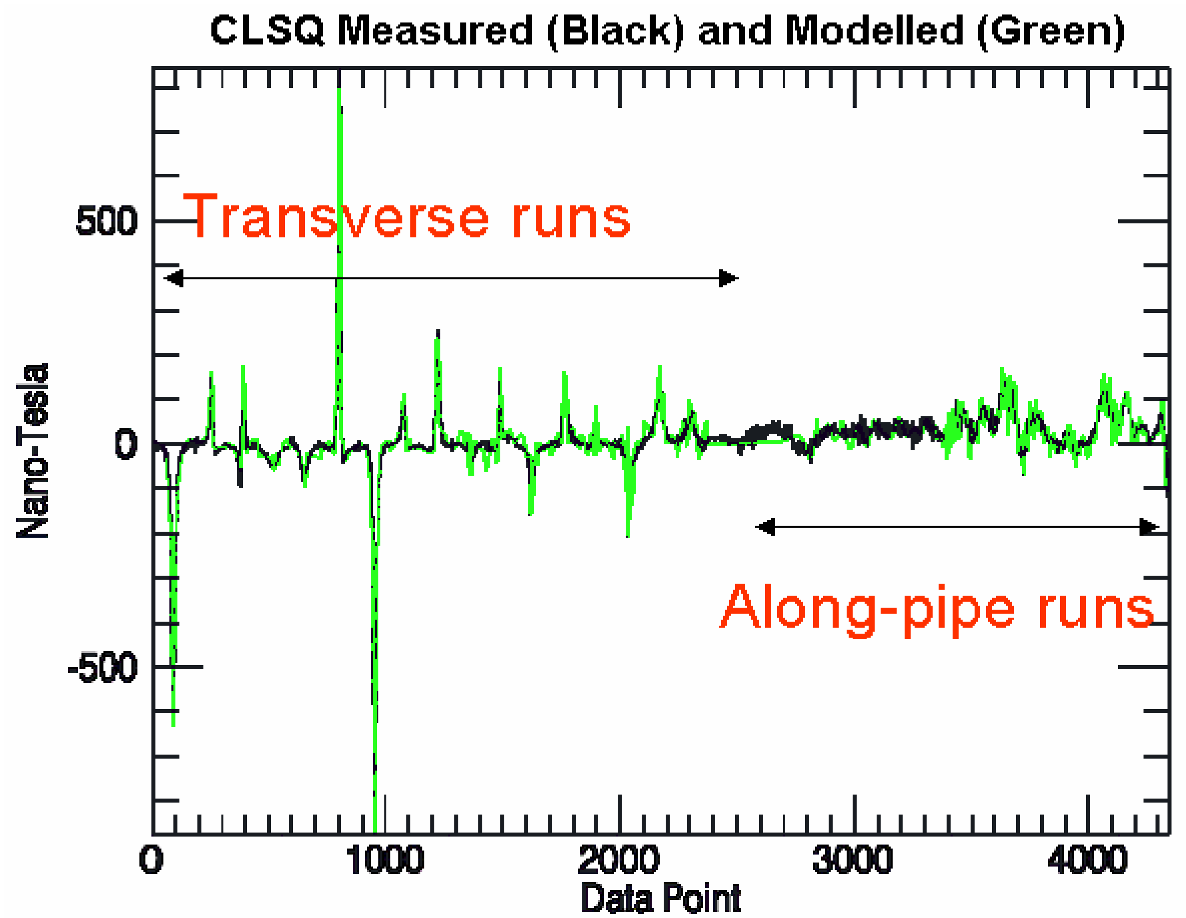


Figure 5.6: Surface Magnetic Fields: Modelled versus Measured

The calibrated numerical model was then used to predict the EM effects at the seafloor in the vicinity of the pipeline by transforming the surface field strengths to the much stronger equivalent strengths at the seafloor as shown in Figure 5.7.

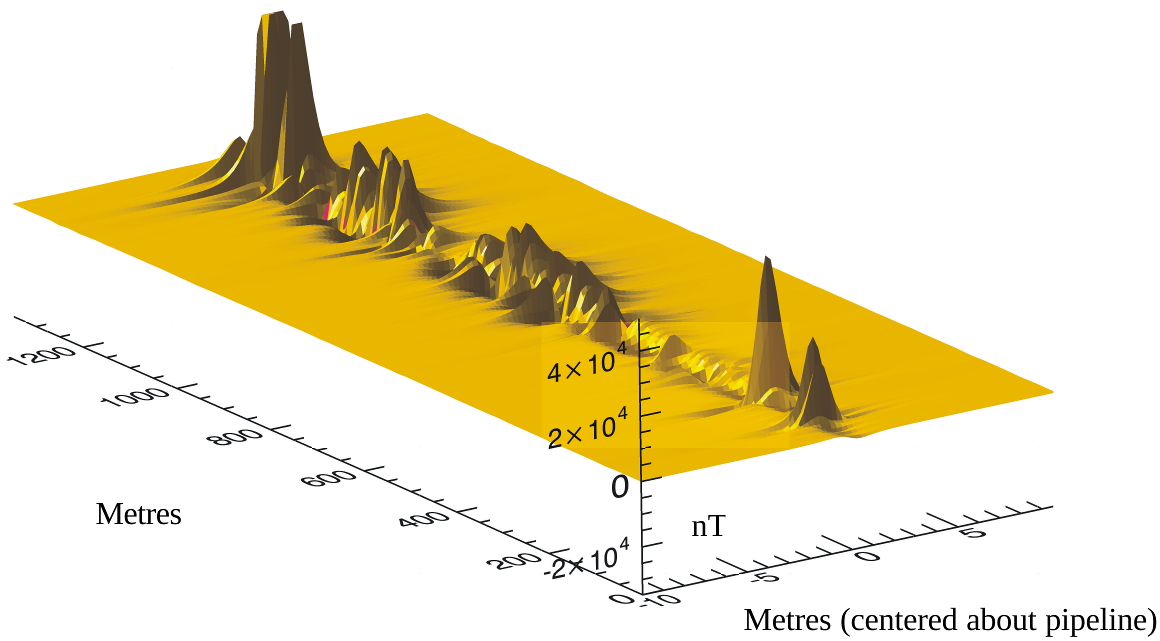


Figure 5.7 Numerical Mode l Predictions of Seafloor Magnetic Field Strengths

(Note that the shoreline is at the 1200 m end of the axis scale)

Originals produced in full colour.

An examination of the magnetic field strengths shows a peak reading approximately 40,000 nanoTesla (nT) with the typical range in the 10,000nT range.

5.3 PERSPECTIVE

To put these magnetic field strengths in perspective, the following table ranks the magnetic field strengths of common household appliances.

Object	Magnetic Field (nanoTesla)
Electric Razor	2,000,000
Vacuum Cleaner	800,000
Television	50,000
Washing Machine	50,000
Bedside Clock	50,000
Background Earth Magnetic Field	55,000
Pipeline – 1 m above seafloor (max)	40,000
Pipeline – 1 m above seafloor (typical)	10,000

5.4 EM CONCLUSIONS

Figure 5.7 shows the results of the numerical model predicting the magnetic field strength along the pipeline at the seafloor. The magnetic field of the pipeline is about one third greater or lesser (depending on the orientation of the individual pipeline segments as installed) than that of the background magnetic field of the earth. The pipeline field strength has a very narrow area of influence (extending approximately two to three metres from the pipeline exterior surface).

6.0 LOBSTER CATCH PROGRAM

6.1 INTRODUCTION

This section details the lobster catch component of the overall study as carried out by CEF Consultants. The field program was carried out during three time periods in the summer of 2003, examining the possible effects in catch associated with the SOEP pipeline, buried just below the seabed, at the Goldboro landfall region. The subsequent analysis was completed following reviews with the project team and the external scientific project advisors. The study took place near Goldboro, and used a local commercial fishing vessel deploying standard lobster traps. Traps were set in close proximity to the nearshore region of the pipeline landfall and at two reference locations remote from the landfall (Figure 6-1).

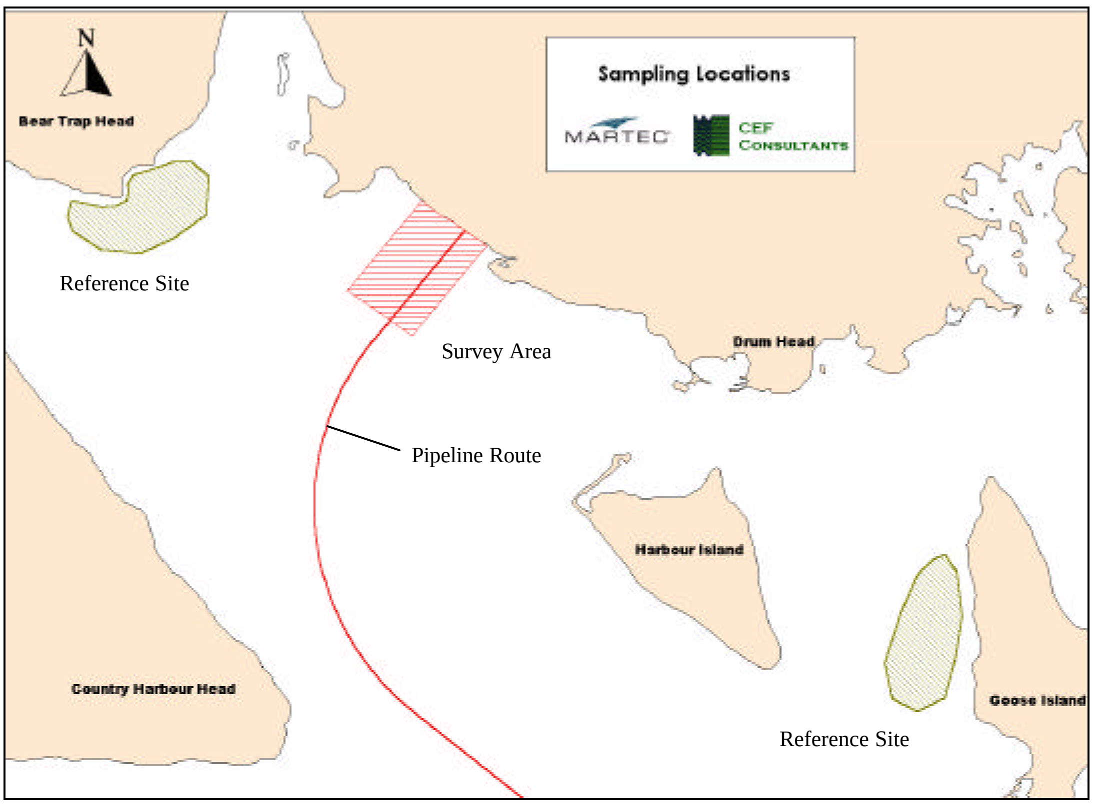


Figure 6.1: Lobster Survey Areas and Reference Sites

Original produced in full colour.

6.2 METHODOLOGY

6.2.1 Experimental Design

The essential hypotheses investigated were that lobster catch did not change with distance from the pipeline, and that lobster size did not change with distance from the pipeline.

Traps in reference areas, at least two kilometres from the pipeline, were set where the local lobster fishermen felt that the benthic habitat was similar to that within the pipeline area. Lobster habitat in reference areas was less widespread, and depth gradients steeper, making parallel lines of traps impractical.

In addition to the basic design of test and reference areas, a series of trap lines in the test area were set parallel to the pipeline to investigate possible changes in catch with distance from the pipeline. These lines of traps were intended to allow further stratification of the pipeline 'test' area based on results from physical studies associated with the pipeline. A distance of 15 m either side of the pipeline, containing a reasonable number of traps (35), was used to investigate possible near field differences in catch. To examine possible larger scale effects, data from the overall pipeline 'test' area was examined for possible relationships between pipeline effects and distance from the pipeline.

6.3 FIELD PROGRAM

6.3.1 Lobster Survey Logistics

6.3.1.1 Trap Preparation

Sixty-six identical wooden traps were used during the entire survey. The escape hatches were closed to retain smaller lobster not normally of interest to commercial fishermen.

6.3.1.2 Trap Distribution

The survey area included the SOEP pipeline route, out to a distance of approximately 920 m from shore. Traps were set in seven lines, with six traps in each line. A line of traps was set along the pipeline route, with original plans to set lines at 20, 200, and 400 m on both sides of the pipeline. The fishing vessel was not able to set traps out to 400 m on the east side, due to safety concerns and bottom conditions, so the distribution of traps was changed. Lines were then set at 20, 100 and 200 meters on each side of the pipeline for the duration of the survey. The 400 m line on the western edge of the pipeline was retained. The lines of traps in the pipeline area are shown in Figure 6-2.

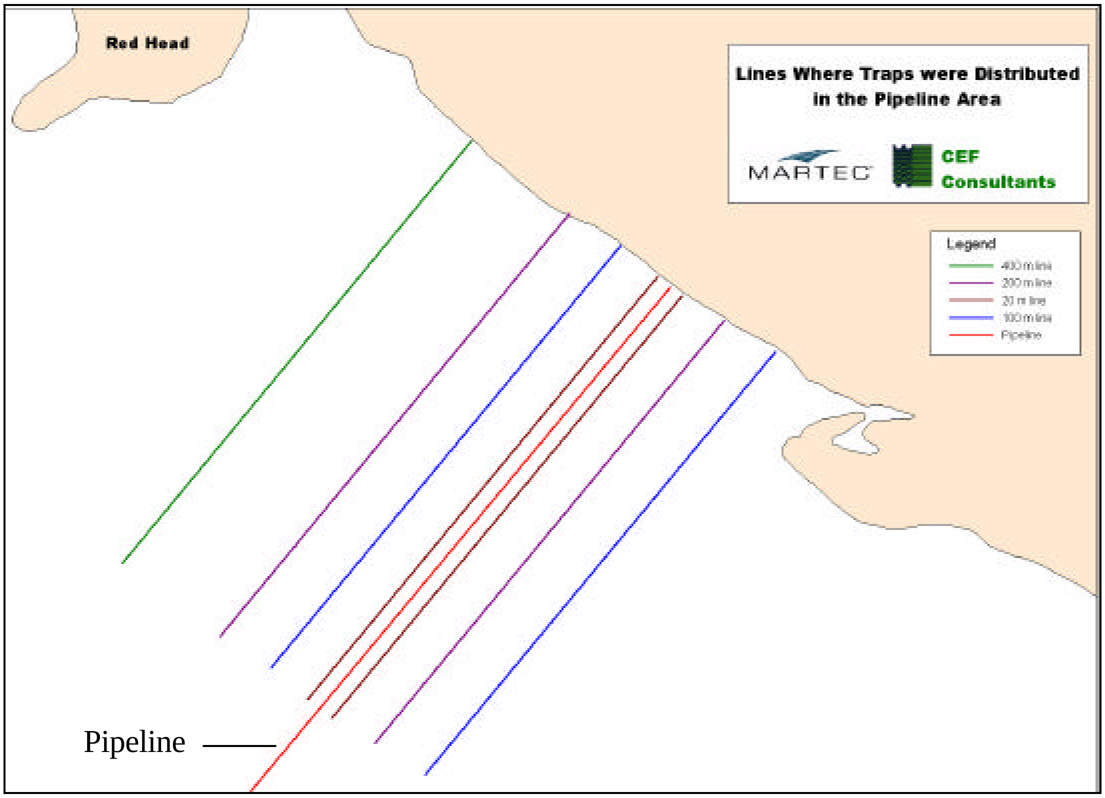


Figure 6.2: Trap Lines In The Pipeline Area

Original produced in full colour.

In addition to these 42 traps, 24 traps were set in two adjacent reference areas, 12 near Bear Trap Head, and another 12 on the west side of Goose Island (see Figure 6-1). Both reference areas were more than two kilometres from the pipeline and considered outside the potential influence of the pipeline effects.

6.3.1.3 Survey Schedule

Three periods of lobster trapping were undertaken. Two of the periods were during the last month of the fishing season, June 3 and again on June 16. The last period starting June 30, ten days after the last day of the fishing season, with the intent to have a study period with no trap competition from the commercial fishery. The dates and associated program activities are summarized in Table 6-1.

Table 6.1: Dates of Lobster Survey Activities

Date	Activity
3-Jun	Set Traps
4-Jun	Retrieval and Set
5-Jun	Retrieval and Set
6-Jun	Storm Day
7-Jun	Retrieval and Set
8-Jun	Retrieval and Landing of Traps
16-Jun	Set Traps
17-Jun	Retrieval and Set
18-Jun	Storm Day
19-Jun	Retrieval and Landing of Traps
30-Jun	Set Traps
1-Jul	Retrieval and Set
2-Jul	Retrieval and Set
3-Jul	Retrieval and Landing of Traps

6.3.2 Permits

CEF Consultants Ltd. was issued a scientific license, number 2003-483 to conduct the lobster survey. The license was issued on May 16, 2003 and was valid until July 4, 2003.

6.3.3 Daily Operations

The lobster survey normally started between noon and 1 pm each day, after the captain returned from commercial lobster fishing.

Traps (Figure 6-3) were baited and set using a differential GPS system at pre-set coordinates for each location. The captain called for the trap to be released when the vessel arrived at each set of co-ordinates. As the trap was released, the depth and exact position (latitude/longitude) were recorded.

Figure 6.3: Photo of Lobs ter Traps on *Casha Dawn.*

The traps were left to fish for 24 hours, and then hauled (Figure 6-4). All lobster were marked, sexed, sized, and then released. Calipers were used to measure the carapace length (Figure 6.5). Lobsters were marked with a non-permanent elastic band to indicate if they were re-captured. Recaptured lobster, berried females or V-notched females were recorded. Each trap was emptied, rebaited and reset after hauling, unless the trapping period was ending. If the weather was fair, the captain stayed in position during this procedure; if he was not able to hold in position, he circled back to the spot where the trap had been. This ensured that the traps were returned to approximately the same location each time they were set.

Figure 6.4: Photo of Lobster trap being brought onto the *Casha Dawn*.

Figure 6.5: Photo Of Measuring The Carapace Length Of Lobster With Callipers

Originals produced in full colour.

6.4 DATASET

A database was compiled to permit statistical analysis of the lobster catch. A total of 588 records (traps) are in the dataset, each with 22 variables. Three categories of variables are contained in the database: time of the survey, the position of the trap, and catch in the trap. Variables that refer to time include a unique number for each trapping event, the date retrieved, and the period number. Periods 1 and 2 encompass trapping done within the lobster season, and period 3 is outside of the normal fishing season. Positional references include the daily trap number (up to 66), latitude, longitude, depth, distance from shore, distance to the pipeline, and the orientation of the trap to the pipeline (west or east). Finally, variables describing the catch in the trap include the total number of lobster caught in each trap, as well as individual size and sex. A field also highlights any lobsters that were recaptured, or females that were berried or V-notched.

Eight traps were not effectively fished because they could not be found on a particular day of fishing, or because the door of the trap had opened and no lobster remained in the trap. Records for these were not used in the analysis.

6.5 ANALYTICAL METHODS

Analysis of Variance (ANOVA) is the primary tool used to investigate differences in catch between test and reference areas. ANOVA compares the means between areas. ANOVA is generally considered a 'powerful' test – one that discriminates differences with a high degree of precision. It tests that the difference between the two means is zero. Regression analysis tested whether the slope of the regression line is significantly different from zero.

A confidence limit of 95% or, expressed another way, a significance level of 5% was used in all the statistical tests. This translates to less than a 5% (0.05) chance of concluding that averages derived from sampling were different when in fact they were not different. These test results are presented in the form of "p equal to a decimal probability". If p is greater than 0.05 (i.e. $p > 0.05$) an hypothesis of no difference between two averages is accepted and, conversely, if p is less than 0.05 (i.e. $p < 0.05$) the averages being compared are significantly different.

In addition to specific statistical tests, catch and size distributions were mapped and examined for patterns, and histograms of variables, such as sex and length, were examined for consistent patterns.

Many statistical analyses are based on the assumption that the data are normally distributed. Two methods were used to evaluate the degree to which the length data were normally distributed (Figure 6-6). First, a normal population frequency was generated and compared to the observed population using a rank test that was not dependent on an assumption of a normal distribution. The test indicated that the two distributions were not significantly different. In addition, length data were transformed using the BoxCox transformation and statistical tests rerun to see if the results changed. The BoxCox transformation is generally suggested for dealing with the type of distribution observed, and the statistical significance of the test results remained unchanged after transformation.

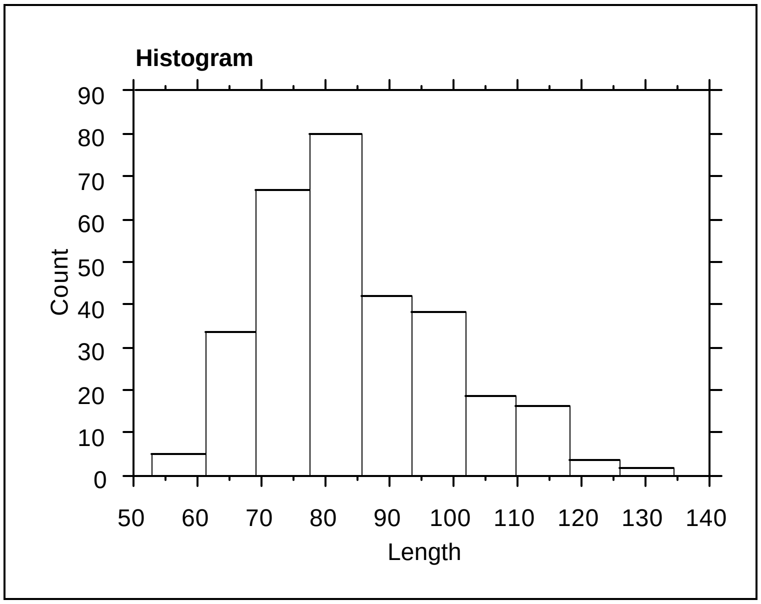


Figure 6.6: Histogram of All Lobster Caught

6.6 RESULTS

6.6.1 Difference in Catch Between the Pipeline 'Test' Area and the Reference Areas

The total number of lobster caught during the survey was 486, of which 307 were caught in the pipeline area, 98 in the Bear Trap Head reference area and 81 in the reference area on the west side of Goose Island.

Table 6-2 shows the number of times that different numbers of lobster were caught in a trap in the pipeline and reference areas. The probability of catching a single lobster, or none at all, in a trap is similar for the reference and pipeline areas. The chance of catching 2 lobsters, or 3 and more lobster, was identical in the pipeline and reference areas. A comparison of these frequencies using the chi-square test shows no difference (X-squared = 1.3, df = 2, p-value > 0.05).

Table 6.2: Frequency of Lobster Trap Catch in the Pipeline and Reference areas.

Number of Lobster Caught In a Trap	Pipeline (n=371)		Reference (n=208)	
	Count	Percent	Count	Percent
0	171	46	88	42
1	122	33	77	37
2	56	15	31	15
3 or more	22	6	12	6

6.6.2 Catch and Distance from the Pipeline

Catch per trap within the pipeline 'test' area is shown in Figure 6-7.

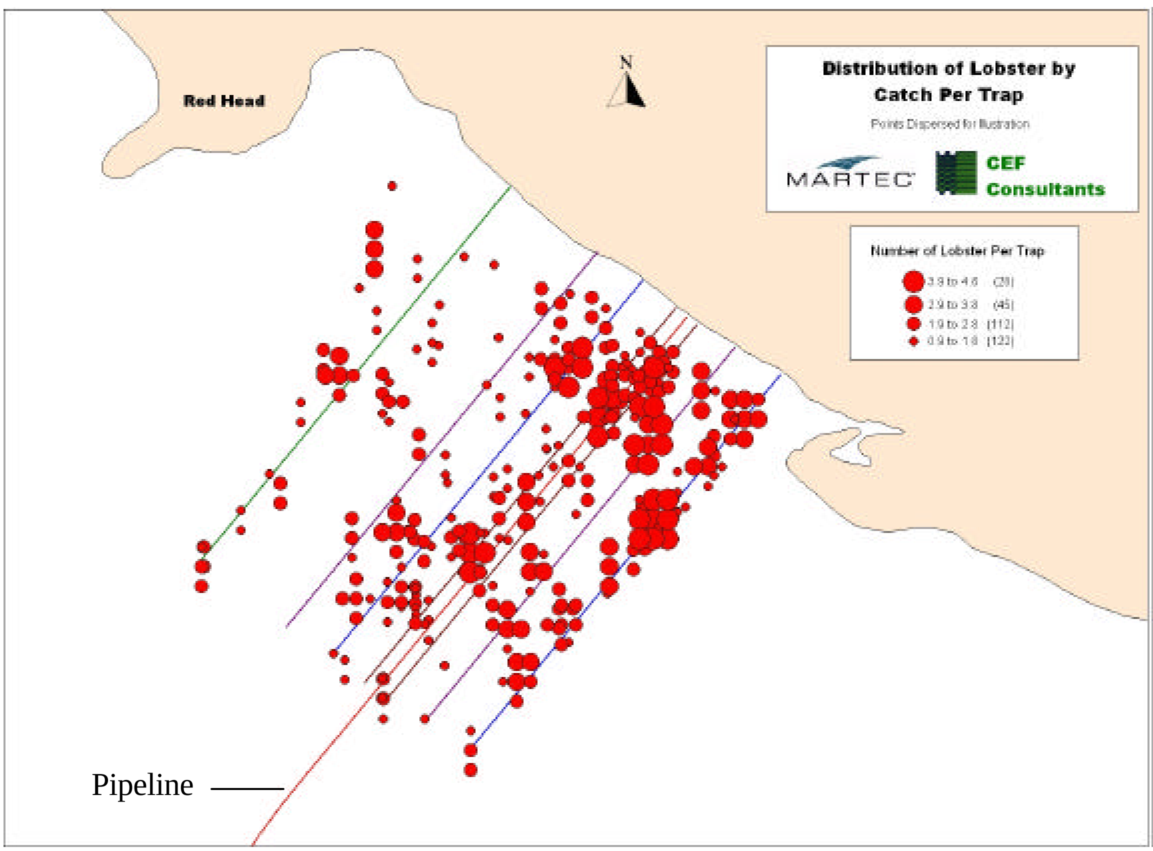


Figure 6.7: Lobster Catch Per Trap In The Pipeline Area

Original produced in full colour.

To investigate possible influence of near field magnetics and noise on lobster catch, the number of lobsters caught per trap were compared within 15 m of the pipeline and in the more distance pipeline 'test' area. The average catches in the two areas were 0.743 and 0.836, respectively, which was not significantly different (p=0.5832, n=337).

6.6.3 Variation in Catch by Direction

Lobster habitat is known to vary over the pipeline area based on previous surveys conducted for ExxonMobil and EnCana. To investigate potential differences resulting from habitat, average catches east and west of the pipeline were compared. The average catch east of the pipeline (n=142) was 0.91 lobsters per trap, compared to 0.78 to the west (n=229).

The mean value in catch east and west, however, were not shown to be statistically different (p=0.20) using an ANOVA.

6.6.4 Influence of Commercial Fishing Season

It was possible that results of the study could have been affected by commercial fishing activities. To investigate this, catch in the pipeline 'test' area was compared during the fishing season and after.

Average catches during (0.79 per trap) and after (0.97 per trap) the season were not statistically different (p=0.326) when compared using an unpaired t-test.

6.6.5 Carapace Length and Location

The average carapace length of males and females caught in the pipeline and reference areas are shown in Table 6-3. In the pipeline area, males were slightly smaller and females were slightly larger than those in the reference areas. However, the ANOVA indicated that the difference in size of lobster caught was not significant between pipeline and reference areas (p=0.8690, n=316).

Table 6.3: Average Carapace Length of Male and Female Lobster in Pipeline and Reference Areas (mm)

Location	Average length of males	Average length of females
Pipeline	83.8	85.5
Reference	84.3	84.3
Overall	84.0	85.0

The catch per trap haul of lobster near the pipeline is 0.83, almost identical to reference value of 0.86 at Bear Trap Head and on the west side of Goose Island.

6.6.6 Sex and Location

The percentage of males and females caught varied little between the pipeline and reference areas. Table 6-3 shows that 54 % of the catch in the pipeline area was male, compared to 49 % in the reference areas.

Table 6.4: Number of Male and Female Lobster Caught in Pipeline and Reference Areas

Location	Number of males	Percentage of males	Number of females	Percentage of females
Pipeline	165	54	142	46
Reference	87	49	92	51
Overall	255	52	234	48

The number of lobsters caught per trap did not vary significantly between pipeline and reference areas when grouped by sex in an ANOVA ($p=0.6982$ and $p=0.6455$, respectively).

Capture of berried females was another sex-related factor recorded. Figure 6-8 illustrates the distribution of these sex-related variables and where lobsters were recaptured. The distribution of recaptured lobsters was not analyzed further because of the small sample size and the apparent random pattern observed.

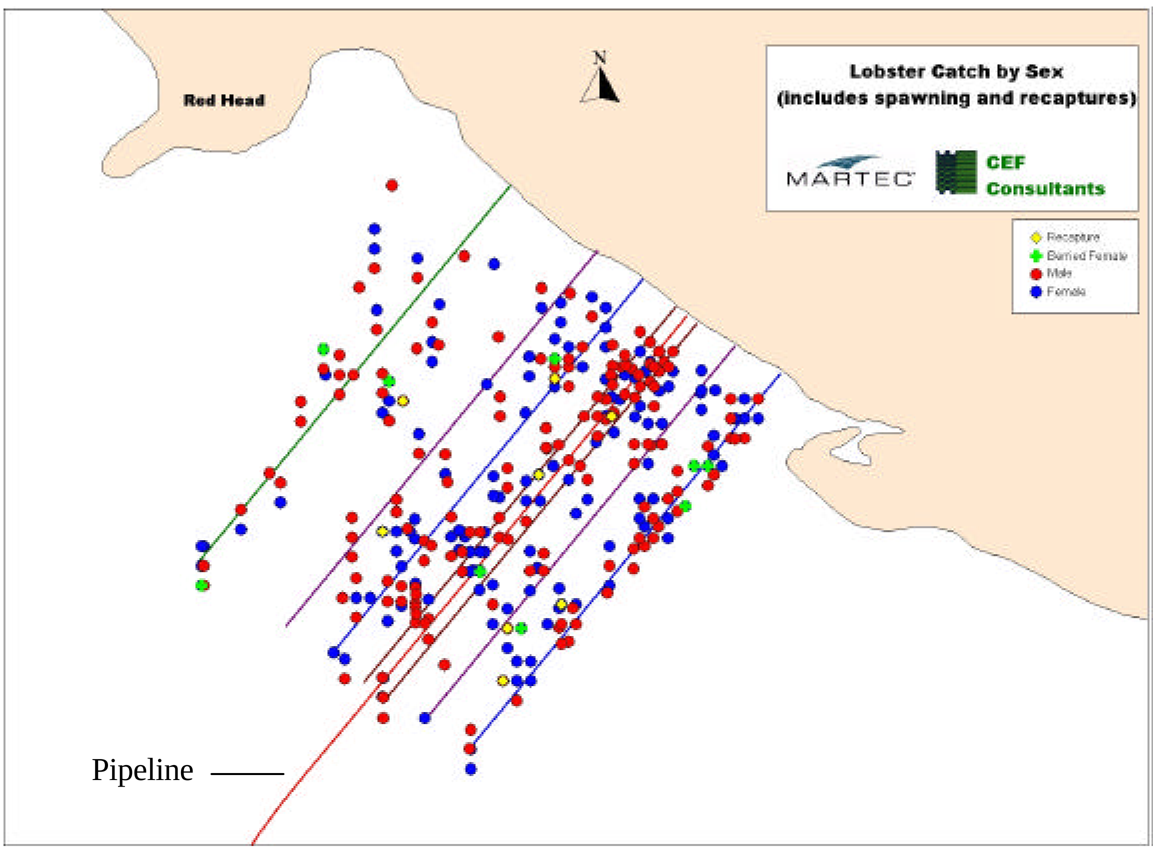


Figure 6.8: Distribution of Lobster Catch by Sex, Recapture and Berried Females

Original produced in full colour.

6.6.7 Differences In Catch, Size Or Sex With Distance From The Pipeline

Regression analysis was used to further investigate whether or not catch, size or sex varied with distance from the pipeline. Within the pipeline 'test' area, linear regression showed no significant correlation between distance from the pipeline and catch ($p=0.3897$, $n=371$). The distribution of lobster catch by size is illustrated in Figure 6-9. Note that the dots indicating lobster length are slightly displaced from the catch location to show the size of individual lobster from each trap.

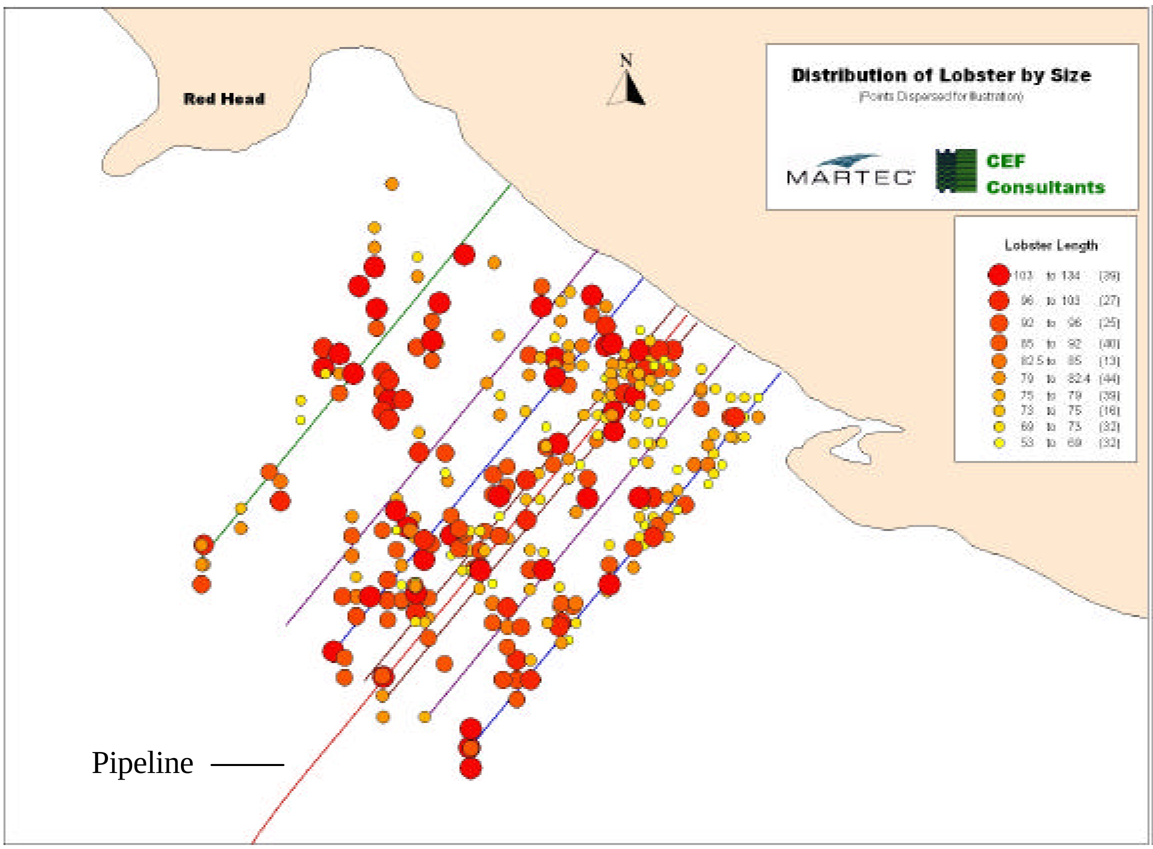


Figure 6.9: Distribution of Individual Lobster caught by Length

Original produced in full colour.

Average carapace length was also compared with distance from the pipeline. In this case, a regression analysis of the data in the pipeline region showed a statistically significant increase in size of lobster with distance from the pipeline ($p=0.0221$). The linear regression of this length data compared to the distance from the pipeline (see Figure 6-10) suggests that a lobster caught over the pipeline would be 6 mm smaller than one caught 400 m from the pipeline, although distance from the pipeline accounts for only 2.6% of the variation in catch.

Table 6.5: ANOVA Analysis - Average Length versus Distance to Pipe

ANOVA Table
Average length vs. Dist to Pipe

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	891.911	891.911	5.321	.0221
Residual	196	32851.616	167.610		
Total	197	33743.527			

The plot of average length to distance from the pipeline shows that the lengths of lobster appear to be normally distributed with no major outliers having a major (skewing) effect on the relationship.

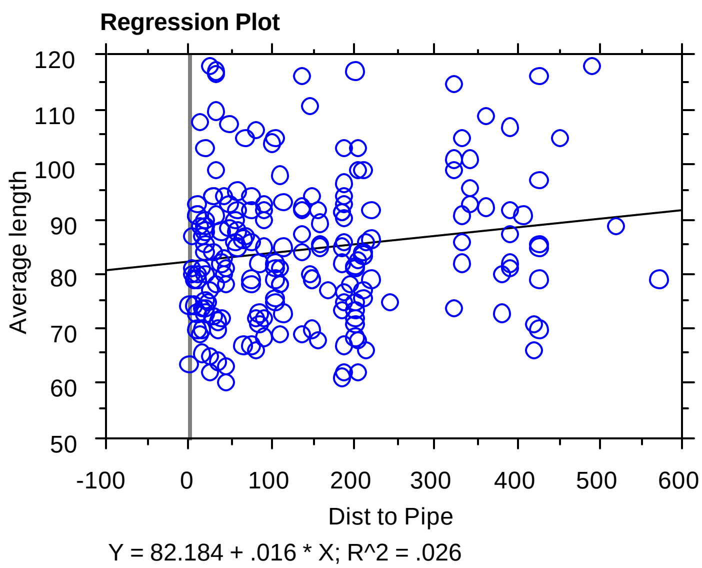


Figure 6.10: Regression Plot

Original produced in full colour.

A subsequent analysis examining the potential effect of size on catch in relation to the pipeline, divided the pipeline area into equal distant quadrants east to west of the pipeline and from inshore to offshore. Figure 6-11 illustrates the quadrants and the results of the analysis.

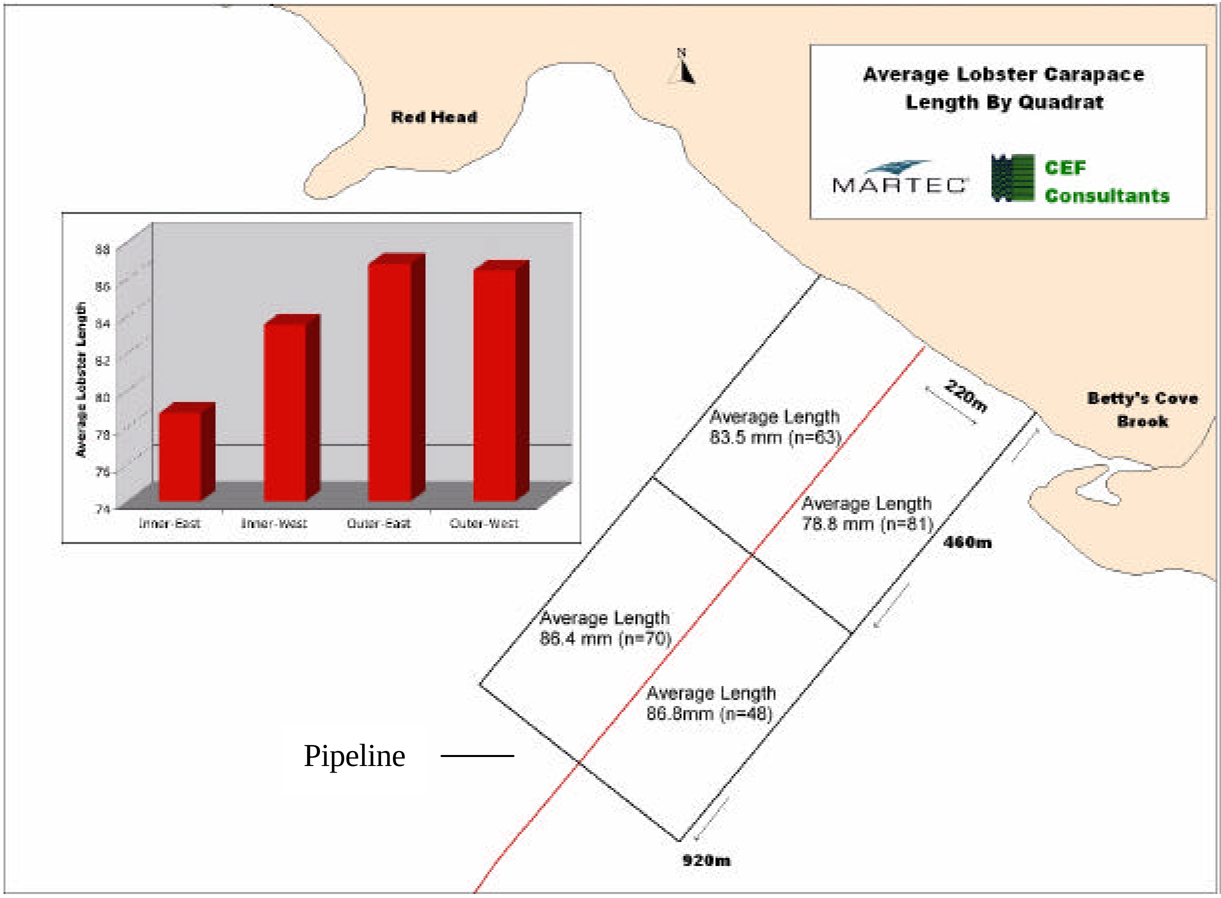


Figure 6-11: Catch of Lobster by Length within four Equal Quadrants

Original produced in full colour.

Comparison of lengths among the four quadrants using a one-way ANOVA indicated that grouping by quadrant accounted for a significant proportion of the variation in the lengths (p=0.002). A comparison of the average lengths showed that lobsters caught within the Inner-East quadrant (mean 78.8 mm) were statistically smaller than those in any other quadrant (mean lengths ranged from 83.5 to 86.8 mm). Mean lengths in the other three quadrants were also not significantly different from each other. Histograms of individual lengths for catches within the Inner-East quadrant and the other three quadrants are provided for comparison in Figure 6-12.

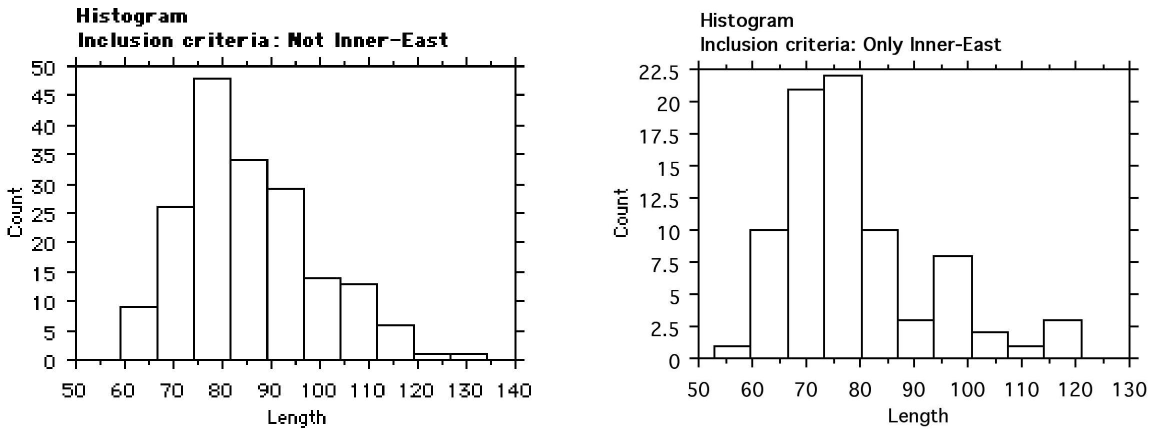


Figure 6-12: Length Frequency Distributions by Quadrant

This analysis shows that the difference in size of lobster is largely isolated to the Inner-East quadrant, and not distributed in a continuous fashion with increasing distance from the pipeline or with direction east or west of the pipeline. This finding suggests strongly that the small difference in size of catch detected in the linear regression of the entire pipeline data set is related to habitat differences within the area adjacent to Betty's Cove Brook, and not the pipeline itself.

Multiple regression analysis was also used to investigate the relationship between catch rates of male and female lobsters with distance from the pipeline. Sex of the lobster did not explain a significant additional amount of the variation in catch (p=0.4277 for males and p=0.9437 for females).

6.7 CONCLUSIONS

The analysis of lobster catch data shows that results within the test area were not significantly different from those in the two reference areas. The mean catch between reference areas was also not significantly different. The catch per trap haul also did not change significantly with distance from the pipeline. Sex of the lobster was not found to affect catch rates, but 7.5 per cent more male lobster were caught overall. A summary of the results from the analysis is provided in Table 6-6.

Table 6.6: Summary of Results of Lobster Catch Analysis

Question Addressed	Results
Did catch within the pipeline area differ from reference areas?	ANOVA showed catch rates in pipeline and reference areas were not significantly different (p=0.902, n=578)
Was catch close to the pipeline different than further away?	ANOVA showed the number of lobster caught per trap was not different within 15 m of pipeline and up to 600 m away (p=0.583, n=371)
Did the catch vary from East to West of the pipeline?	ANOVA showed the average catch east of the pipeline (0.91 lobster/trap) was not different (p=0.20, n=371) than west of the pipeline (0.78 lobster/trap)
Did the catch differ within and outside the commercial season?	A t-test showed the mean number of lobster caught per trap during (0.79) and after the commercial season (0.97) were not different (p=0.33, n = 371)
Did other variables affect catch or size of lobster?	Distance from shore, water depth, and sex did not explain significant differences in the catch/rates
Did the size of lobster differ with distance from the pipeline?	When catch from both sides of the pipeline were grouped together, distance from the pipeline was not correlated with catch rates (p=0.39, n=371)
Was the size of lobster different within a particular area?	A one-way ANOVA using catch separated into four quadrants around the pipeline showed that lobster caught in the Inner-East quadrant were smaller than those caught in any other quadrant (p=0.002, n=371)

Analysis within the pipeline 'test' area showed that the average size of lobsters was significantly smaller in the inner eastern quadrant, the area closest to Betty's Cove. Lobsters caught in this area were 6.7 mm smaller on average than in other quadrants. The clustering of small lobster in this area suggests a habitat influence rather than a pipeline effect, because in the other quadrants the size of lobster caught was not significantly different.

Overall, lobster catches were not shown to be influenced by the pipeline in terms of numbers caught, size, or sex of the lobster.

7.0 LOBSTER MOBILITY TANK STUDIES

7.1 INTRODUCTION

Concern has been expressed about the ability of lobsters to scale (either by climbing or swimming) underwater gas pipelines that are either fully or partially exposed above the seafloor. This component of the study addresses this concern by determining whether lobsters placed in tanks containing a mock-up pipeline could scale the pipeline structures using a bait incentive on the far side of the pipeline structure. The lab-based experimentation was carried out at St. Francis Xavier University (St. F.X), Biology Department, Antigonish, Nova Scotia.

7.2 EXPERIMENT DESCRIPTION

Mock-up gas pipelines of 32" and 48" external diameter (to mimic the size of the ExxonMobil Sable Offshore pipeline and the proposed Blue Atlantic Transmission System pipeline, respectively) were constructed to examine whether lobster were able to scale the structures in a lab environment. Lobsters used for the 32" diameter pipeline study were collected from ExxonMobil landfall locale in Goldboro, N.S. while lobsters used in the 48" diameter pipeline trials were collected from the Shelburne, N.S. region (near the proposed site of the Blue Atlantic Transmission System Project).

Four heights of pipeline exposure (¼, ½, ¾ and full height above the seafloor) were tested. This was achieved by positioning a moveable tank floor relative to the top of the tank (see Figures 7.4 and 7.5). This was used to simulate various levels of burial of the pipeline; for example a ¼ height exposure would simulate a condition in which ¾ of the pipeline was buried. Two exterior pipeline coatings were modelled; termed 'rough' and 'smooth'. The 'rough' and 'smooth' surface coatings were used to mimic those achieved when using either shotcrete or wrap methods (respectively) of applying a protective outer jacket to the steel pipeline.

The water temperature was kept at approximately 10 degrees Celsius for the trials.

Mussels or dead smelts were placed on the far side of the mock-up pipeline to act as an incentive for lobsters to move over the pipeline. Lobsters were placed individually in the tank for a period of 24 hours. Dimmed lighting in the observation tank was set on a natural day/night cycle. Night video recording was achieved by illuminating the tank with infrared emitters. Video cameras were set up at several positions and recorded the movement and behavior of the experimental animals with a time-lapse recorder. The tapes were viewed to determine if and how the lobsters scaled the pipelines.

The 32” diameter pipeline was examined first (using 8 market size lobsters), and the results of the experiment were used to facilitate the design of the subsequent experiment with the 48” diameter pipeline (using 10 lobsters).

Experiments on the 48” diameter pipeline were conducted using 13 lobsters, which spanned a large size range including lobsters that were below market-size and berried females (permission granted from the Fisheries and Oceans Canada). In order to complete the work in a timely fashion, the testing protocol was optimized using the results from the 32” pipeline testing results. For example, because lobsters were able to scale the rough ½ exposure, the rough surface ¼ exposure was not examined.

The 32” pipeline tests were conducted using existing facilities at St. F.X. while a larger tank facility to house the 48” pipeline structure was purpose built for this project. The two different tank facilities are shown below.

Figure 7.1: Picture of Tank Facility and Mock-Up Model of 32” ‘Smooth’ Pipeline

Original produced in full colour.

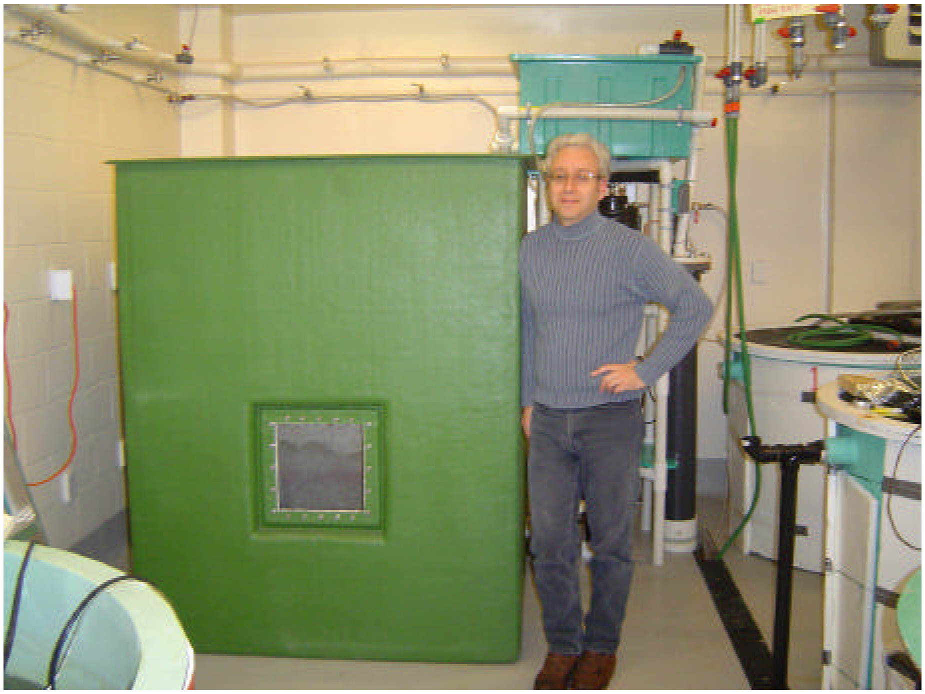


Figure 7.2: Experimental Tank In which the 48" Diameter Pipeline Model Was Placed

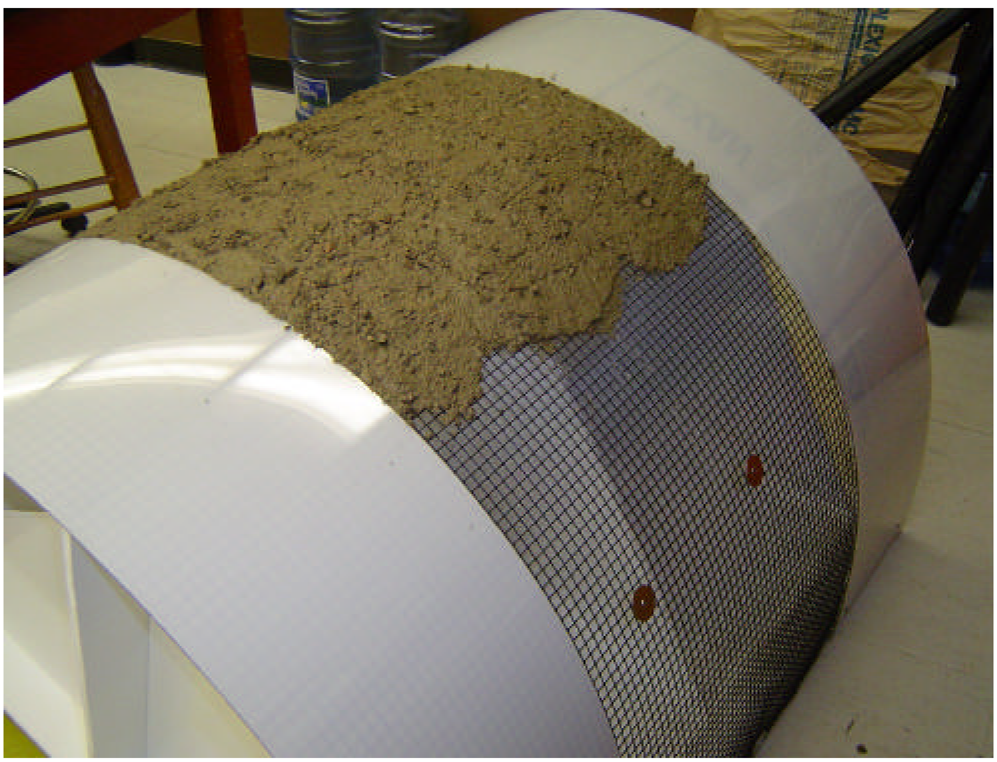


Figure 7.3: A Partially Constructed 48" Diameter Model Pipeline

The white regions on the edges are embedded Plexiglas strips used to prevent the lobsters from utilizing the corners of the tank/pipeline model to climb the barrier.

Originals produced in full colour.

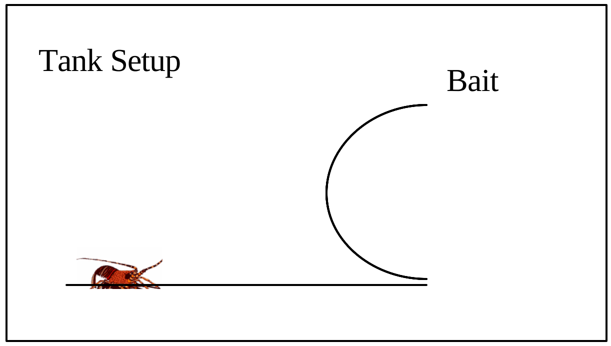


Figure 7.4: Schematic Of Lobster On The 'Sea Floor' In Front Of The Pipeline

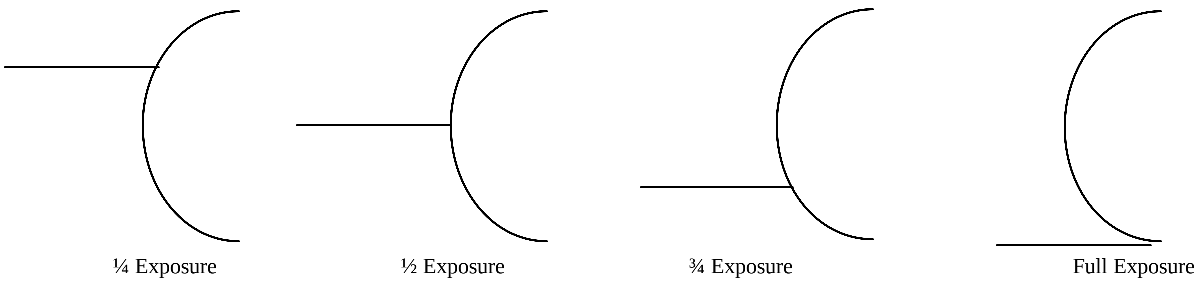


Figure 7.5: Showing How The Seafloor Is Moved To Create Different Exposure Heights

7.3 MAIN FINDINGS (32" PIPELINE)

Table 7.1 (below) presents the results from the ¾ height and fully exposed tests. The table is sorted as follows: whether lobster was able to cross the pipeline, then surface type and finally by exposure height.

- At ¼ and ½ height exposure, all the lobsters can readily scale both smooth and rough surfaces regardless of size (results not displayed in the table).
- Generally, the 'rough' surface pipeline proved better for scaling successes than the 'smooth' surface at the ¾ and full height exposures.
- Smaller (i.e. lighter) lobsters were better able to scale the pipeline at ¾ and full height exposure.

Table 7.1: 32" Partial Pipeline Results

Lobster Pipeline Interactions

32" Pipeline: 3/4 and Full Height Results

Tape #	Exposure	Surface	Mass (kg)	Crossed	Activity
R3	3/4	rough	0.442	Y	crawl
R1	3/4	rough	0.63	Y	crawl
R6	3/4	rough	0.634	Y	crawl
R2	3/4	rough	0.688	Y	crawl
R7	3/4	rough	0.855	Y	crawl
R8	full	rough	0.442	Y	crawl
R13	full	rough	0.63	Y	swim/crawl
R15	full	rough	0.855	Y	crawl
14	3/4	smooth	0.442	Y	swim
21	full	smooth	0.442	Y	swim
R4	3/4	rough	0.774	N	
R16	3/4	rough	0.903	N	
R5	3/4	rough	1.429	N	
R14	full	rough	0.634	N	
R9	full	rough	0.688	N	
R12	full	rough	0.774	N	
R11	full	rough	0.903	N	
R10	full	rough	1.429	N	
15	3/4	smooth	0.63	N	
17	3/4	smooth	0.688	N	
18	3/4	smooth	0.774	N	
13	3/4	smooth	0.855	N	
16	3/4	smooth	0.903	N	
19	3/4	smooth	?	N	
25	full	smooth	0.63	N	
26	full	smooth	0.634	N	
20	full	smooth	0.688	N	
22	full	smooth	0.774	N	
23	full	smooth	0.855	N	
24	full	smooth	1.429	N	

7.4 MAIN FINDINGS (48" PIPELINE)

Results from the 48" diameter testing are shown in Table 7.2. As before, the table is sorted as follows: whether lobster was able to cross the pipeline, then surface type and finally by exposure height.

- Only one lobster scaled the fully exposed rough surface, while three lobsters scaled the ¾ exposure rough surface. At the ½ exposure, most of the lobsters scaled the rough surface pipeline, including two of the berried females (the experiment was not conducted with the rough surface at ¼ height exposure).

- The smooth surface was assumed to be unscalable at ¾ and full exposure based on the results of the 32" testing. About 40% of the lobsters were able to scale the 48" inch structure at the ½ height exposure with the smooth surface.

- All except one lobster were able to scale the 48" diameter pipeline at ¼ exposure with the smooth surface including all of the berried females.

Table 7.2: 48" Pipeline Results

Lobster Pipeline Interactions

48" Pipeline - All Height Results

Tape	Exposure	Surface	Mass (kg)	Crossed	Activity	Berried
KR030	1/2	Rough	0.427	Y	crawl	
KR029	1/2	Rough	0.464	Y	crawl	
KR033	1/2	Rough	0.607	Y	crawl	
KR038	1/2	Rough	0.635	Y	crawl	Y
KR040	1/2	Rough	0.661	Y	crawl	Y
KR028	1/2	Rough	0.711	Y	crawl	
KR037	1/2	Rough	0.734	Y	crawl	
KR032	1/2	Rough	0.838	Y	crawl	
KR027	1/2	Rough	1.177	Y	crawl	
KR036	1/2	Rough	1.702	Y	crawl	
KR031	1/2	Rough	2.488	Y	crawl	
KR034	1/2	Rough	Under	Y	crawl	
KR035	1/2	Rough	Under	Y	crawl	
KR011	3/4	Rough	0.607	Y	crawl	
KR013	3/4	Rough	1.702	Y	crawl	
KR024	3/4	Rough	Under	Y	tail flip	
KR007	Full	Rough	0.362	Y	crawl	
KS005	1/2	Smooth	0.427	Y	crawl	
KS003	1/2	Smooth	0.607	Y	crawl	
KS010	1/2	Smooth	0.635	Y	tail flip	Y
KS001	1/2	Smooth	0.822	Y	tail flip	
KS007	1/2	Smooth	2.488	Y	crawl	
KS016	1/4	Smooth	0.339	Y	crawl	
KS012	1/4	Smooth	0.362	Y	crawl	
KS013	1/4	Smooth	0.427	Y	crawl	
KS011	1/4	Smooth	0.464	Y	crawl	
KS018	1/4	Smooth	0.57	Y	crawl	
KS017	1/4	Smooth	0.607	Y	crawl	
KS021	1/4	Smooth	0.635	Y	crawl	Y
KS022	1/4	Smooth	0.661	Y	crawl	Y
KS023	1/4	Smooth	0.805	Y	crawl	Y
KS014	1/4	Smooth	0.822	Y	crawl	
KS015	1/4	Smooth	1.702	Y	crawl	
KS019	1/4	Smooth	2.488	Y	crawl	

KR039	1/2	Rough	0.805	N		Y
KR041	1/2	Rough	0.805	N		Y
KR016	3/4	Rough	0.2488	N		
KR019	3/4	Rough	0.339	N		
KR020	3/4	Rough	0.362	N		
KR022	3/4	Rough	0.408	N		
KR018	3/4	Rough	0.427	N		
KR026	3/4	Rough	0.464	N		
KR025	3/4	Rough	0.57	N		
KR021	3/4	Rough	0.711	N		
KR017	3/4	Rough	0.734	N		
KR014	3/4	Rough	0.838	N		
KR015	3/4	Rough	1.177	N		
KR012	3/4	Rough	Under	N		
KR023	3/4	Rough	Under	N		
KR004	Full	Rough	0.408	N		
KR002	Full	Rough	0.427	N		
KR009	Full	Rough	0.464	N		
KR010	Full	Rough	0.57	N		
KR006	Full	Rough	0.607	N		
KR003	Full	Rough	0.711	N		
KR008	Full	Rough	0.734	N		
KR001	Full	Rough	1.177	N		
KR005	Full	Rough	2.488	N		
KS006	1/2	Smooth	0.339	N		
No Video	1/2	Smooth	0.408	N		
No Video	1/2	Smooth	0.464	N		
No Video	1/2	Smooth	0.57	N		
KS008	1/2	Smooth	0.661	N		Y
KS009	1/2	Smooth	0.805	N		Y
KS002	1/2	Smooth	0.838	N		
KS004	1/2	Smooth	1.177	N		
KS020	1/4	Smooth	Under	N		

7.5 DISCUSSION

This work examined the potential of lobsters to scale full-size models of submerged natural gas pipelines, and examined the effect of the two surface textures used to cover the submerged pipelines.

For the 32” diameter pipeline, the ¼ and ½ height exposures do not present a barrier (regardless of surface texture) and all lobsters could scale the structure. For full and ¾ exposures, the rough surface enhanced the success of the lobsters dramatically.

For the 48” diameter pipeline, the ½ height exposure can be scaled by the lobsters, but the likelihood of success is highly dependent on the surface texture, with the rough surface greatly enhancing the success of the lobsters.

7.6 CONCLUSIONS

Successful scalability of a pipeline structure by lobster is a function of pipeline diameter, exposure height above the seafloor and the surface roughness of the outer protective coating.

Overall, the 32” diameter pipeline is more readily scaled as compared to the 48” pipeline. This is particularly noticeable at exposure heights of ¾ and greater.

For the 32” diameter pipeline, the rough surface provides a significant advantage at ¾ and full height exposures but for ½ height or less no appreciable differences were observed between rough and smooth surfaces.

Results from the 48” diameter testing demonstrate the effects of the surface texture even more dramatically. The rough surface permitted all the lobsters to scale the ½ height exposed pipeline but only 5 of the 13 lobsters were able to scale the ½ height exposure with a smooth surface coating. Because of the lack of success in lobster scalability with the 32” ¾ exposure pipeline, no ¾ exposure testing was warranted with the smooth surface with the 48” pipeline. In addition, 48” pipeline ¾ exposure with the rough surface proved more difficult to scale when compared to the 32” ¾ exposure rough surface.

8.0 SNOW CRAB

Jacques Whitford Limited (Jacques Whitford Limited 2003) performed a survey, based on a ROV pipeline inspection video, of the ExxonMobil/SOEP main gas pipeline in 2001 beginning at 1.2 km from landfall and continuing out to 120.5 km from shore. In total, 11,886 animals were counted and identified on the main pipeline.

The break down for all crabs is as follows:

Table 8.1: SOEP Pipeline Crab Count

Jonah crab	10
Rock crab	35
Toad crab	253
Snow crab	414
Unidentifiable crab	9

Based on the survey, the 32" Sable Offshore Energy Pipeline appears to be readily scalable by a variety of crab species.

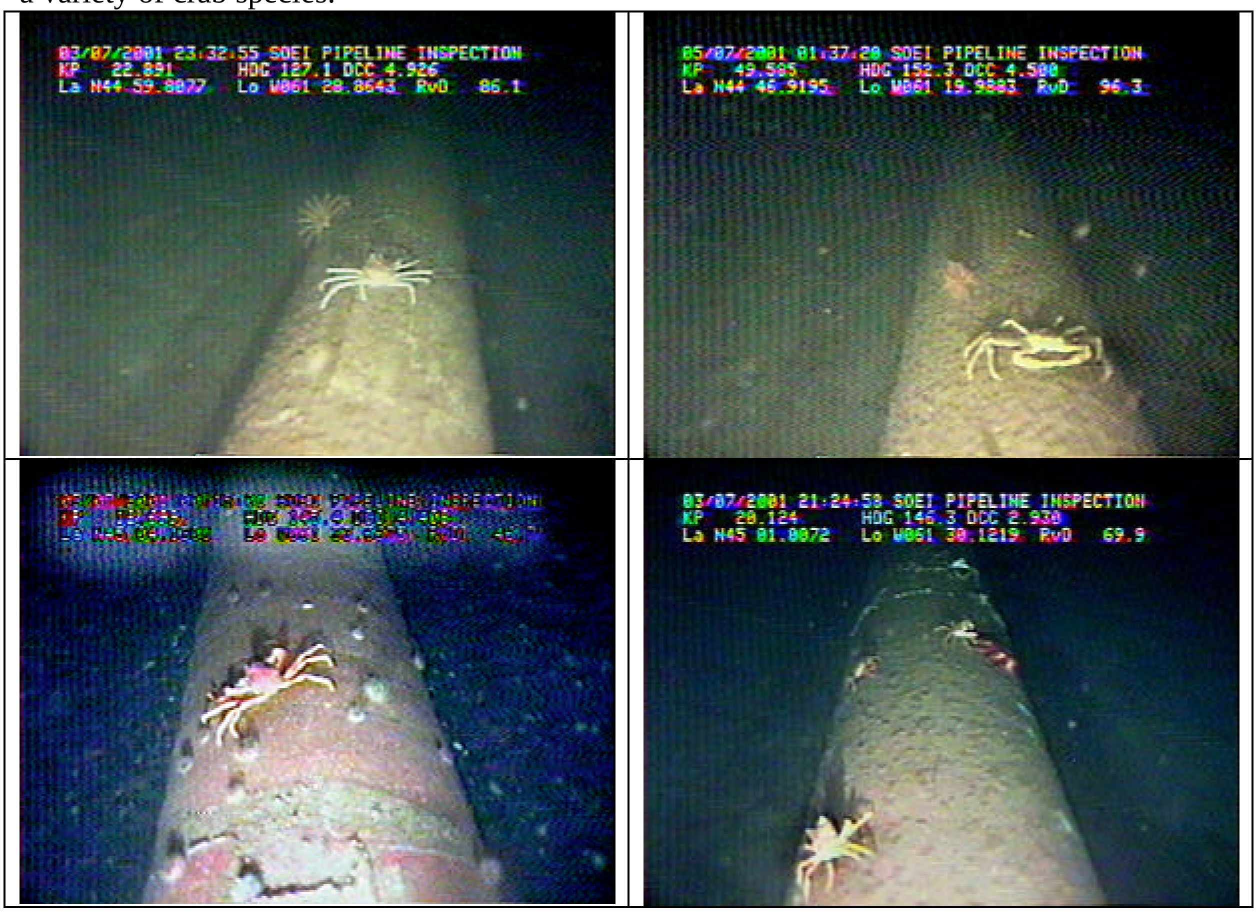


Figure 8.1: Pictures Showing Snow and Toad Crab on the Sable Offshore Energy Project Pipeline

(Toad crab shown lower right)

9.0 CONCLUSIONS

This study was undertaken to investigate the effects of subsea pipelines on crustaceans such as lobsters and crabs. The focus of the study was the Sable Offshore Energy Project's subsea gas export pipeline which has a landfall location near Goldboro, Nova Scotia.

Acoustic surveys determined that this pipeline emits low frequency sounds while in operation. While these sounds are within the hearing range of lobsters, they are not significantly different than natural background sound levels. Electromagnetic surveys and modeling revealed a very localized field (within three metres of the pipeline) of electromagnetic energy surrounding the pipeline which has a magnitude of one third that of the Earth's naturally occurring level.

Statistical analysis of lobster catch data from an experimental fishery conducted in the nearshore landfall area and at two distant reference sites showed that the pipeline had no influence on lobster catch as measured by numbers caught per trap haul, individual size, and sex ratio.

Laboratory experiments were also carried out to assess the ability of lobsters to scale (commonly by climbing but also by swimming) unburied and partially buried pipelines. The testing considered two pipeline sizes; 32" and 48" outer diameter pipelines corresponding to the Sable Offshore Energy Project pipeline and the proposed Blue Atlantic Transmission System line respectively. Key findings of these experiments were:

- Lobsters were more successful at scaling a rough-textured pipeline than one with a smooth surface and overall, a 32" pipeline was more readily scaled than a 48" outer diameter pipeline. The differences were most noticeable when pipelines were at the 1/2 diameter and full height exposures above the seafloor;

- Extrapolating the results of the testing on the 32" outer diameter pipeline, we inferred that the 48" diameter pipeline with a smooth texture coating was unscalable at the ¾ diameter and full height exposures;

- Within the size range tested (0.34 Kg to 2.49 Kg) smaller lobsters scaled both sizes of pipelines more readily than the larger lobsters.

The exposed sections of the 32" Sable Offshore Energy Project export pipeline appears to be readily scalable by a variety of crab species based on evidence from pipeline inspection video camera surveys.

10.0 ACKNOWLEDGMENTS

The project team would like to make special acknowledgement of the ESRF scientific authority Mr. Geoff Hurley, Hurley Environmental Ltd, for his support, guidance and advise throughout every stage of the project and of Dr. Robert Miller, Research Scientist, Fisheries and Oceans Canada, for providing technical expertise related to the lobster catch, statistical analysis advice, for providing lab study direction and for his reviewing of the reports.

The very valuable assistance of the following Goldboro/Drumhead locale residents:

Jason Langley	Vernon Bingley
Francis Manthorne	Gordon Keith
Joseph Manthorne	Paul Keith

In particular, the project team would like to thank Messrs. Jason Langley and Joe Manthorne for their assistance with the lobster program and are especially indebted to Mr. Frank Manthorne for volunteering and assisting in all areas of the field programs.

Mr. Adam D. Frame, Technical Services Manager, Bredero Shaw, for supplying the project with sample protective pipeline coatings used in developing the mock-up pipeline structures.

Ms. Virginia Soehl, Jacques Whitford Limited, for reviewing the draft reports and for assistance and logistical planning with lobster mobility 48” pipeline project extension.

Ms. Susan Belford, Jacques Whitford Limited, for assistance with the snow crab data.

Mr. Cal W. Ross, Sr. Environmental Advisor, ExxonMobil Canada for supplying the pipeline flow data and snow crab information.

11.0 REFERENCES

1. Pye, Heidi J. and Winsor H. Watson III May 2004. Sound detection and production in the American lobster, *Homarus americanus*: Sensitivity range and behavioral implications. The Journal of the Acoustical Society of America -- Volume 115, Issue 5, p. 2486

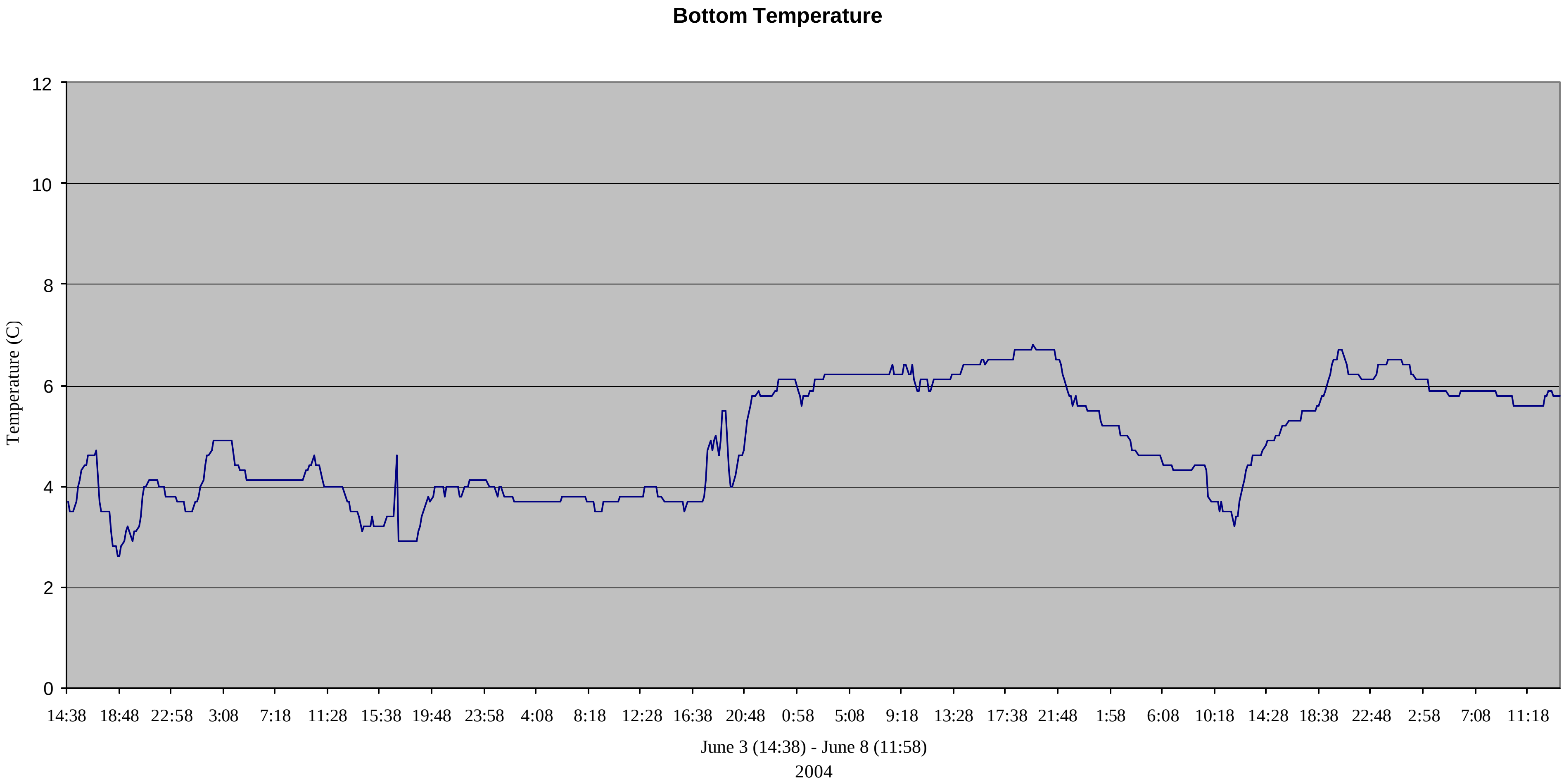
2. Lohmann, Kenneth J., N. Dean Pentcheff, Gabrielle A. Nevitt, George D. Stetten, Richard K. Zimmer-Faust, Hugh E. Jarrard and Larry C. Boles 1995. Magnetic Orientation Of Spiny Lobsters In The Ocean: Experiments With Undersea Coil Systems. The Journal of Experimental Biology 198.

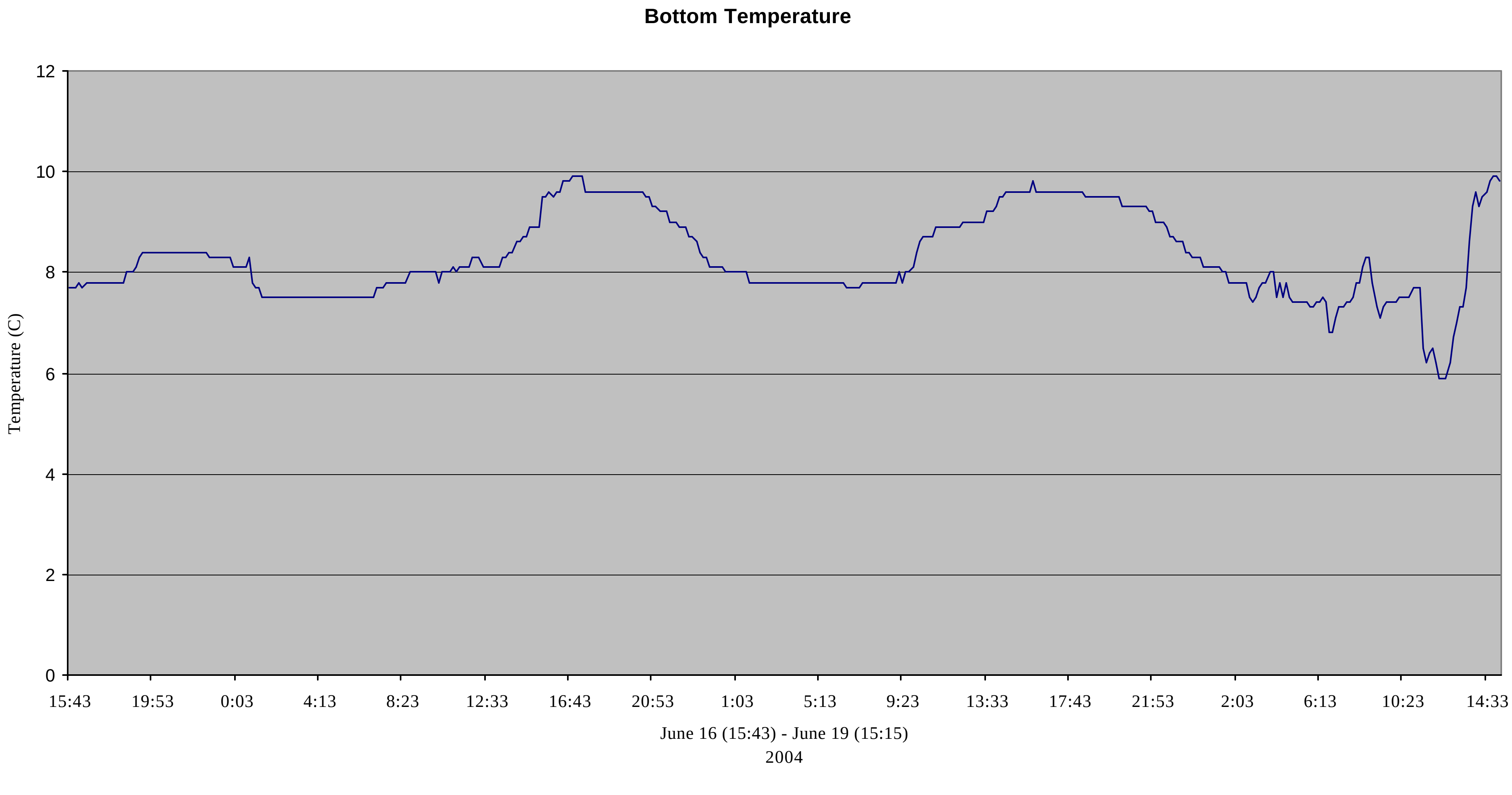
   http://www.unc.edu/depts/oceanweb/lobsters/2041.pdf

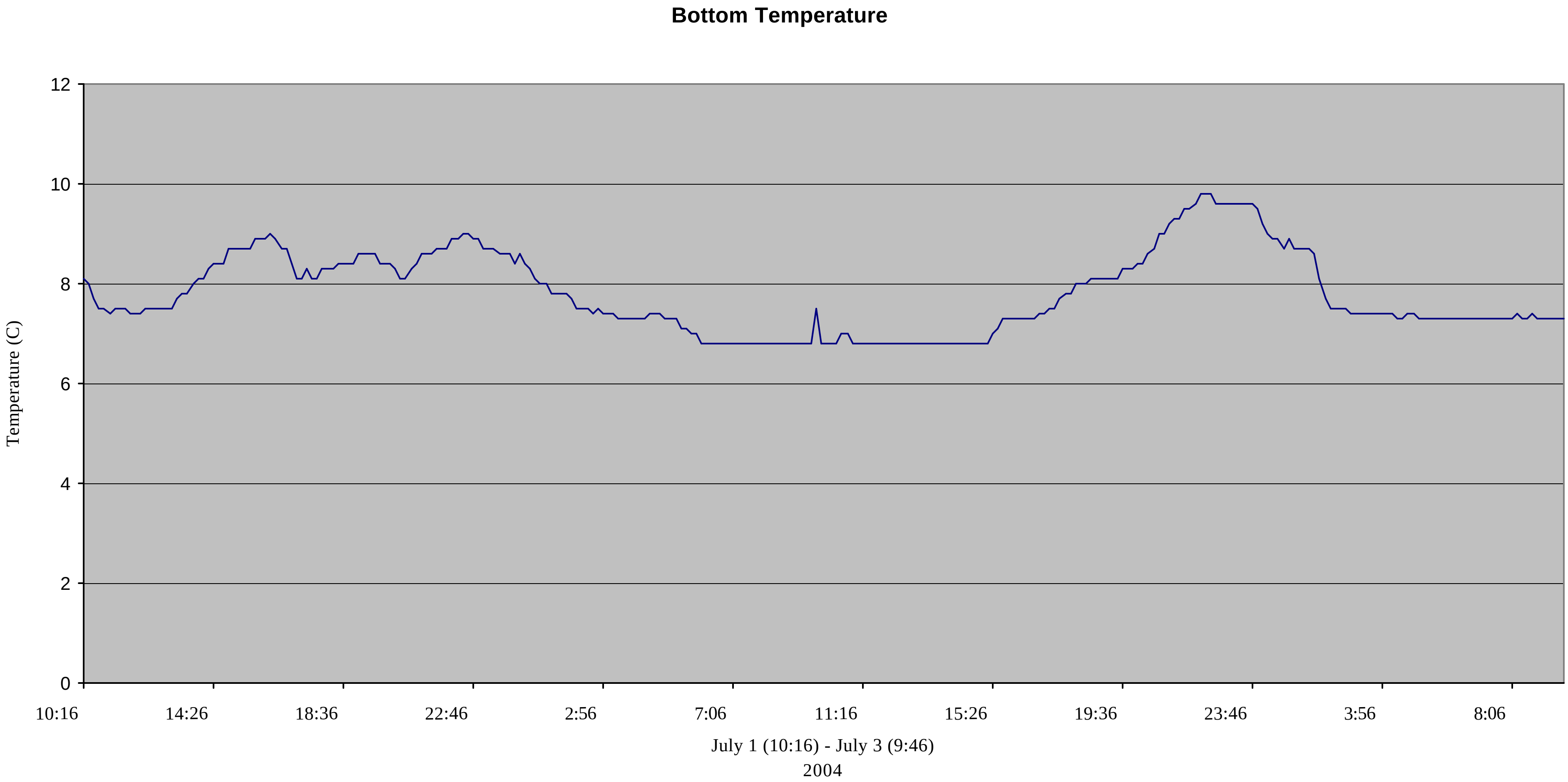
3. Jacques Whitford Limited 2003. Marine Production and Fish Habitat Associated with SOEP Tier I Offshore Facilities. Report prepared for ExxonMobil Canada East.

Appendix A

Temperature Plots


Bottom Temperature
Temperature (C)
12
10
8
6
4
2
0
14:38
18:48
22:58
3:08
7:18
11:28
15:38
19:48
23:58
4:08
8:18
12:28
16:38
20:48
0:58
5:08
9:18
13:28
17:38
21:48
1:58
6:08
10:18
14:28
18:38
22:48
2:58
7:08
11:18
June 3 (14:38) - June 8 (11:58)
2004


Bottom Temperature
Temperature (C)
12
10
8
6
4
2
0
15:43
19:53
0:03
4:13
8:23
12:33
16:43
20:53
1:03
5:13
9:23
13:33
17:43
21:53
2:03
6:13
10:23
14:33
June 16 (15:43) - June 19 (15:15)
2004


Bottom Temperature
12
10
8
6
4
2
0
Temperature (C)
10:16
14:26
18:36
22:46
2:56
7:06
11:16
15:26
19:36
23:46
3:56
8:06
July 1 (10:16) - July 3 (9:46)
2004

Appendix B

Acoustic Report