

EMERA NEWFOUNDLAND AND LABRADOR
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MARITIME LINK HABITAT UTILIZATION STUDY

AMERICAN LOBSTER AND SNOW CRAB MOVEMENT ASSESSMENT RELATIVE TO THE MARITIME LINK CABLE

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CONFIDENTIAL





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EXECUTIVE SUMMARY

The Maritime Link involved the construction and operation of a new high-voltage direct current transmission line, as well as a high-voltage alternating current transmission line and associated infrastructure between Granite Canal, Newfoundland and Labrador (NL), and Woodbine, Nova Scotia (NS). Part of this connection included two 170 kilometre submarine cables across the Cabot Strait between Cape Ray, NL, and Point Aconi, NS. Construction was completed in 2017, and the Maritime Link went into service in January 2018. An Environmental Effects Monitoring Program (EEMP) was required as part of the Project Environmental Assessment (EA) to assess the potential impact(s) of the energized submarine cables on local lobsters and crabs. An *in-situ* field study of lobster and crab behaviour was selected for this EEMP as lab studies, particularly those focused on movement behavior, suffer from a lack of realism.

Acoustic telemetry was selected to address the challenge of fine-scale animal detection for both snow crab and lobster. This involved two main components: 1) arrays of hydroacoustic receivers to detect transmissions, and 2) external acoustic transmitter tags attached to crab and lobster sending unique identifier signals. To enable behaviour analysis, animal movements needed to be tracked over long periods of time. This was achieved through recording successive tag transmissions and rebuilding a movement track for each tagged animal. To this end, multiple receivers were set up in two separate arrays overlapping the submarine cables route, as a minimum of three receivers are needed to triangulate the position of animal tags. The array for American lobster was set up around the cable route in water depths of 7 m to 21 m near Point Aconi, Cape Breton, NS. The snow crab array was set up in deeper water (100 m to 120 m depth) along the cable route east of Ingonish, Cape Breton, NS. These arrays were deployed twice before the installation of the cable (in 2014 and 2015), and twice after installation (in 2018 and 2023). In 2018, the study was performed while the submarine cables were energized but not transmitting power. In contrast, the 2023 study was conducted under typical Maritime Link operating conditions, with substantial power flows across the cables.

With each deployment, 40 lobsters and 48-116 crab were caught, had tags attached, and were released within the respective arrays to track their movement.

The objective of this study was to determine whether energized submarine cables influence snow crab and lobster behaviour by addressing the following items:

1. Assess crossing success of tagged animals from before installation to normal operation,
2. Evaluate the influence of cable current load, and
3. Compare movement rates:
 - a. Inside vs outside the cable “zone of influence” (ZOI)
 - b. Before vs after cable energization

Statistical analyses were run using animal position data from before and after the submarine cables were installed (2014/2015 and 2015/2016), and data collected during normal operation after installation (2023-2024). These results concluded that there was no significant change in animal movement patterns (i.e., horizontal displacement along the seafloor) between the period before the installation of the submarine cables and during normal operation of the Maritime Link. It also determined that cable current load did not impact natural crossing behaviour, i.e. snow crabs and lobsters behaved similarly whether the energy transfers were high, low, or nonexistent. Further, animal movement rates (i.e., horizontal displacement

along the seafloor) within the “zone of influence” of the submarine cables (defined as within 5 m of the cables) were not significantly different from before the cable installation and after.

Movement rates were influenced by time of day and temperature, with American lobsters moving faster during the day and snow crab moving faster at night, and both species moving faster at higher temperatures. Acclimation status was also included in the movement rate models to account for potential handling and release effects, as individuals may exhibit atypical movement shortly after release.

Interpretation of this effect should be cautious, as the final datasets may underrepresent individuals that left the array shortly after release; therefore, greater weight should be placed on the post-acclimation period, which contained substantially more data. Snow crab movement rates were also higher before the installation of the cable compared to after; however, as this pattern was observed both within and outside the “zone of influence”, it is not likely related to the presence or operation of the submarine cables.

Overall, no statistically significant behavioural changes were detected before and after the cables’ installation and operation, at varying current loads, or within the “zone of influence” for either American lobster or snow crab.

1 INTRODUCTION

The Maritime Link Project involved the construction and operation of a new 500-megawatt (MW) $\pm$ 200 kilovolt (kV) high-voltage direct current (HVDC) line, as well as a 230 kV high-voltage alternating current (HVAC) transmission line and associated infrastructure between Granite Canal, Newfoundland and Labrador, and Woodbine, Nova Scotia. The Project also includes two 170 kilometres (km) HVDC submarine cables across the Cabot Strait, close to 50 km of overland transmission in Nova Scotia and nearly 300 km of overland transmission on the island of Newfoundland. Construction was completed in 2017, and the Maritime Link went into service in January 2018. The rationale behind the Maritime Link included enhanced interconnection between the Nova Scotia and Newfoundland and Labrador electric grids, providing increased reliability, and giving Nova Scotia access to renewable energy to offset the use of fossil fuels and help the province achieve its decarbonization goals.

The integration of power transmission infrastructure, such as offshore wind turbines or HVDC submarine cables, into marine development can have significant impacts on marine ecosystems. HVDC submarine cables generate electromagnetic fields (EMF), which, if strong enough, can induce local magnetic anomalies that interfere with the Earth's natural geomagnetic field. Many marine species rely on this geomagnetic field for essential behaviors like navigation, locating conspecifics, and detecting prey (Hutchison et al. 2020a; Hermans et al. 2024). Species such as salmon, turtles, and spiny lobsters use natural EMF to guide their long-distance migrations (Lohmann and Lohmann 2006, 2007; Putman et al. 2013), while elasmobranchs, like sharks and rays, rely on EMF fluctuations to locate prey (Hermans et al. 2024).

However, our understanding of how marine species respond to anthropogenic changes in EMF - particularly in natural conditions - is still limited (Boehlert and Gill 2010; Woodruff et al. 2013). This knowledge gap not only generates resistance to infrastructure projects but also impedes the development of effective mitigation strategies to minimize potential ecological impacts (Woodruff et al. 2011).

EMF may also affect benthic organisms by distorting navigational fields, masking the signatures of potential prey (Hutchison et al. 2020a), or attracting predators (e.g., Gill et al. 2009). While studies have investigated these effects on American lobster in controlled environments, such as tanks (Woodruff et al. 2013) and mesocosms (Hutchison et al. 2020b), assessing these effects in natural conditions remains challenging. To detect changes in movement behavior, it is necessary to examine how species' movements deviate in the presence of EMF anomalies. For example, reduced success in crossing an HVDC cable could indicate that the EMF is acting as a barrier. Other subtle behavioral shifts, such as changes in movement velocity, turn angles, or behavioral states (e.g., feeding or refuge-seeking), may also indicate disturbances. For example, increased straight-line movements near submarine cables could signal avoidance, even if the cable is not an absolute barrier. Alternatively, more meandering movement tracks might reflect disorientation or increased foraging behavior near the cables.

While simple mark-recapture techniques can assess whether tagged animals cross HVDC cables (e.g., Love et al. 2017), detecting smaller-scale behavioral changes requires precise movement data. This can only be obtained through telemetry positioning systems and advanced movement models, which are necessary to track animals' movements in deep-water environments (Westerberg and Lagenfelt 2008; Gill et al. 2009; Normandeau 2011; Klimley et al. 2021).

In Atlantic Canada, Snow Crab (*Chionoecetes opilio*) and American Lobster (*Homarus americanus*) are key commercial species. Although these species do not exhibit migrations on the scale of known EMF-sensitive animals, they do undergo regional seasonal migrations and dispersals (Pezzack and Duggan 1986; Mullowney et al. 2018) that could be affected by EMF anomalies. Consequently, when a major submarine HVDC transmission line was proposed to link southwestern Newfoundland to Cape Breton,

Nova Scotia - bisecting the Cabot Strait, a crucial fishing area for lobster and snow crab - concerns about the potential impact of the cables on species movements were raised by both harvesters and regulators (Fisheries and Oceans 2012).

Emera Newfoundland and Labrador (ENL) conducted an Environmental Assessment (EA) of the Maritime Link Project which was approved in 2013 with a number of conditions, including the requirement to design and implement an Environmental Effect Monitoring Program (EEMP) to assess the potential effects of the installation and operation of the Maritime Link submarine cables on local fisheries. WSP Canada Inc. (formerly Amec Foster Wheeler and Wood E&I Canada) was commissioned by ENL to collect baseline and post-energization data on snow crab and American lobster habitat use and movements in the vicinity of the Maritime Link submarine cables. The goal was to assess whether there are behavioural effects on snow crab and lobster related to the Maritime Link Project submarine cables, which were installed in 2017. At the time of the EA, few studies had assessed the residual effects of submarine cables on benthic invertebrates. After consultation with Fisheries and Oceans Canada (DFO) Science, DFO's Fish and Fish Habitat Protection Program (FFHPP), and local commercial harvesters, the study areas were identified within the very active fishing grounds for both lobster and crab in the Sydney Bight, on the Nova Scotia side of the Cabot Strait. Through these discussions, a methodology employing positioning telemetry technology (Vemco Positioning System – VPS) using hydroacoustic tags and receiver arrays was deemed the most effective approach for *in-situ* monitoring of lobster and crab (Cote et al. 2019). To minimize artifacts and confounding factors, the study was designed to closely replicate real-world conditions, and used a before-after control-impact (BACI) design, with two years of monitoring pre-installation of the cable and two years post-installation under normal operation; however, results from the first post-installation tagging (2018-2019) were excluded from the statistical analysis (see Section 2.4.3 for detail).

1.1 PROJECT LOCATION

The final submarine cables route was determined based on engineering solutions which ensured that cable technical properties were met during installation, as well as avoiding hazardous and sensitive areas, while minimizing overall cable length. The cables were protected by:

1. Horizontal Directionally Drilled (HDD) casing at transition locations from land-to-subsea in Cape Ray (Newfoundland) and Point Aconi (Nova Scotia),
2. Rock berms at the submarine exit points of the HDD casings,
3. Trenching in the seabed where possible, and
4. Rock berms in locations where trenching alone could not achieve the required cable protection criteria (i.e. ≥ 1 m below seabed).

Off the coast of Nova Scotia (Point Aconi), the HDD boreholes emerge onto the seabed approximately 1.2 km from shore at a depth of about 12 m. In Newfoundland, the cables exit the HDD roughly 600 m from shore at a depth of approximately 23 m. For the most part, protection of the submarine cables was achieved through trenching, including across both lobster and snow crab study areas. Trenching was achieved using a remotely operated subsea system that uses high-pressure water jets to fluidize seabed sediments and bury the cables below the sea floor for protection from anchors, fishing gear, and environmental damage. Hence, the installation of the cables itself had a minimal impact on the local seabed and substrate conditions.

The project area is located in the Sydney Bight, off the coast of Nova Scotia, in eastern Canada. The locations of the acoustic telemetry arrays were determined through consultations with local harvesters and regulators to ensure alignment with known snow crab and lobster habitats, which overlapped with the proposed submarine cables installation. Two distinct study areas were established, reflecting the differing habitat preferences of each species. The snow crab study area was located about 35 km from the cables' landing point at Point Aconi, at depths ranging from 100 to 120 meters, while the lobster study area was situated approximately 2 km offshore, at depths between 12 and 15 meters (Figure 2-2).

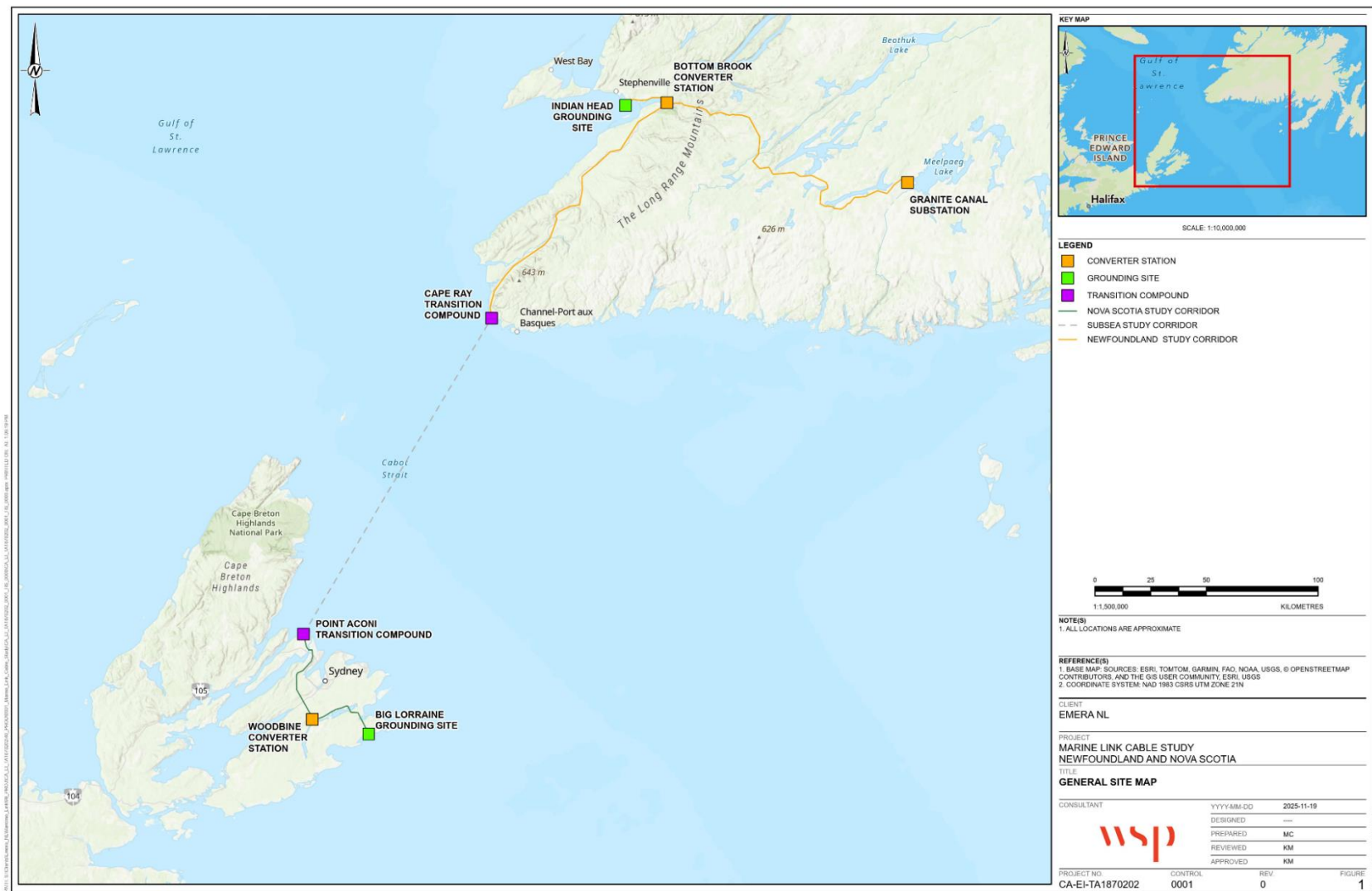


Figure 1-1 Maritime Link Project Area

1.2 ENVIRONMENTAL ASSESSMENT

The Environmental Assessment (EA) Report for the Maritime Link Project was filed with the Canadian Environmental Assessment Agency, Nova Scotia Environment, and Newfoundland and Labrador's Department of Environment and Conservation on January 17, 2013. The EA indicated that the adverse residual environmental effects from the Project activities (i.e., operations of the submarine cables) were predicted to be not significant, including Valued Ecosystem Components such as commercial fisheries and the marine environment. Consequently, on June 21, 2013, the Maritime Link Project received Ministerial approval and was released with conditions.

The EA condition for the habitat utilization study reads as follows: "ENL [Emera Newfoundland and Labrador] will develop and implement a pre-construction study and [environmental effects] monitoring program (EEMP) in consultation with the FLCs [Fisheries Liaison Committee], which will continue through the operation phase of the Project, to verify potential effects of magnetic fields or other Project effects on migration of benthic organisms for relevant fisheries"

This condition led to the development and implementation of an EEMP using relevant baseline data and appropriate environmental effects indicators. Through engagement with Fisheries and Oceans Canada (DFO; lead agency for the marine portion) in Dartmouth, Nova Scotia Power Maritime Link Inc. (NSPML) and Amec Foster Wheeler (now WSP) developed an EEMP for snow crab (*Chionoecetes opilio*) and American lobster (*Homarus americanus*) to confirm that the physical presence and energization of the submarine cables do not have an adverse impact on the movements of these benthic species. The focus on these two species emerged from the EA screening and consultations with DFO which determined that only mobile benthic species would be exposed to magnetic field anomalies at levels potentially significant enough to pose a risk of impact. American lobster and snow crab are two of the most important commercial species in the region that are benthic and mobile.

1.3 POTENTIAL CABLE EFFECTS ON MARINE FAUNA

Ways in which the submarine cables could cause a partial or full barrier include avoidance responses associated with temperature or altered navigational cues due to magnetic fields associated with operation of cables.

1.3.1 TEMPERATURE

The flow of an electric current in a wire creates heat through a phenomenon known as Joule heating. This heat is minimized though the sheathing around the cables as well as by the burial of the cables. Worst-case scenario modelling conducted as part of the EEMP determined that the seabed surface temperature changes associated the operation of the submarine cables at full capacity (250 MW each) will be extremely small (+0.2°C), remaining within the natural variability of the environment and are not likely to be detected by epifaunal animals as the cables are buried into the sediment or buried under rock berms (Nexans 2015). Temperature anomalies caused by the submarine cables were therefore not part of the focus of the EEMP.

1.3.2 MAGNETIC FIELDS

A fundamental property of electromagnetism is that an electric current creates a magnetic field centered on the conductor. This is true of any type of conductor and any electric current intensity. In a wire or

cables, the strength of the magnetic field is directly proportional to the current, with the strength of the field at any given distance from the conductor calculated using the formula below:

$$B = \frac{I}{2\pi r} \mu_0$$

Where:

B is the magnetic field strength,

I is the current,

r is the distance from the source/wire,

and μ_0 is the permeability of free space ($4\pi \cdot 10^{-7} \text{ N/A}^2$).

As such, the magnetic field is proportionally stronger the closer you are to the cables, and proportionally stronger when you increase the current. Magnetic fields cannot be directly shielded or blocked, though fields can be redirected by using high permeability materials. However, this technology is designed to shield sensitive equipment and weak signals from magnetic interference and is not an effective method to shield high voltage transmission cables. Understanding the behaviour of magnetic fields as described by the equation above, the most effective way to reduce the intensity of local magnetic anomalies is to increase the distance between the source (e.g. the cables) and any receptor (e.g., benthic fauna), such as by trenching or burying electric cables.

As part of the measures to protect the Maritime Link submarine cables and mitigate environmental impact, the cables were trenching in soft sediment along the majority of the installation route. In areas where trenching alone could not achieve the required level of protection, the cables were covered with rock berms.

As previously noted, the magnetic field generated by each cable decreases rapidly with distance. Along the Maritime Link route, the two submarine cables are separated by distances ranging from several tens of meters to several hundreds of meters, depending on water depth. At these separations, the magnetic fields produced by the individual cables have little to no influence on one another.

For organisms living on or near the seabed, this means they are exposed to both the Earth's natural geomagnetic field and the magnetic field produced by the energized cables. Depending on the direction of power flow (from NL to NS or from NS to NL), the cable-generated magnetic field will tend to align with or oppose the direction of the Earth's magnetic field (Figure 1-2).

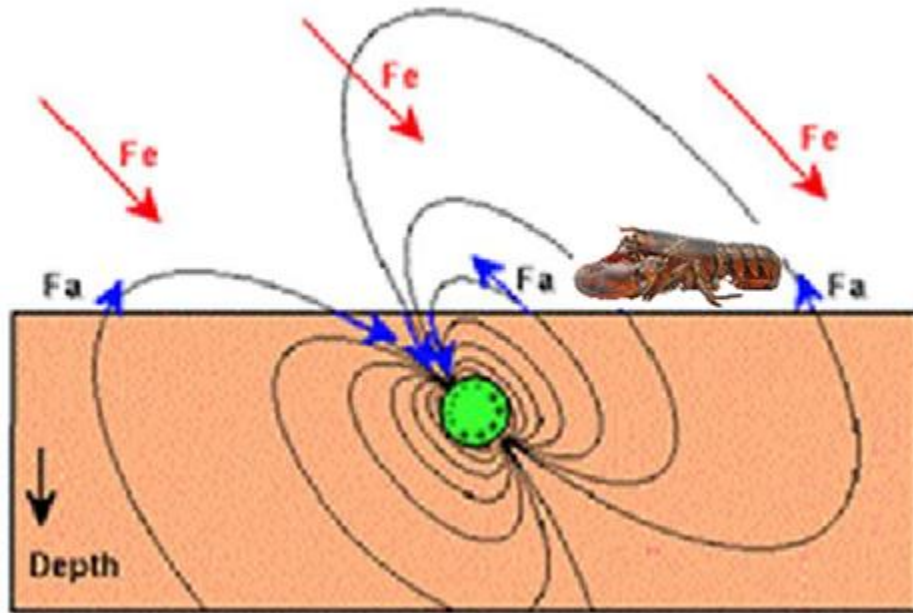


Figure 1-2 Schematic representation of magnetic field lines surrounding a buried energized submarine cable (green core). The Earth's geomagnetic field (Fe, red arrows) interacts with the cable-generated magnetic field (Fa, blue arrows).

Electromagnetic fields can affect marine life, especially species that use magnetic fields for navigation (e.g., Pacific salmon, spiny lobsters) or prey detection (e.g., elasmobranchs) (Lohmann et al. 1995; Boles and Lohmann 2003; Wiltchko and Wiltchko 2005; Lohmann and Lohmann 2006; Lohman et al. 2007). Magnetic anomalies associated with submarine power cables may result in behavioural changes in marine species, including altered foraging activity, reduced movement rates, directional disorientation, and physiological stress responses. Reported effects are highly species-specific and may also vary across life stages. Species that rely on geomagnetic cues for orientation, navigation, or prey detection are considered more likely to be affected by anthropogenic magnetic fields. Although magnetoreception and magnetic-field-related behavioural responses have been documented in several crustaceans, including spiny lobsters and crabs, there remains a limited body of published research examining the long-term effects of cable-generated magnetic fields on benthic invertebrates under *in-situ* conditions. Whether at the time of the EA or at present, existing studies on lobster species have primarily focused on short-term behavioural responses to electromagnetic fields associated with subsea cables (e.g., Hutchison et al., 2020), while information for snow crab and other benthic decapods remains particularly scarce. Inputs from the EA for the Maritime Link Project from local harvesters indicated concern that the electromagnetic anomalies caused by the submarine cables may interfere with the life cycle of American lobster and/or snow crab.

1.3.2.1 SUBMARINE CABLE MAGNETIC FIELD MEASUREMENTS

Based on predictive modelling, altered electromagnetic fields are expected to occur in close proximity to the Maritime Link submarine cables, dissipating to similar levels of intensity to the Earth's field ($51 \mu\text{T}$) at approximately five metres from the cable (at maximum load) and to levels of 1-3% of the Earth's field at approximately 10 m (Figure 2-1).

To measure the *in-situ* intensities of magnetic anomalies from the Maritime Link submarine cables and grounding sites, a 72-hour "outage" was coordinated with both NS and NL utilities to temporarily control the energy flow across the system. During this period, current was transmitted from NL to NS at 50% of maximum capacity across both submarine cables (125 MW on each cable). The operation of both submarine cables in the same direction resulted in an additive power flow of 250 MW to the grounding electrode sites. This 50% limitation on the cables was imposed by the design capacity of the grounding

electrode sites, which is set at 250 MW, as these sites are intended to replace one of the poles in the event of a failure. As such, the magnetic anomalies generated under these conditions represent half of the values that would be expected under maximum load conditions for the submarine cables.

CSR GeoSurveys Ltd. (CSR) was contracted in 2018 to undertake a marine magnetic survey over the Maritime Link HVDC submarine cables on the Nova Scotia side of the Cabot Strait at two locations during this outage:

- a nearshore location over the 20 m isobath (over the lobster habitat) approximately 3 km from the Point Aconi landfall site, and
- an offshore location over the 105 m isobath (over the snow crab habitat), approximately 23 km from the Point Aconi landfall site.

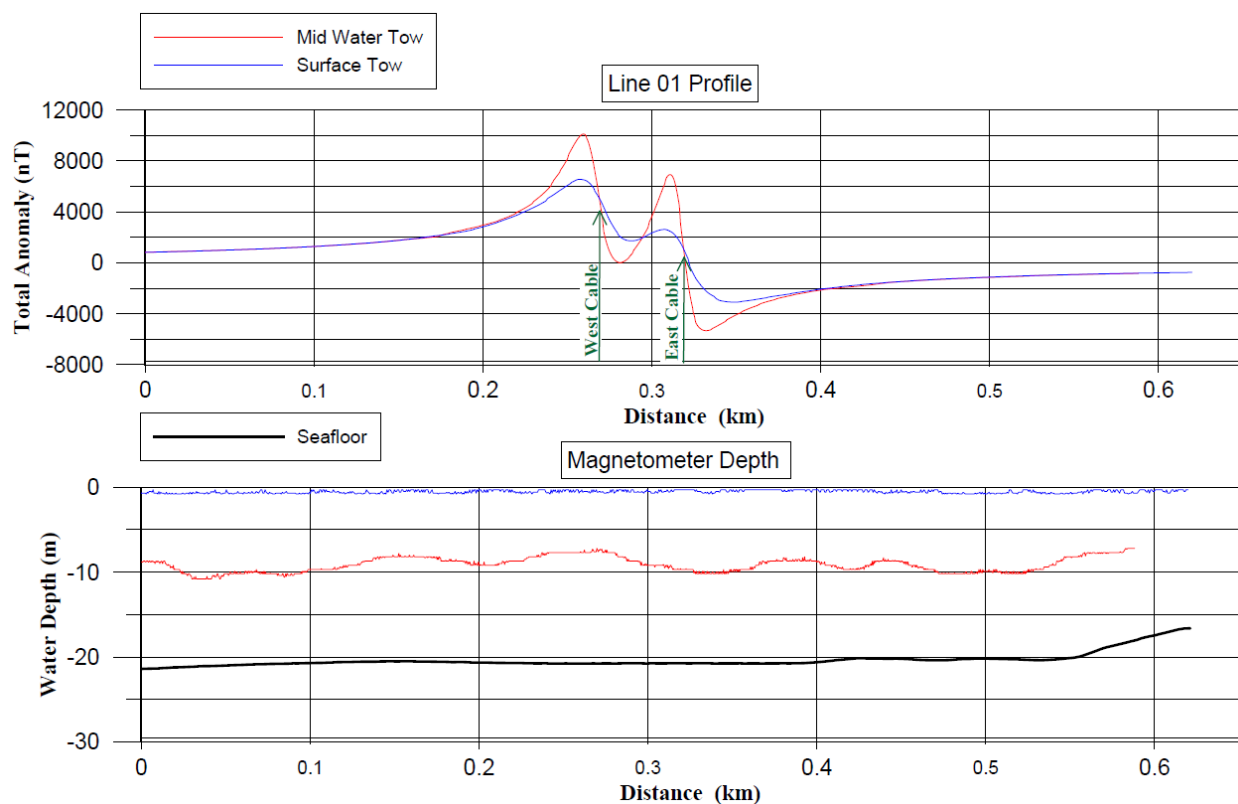


Figure 1-3 Top graph shows the typical magnetic anomalies measured over the Maritime Link submarine cables off Point Aconi (NS), while cables were operated at 50% capacity. Bottom graph shows the corresponding depth of the magnetometer during the survey. The black line represents the seabed.

The survey was completed between May 8th and May 10th, 2018, with cables operated at half the maximum capacity of the system (125 MW) for 72 hours. Figure 1-3 above illustrates the results from a typical transect line perpendicular to the submarine cables, as described in detail in the survey report (CSR GeoSurveys Ltd, 2018). Overall, the Earth's magnetic field recorded during the survey at the base station ranged from 51,395 nT to 51,447 nT. Over the duration of the surveys, maximum values recorded through the Maritime Link ranged between -7,210 nT (over the eastern cable) and 17,698 nT (over the western cable), representing -14% and 34% of the Earth magnetic field, respectively.

The figure below illustrates the distribution of the average magnetic field intensities measured perpendicular to the Maritime Link submarine cables in the coastal environment (lobster habitat) and

further offshore (snow crab habitat) alongside the Earth's natural magnetic field for comparison (Figure 1-4). Note the attenuation of the field with distance from the cables, consistent with the equation given in Section 1.3.2.

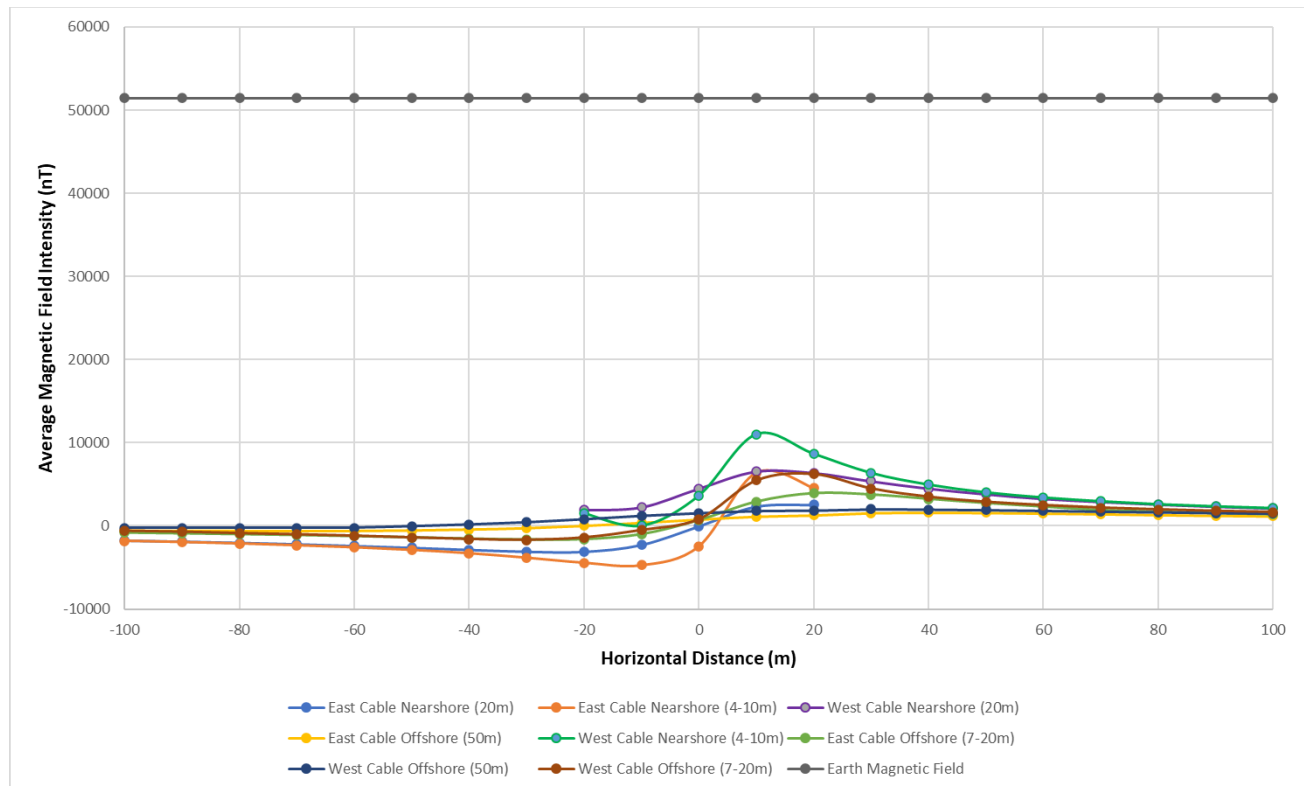


Figure 1-4 Average magnetic anomalies measured across the Maritime Link submarine cables under 125 MW load compared to Earth's natural magnetic field

1.4 STUDY OBJECTIVES AND RATIONALE FOR APPROACH

1.4.1 BACKGROUND

Altered electromagnetic fields at full transmission power are expected to occur in close proximity (<5 m) to the submarine cables; i.e. a magnetic field greater than the Earth's geomagnetic field (i.e., 51 μT in the Cabot Strait) may extend up to 10 m from the submarine cables (DFO 2013). Behavioural responses for decapods (American lobster and Dungeness crab) have not been detected or have been inconclusive in laboratory trials that have specifically tried to replicate the level of EMF disturbance associated with submarine cables (Woodruff et al. 2012; Woodruff et al. 2013). Moreover, there are no known examples of significant behaviour modification caused by the many existing submarine cables throughout the world (Woodruff et al. 2013).

To ensure conditions reflected the natural environment as closely as possible, an *in-situ* study of lobster and crab behaviour was selected for this EEMP. Laboratory experiments or experiments conducted in submerged enclosed environments restrict animal movement by the nature of the study and may not represent real-world exposure to magnetic field anomalies that animals on the seafloor may perceive.

One challenging aspect of the study is that the nature of the questions and spatial scales at which interactions occur could be very fine, that is, the effects may only occur within a small area around the submarine cables. As a result, many conventional study approaches may not be well suited for assessing submarine cable-related effects. For example, conventional mark-recapture movement studies may provide information on large scale movements of individuals, but they lack the resolution to determine the use/avoidance of a relatively small area affected by heat or magnetic signatures of a submarine cable. Conventional mark-recapture approaches would also be unable to detect subtler behavioural effects of animals as they approach and interact with a submarine cable area.

Similarly, reliance on stock status/abundance may not be effective at the timescales needed for assessment, and such approaches would be expected to be strongly influenced by existing stock trajectories and changing ecosystem conditions that are external to the project (e.g. Choi et al. 2014).

1.4.2 OBJECTIVES

There are three primary mechanisms in which snow crab and American lobster can potentially be affected by the installation of the submarine cable:

1. Direct mortality during installation;
2. A reduction of habitat quality following cable installation; and
3. The creation of a barrier (physical, navigational, or physiological) to migratory movements.

Of these three potential mechanisms, direct mortality is short-term (i.e., during installation) and affects animals across a limited spatial extent. The latter two mechanisms, in contrast, could potentially have ongoing effects that continue through the operational phase of the Maritime Link. Consequently, the focus of this study was to collect data that will facilitate the evaluation of the potential effects given as 2) and 3) above when the submarine cables are installed and operated under steady state.

1.4.3 RATIONALE

Acoustic telemetry was selected to address the challenge of fine-scale animal detection for both snow crab and lobster. Acoustic telemetry systems are widely used around the world in challenging environments and on a variety of species that include benthic and deep-water species such as snow crab (e.g., Kanawa et al. 2014, Cote et al. 2019). The systems boast reduced tag sizes, longer tag life, and are capable of simultaneously tracking multiple individuals at relatively high resolution (<10 m; Konecny et al. 2024). A proof of concept and baseline data collection program was completed in 2014-2015 that allowed the methods and analysis to be developed and confirmed specifically for the Project area (e.g., distance between acoustic receivers and array geometry for adequate positioning accuracy within the fine-scale array). This helped optimize the likelihood that tags within the array would be detected by at least 3 receivers, thus allowing for triangulation of tag position and track reconstruction.

Two types of acoustic array were employed during this study:

1. VPS arrays which are an acoustic fine-scale positioning system, capable of providing metres level position resolution of many animals simultaneously. It is composed of equally spaced receivers configured to ensure that tag transmissions occurring within the array are detected by at least three acoustic receivers, thereby permitting accurate triangulation of the tag's position.
2. Presence/absence array consisting of a chain of receivers deployed along both sides of the submarine cables at wider interval, acting as gates to provide far-field evidence that crabs could cross the submarine cables corridor. These arrays were installed to increase the range of detection at the request of local snow crab harvesters following engagement with the fisheries liaison committee and DFO, understanding that snow crab can move tens of kilometers in a season.

Presence/absence telemetry provides important information on larger scale occurrences and movements of study animals; specifically, the likelihood that the species of interest naturally crosses the proposed submarine cables route. These arrays consisted of acoustic receivers spaced further apart along parallel transects on both sides of the Maritime Link cables route. They extended North and South beyond the VPS array (Figure 2-2). Due to the larger spacing (approximately 400-800 m apart), the array could only detect tagged animals as being present or moving towards/away from the receiver, hence only providing information on movement direction. These presence/absence arrays were only deployed at the deeper snow crab study area.

Processing of VPS detections allows for the reconstruction of movement tracks through time, thus permitting the analysis of more subtle changes in movement behaviours (velocity, direction, and the consistency at which such behaviours are presented) should they be exhibited by animals when in proximity to the submarine cables. The arrays consist of a series of 9-16 acoustic receivers deployed in a 3x3 or 4x4 configuration with overlapping detection ranges to allow for triangulation of tagged animal locations as described below.

2 METHODS

2.1 STUDY AREA

Emera Newfoundland and Labrador (ENL), with input from the fisheries liaisons committees, Indigenous Peoples and regulators, identified the study areas for the array layout for both lobster and crab in 2014. The post-installation study areas and array geometries were adjusted slightly based on final submarine cable route selection and as-built information to ensure optimal coverage of the cables. The locations of the telemetry arrays were determined through consultations with local harvesters and regulators to ensure alignment with known snow crab and lobster habitats, which overlapped with the proposed submarine cables installation. Two distinct study areas were established, reflecting the differing habitat preferences of each species. Following installation, submarine cables within the study areas were embedded in the sediment using the trenching technique. To characterize and map habitat types within each study area, GIS-stamped (Geographic Information System) video transects were conducted.

2.1.1 ZONE OF INFLUENCE

As described in Section 1.3.2, the strength of a magnetic field decreases proportionally with distance from the source. For the purpose of statistical analysis, a “zone of influence” (ZOI) of the cables was defined as the area within 5 m of the proposed cable locations for pre-installation analyses, and within 5 m of actual cables locations during normal-operation analyses. This distance represents the point at which the cables’ magnetic fields under full load (250 MW) were modeled to be of comparable intensity to the Earth’s (51 μT ; Figure 2-1). Animal positions were also categorized according to whether they occurred in a larger, secondary area, referred to as the Extended ZOI (EZOI). This zone included the entire area between the two submarine cables and extended 50 m beyond both cables.

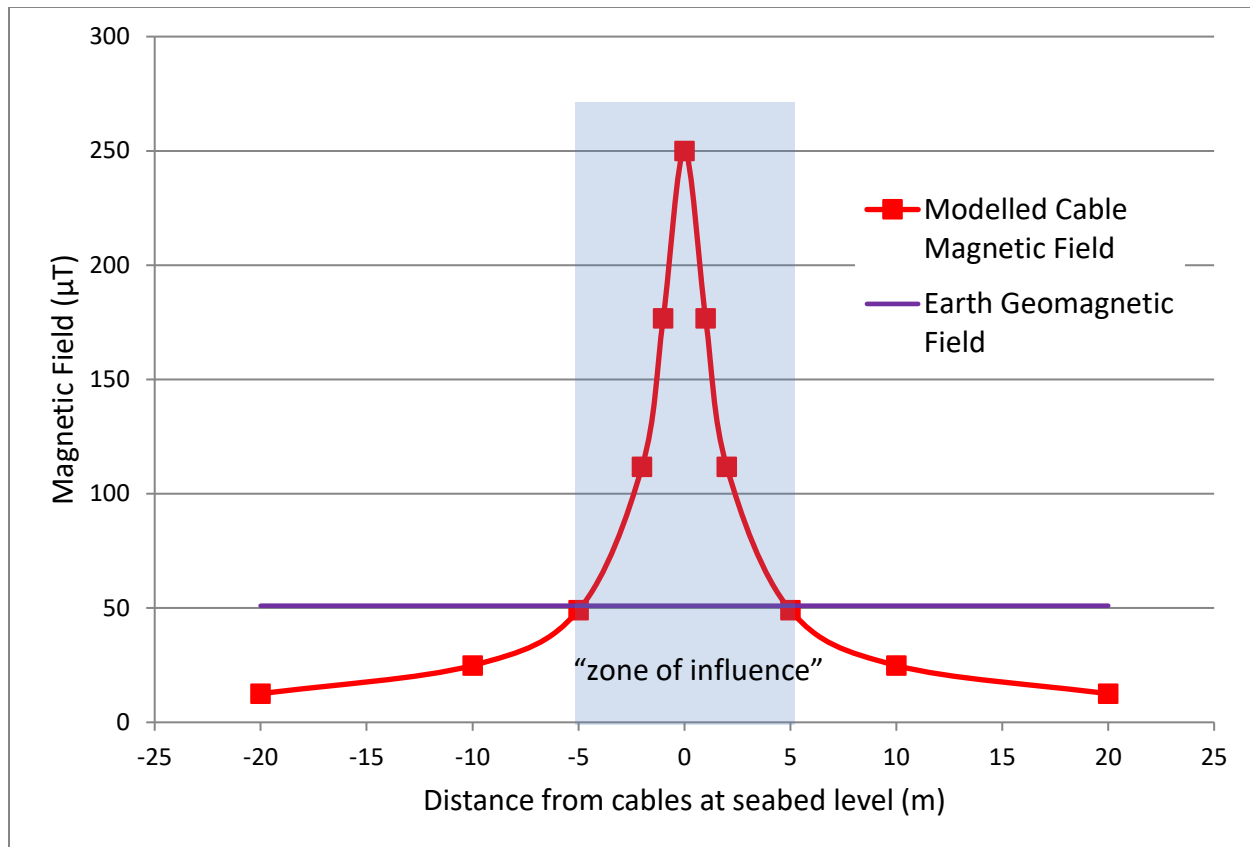


Figure 2-1 Modeled magnetic field intensity with increasing distance from the cable under maximum power transmission conditions (250 MW) assuming a 1 m burial depth

2.1.2 BASELINE HABITAT CHARACTERIZATION

Two separate study areas were delineated for American lobster and snow crab due to differing habitat preferences of each species. The substrate and aquatic benthic vegetation composition was characterized at each site; each location selected had suitable habitat features for each species within the cable corridor. The lobster study area was located nearshore in water depths from 7 to 21 m while the snow crab study area was further offshore in depths from 100 to 115 m (Figure 2-2). Habitats within the snow crab and American lobster VPS positioning arrays were characterized and mapped using drop video camera methods outlined by DFO (see Simkanin et al. 2005 and Kelly et al. 2009) in January and August 2015, respectively. In the shallow water of the lobster array, the camera was towed along pre-defined transects. However, the depths (~100 m) and currents associated with the snow crab study area, required the use of drift transect methods resulting in non-linear and non-parallel transects (Figure 2-3). Video from the camera was recorded and stamped with the geographic position and time and summarized in GIS.

The snow crab study area was composed of uniform soft substrate with occasional rock or boulder emerging from the sediment, which is consistent with the hydroacoustic mapping surveys assessments for this area (Figure 2-3; MacGregor Geoscience Limited 2012). Unlike some other crab species, commercially targeted, snow crabs (terminal moult males) do not show a strong affinity for complex emergent benthic structures, instead settling in areas with little to no emergent structure (Ottmar et al., 2022). Snow crabs are highly stenothermic, favoring cold water (<2°C; Thesslund et al., 2024; McGinn & Chen, 1992) and fine, organically rich sediments such as mud or sandy mud, especially during early

benthic stages. As such, the habitat of the snow crab study area was categorized in uniform muddy bottom.

The lobster study area included a variety of habitats, such as sandy bottom, coarse substrate, and bedrock, with varying degrees of algal cover. For this study, the area was mapped based on the percentage of algal cover, as canopy presence is known to significantly influence lobster behavior (Jarrett et al., 2024; Konecny et al. 2024). Shelter selection is a critical aspect of American lobster ecology, influencing survival, growth, and behavior. The role of algal canopies and related habitat features in providing shelter and shaping lobster behavior has been explored in both laboratory and field studies, with recent research highlighting shifts in habitat use due to environmental changes. Long-term field studies in coastal Maine have documented a decline in kelp abundance and a rise in diminutive algal turfs, coinciding with a reduction in lobster occupancy of traditional boulder shelters and increased use of featureless habitats. These habitat changes, along with warming waters, may indirectly affect lobster sheltering behavior and distribution, suggesting behavioral plasticity in response to environmental shifts (Jarrett et al., 2024; Karnofsky et al, 1989; Cobb, 1971).

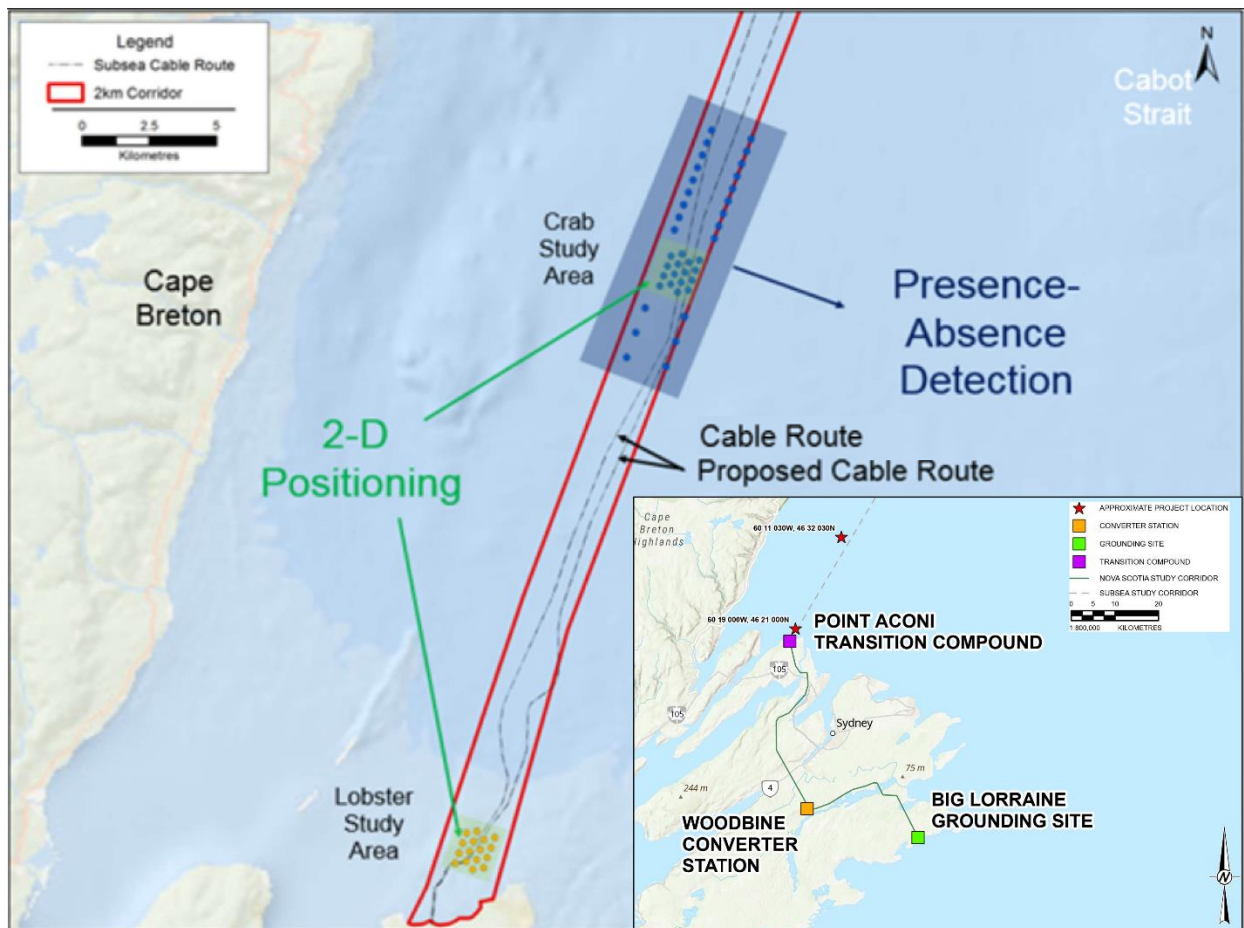


Figure 2-2 American lobster and snow crab study areas

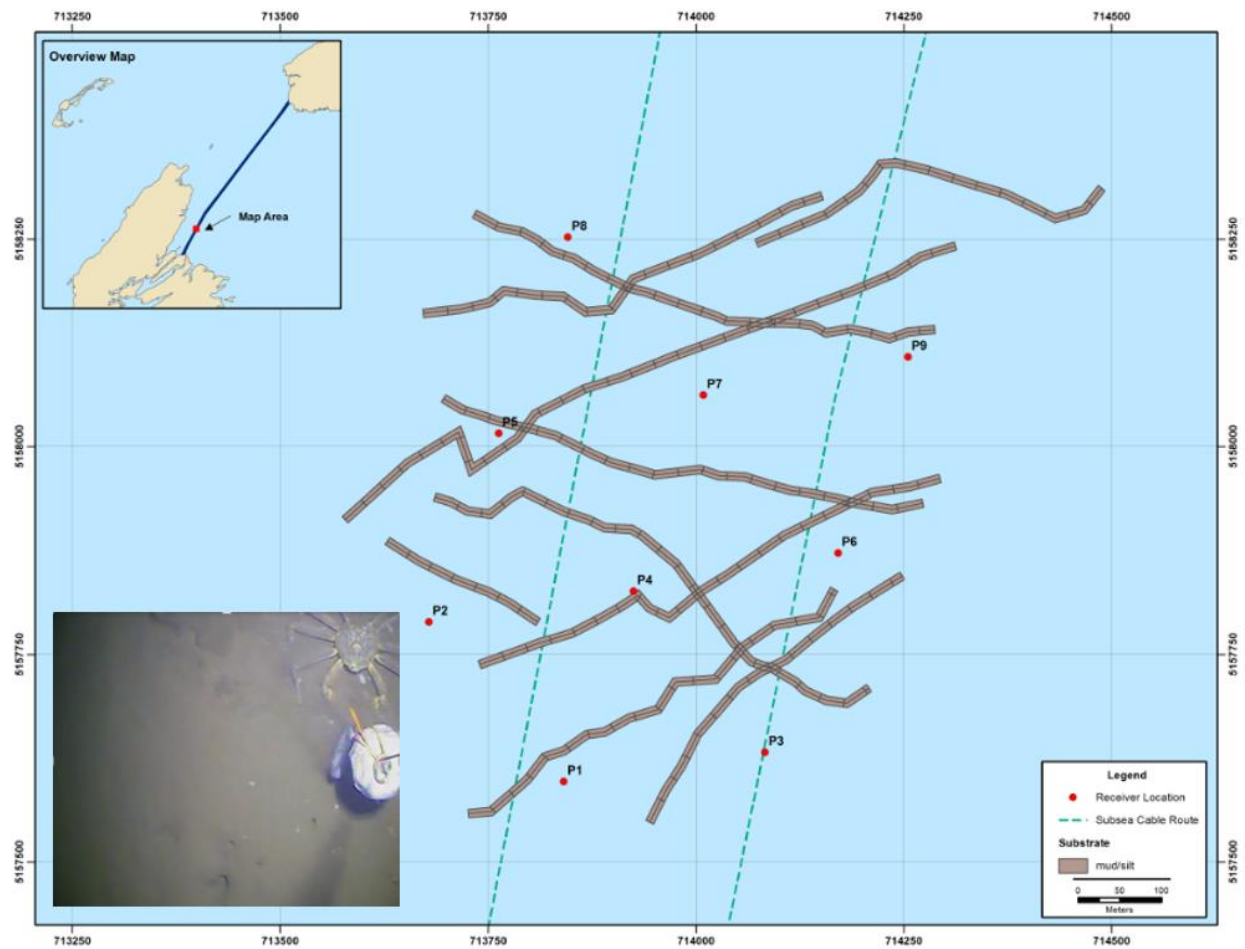


Figure 2-3 Habitat mapping drift transects within the 2014 snow crab VPS array. The subsea cables are represented by green dashed lines. Inset: Photograph representing the uniform bottom found throughout the VPS area (Note: grey object in the picture is a weight associated with the camera system)

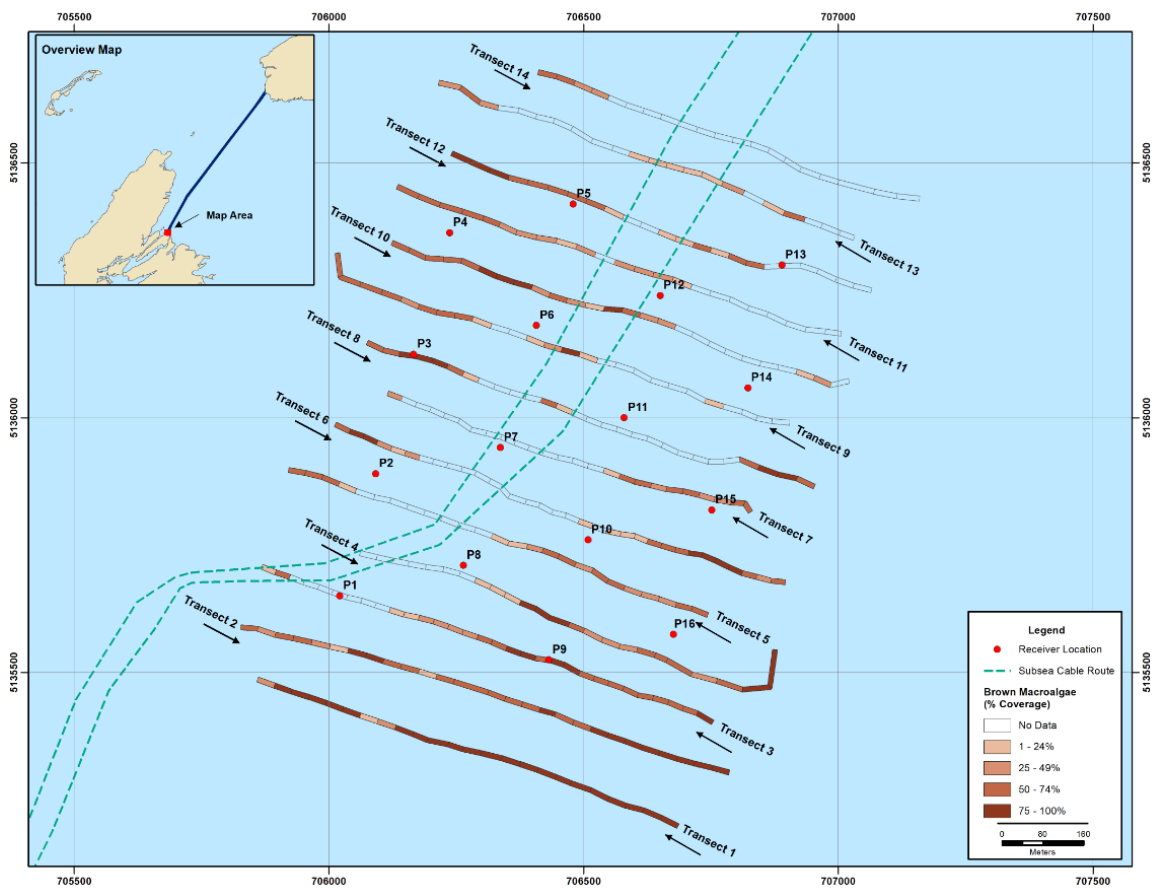


Figure 2-4 Habitat mapping towed video transects within the 2014 American lobster VPS array. The subsea cables are represented by green dashed lines

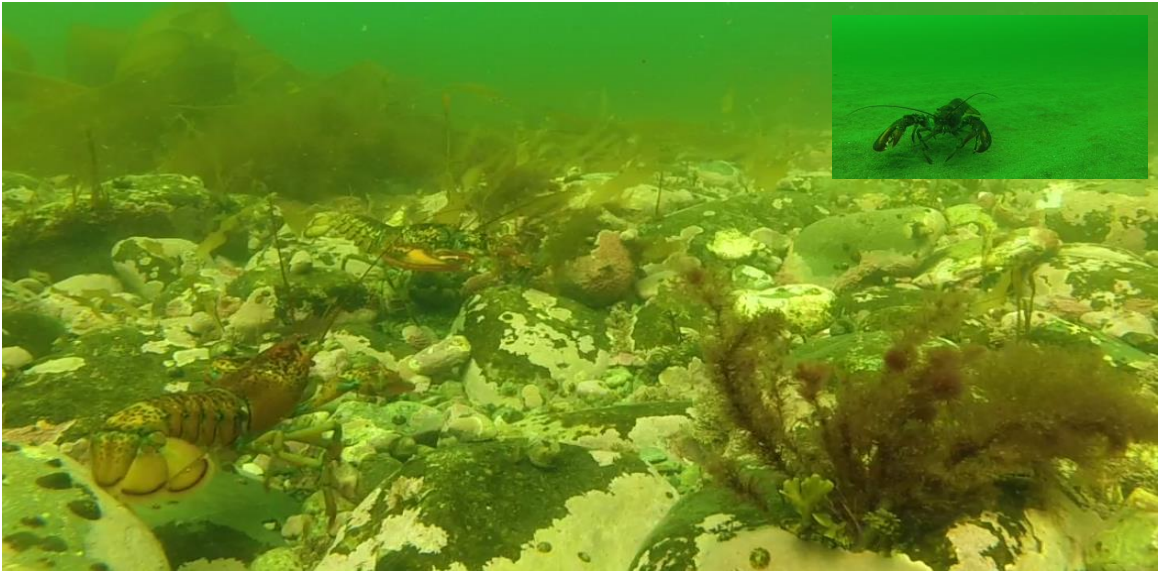


Figure 2-5 Examples of habitat types within the American lobster array observed at Point Aconi

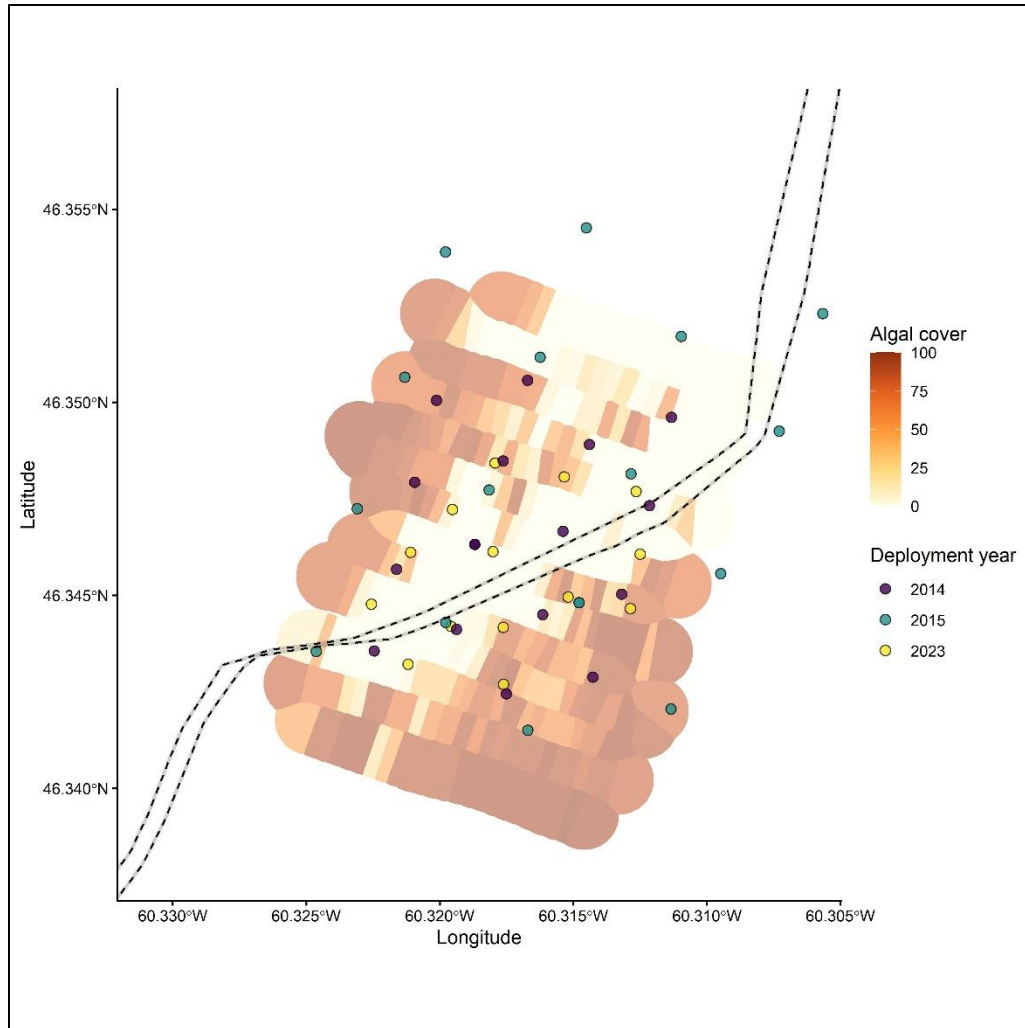


Figure 2-6 Habitat categorization of the Point Aconi Study Area used in movement modelling of American lobster. Legend: Black lines – submarine cable locations, grey lines – extended “zone of influence”, circles – receiver locations, coloured area – percentage algal cover.

2.1.3 AMERICAN LOBSTER

The defined Study Area for investigating the effects of the proposed submarine cables on American lobster was selected based on several key considerations. These included the geographic overlap with the planned route of the submarine cables, the proximity to known lobster fishing grounds, input from local harvesters, established commercial fishing zones, and the specific habitat area required to assess potential impacts on lobster behaviour. The study area was located within the Maritime Link installation corridor, approximately 3 km off Point Aconi, Cape Breton within water depths ranging from 7 meters to 21 meters (Figure 2-7). Initially, the study area was defined as a 750 m by 750 m zone during the 2014/2015 deployment based on detection range testing, and subsequently, the area was expanded to 1,200 m by 1,200 m in later years as detection range proved to be greater than initially tested (see Section 2.2.1 for further details on the study design and methodology).

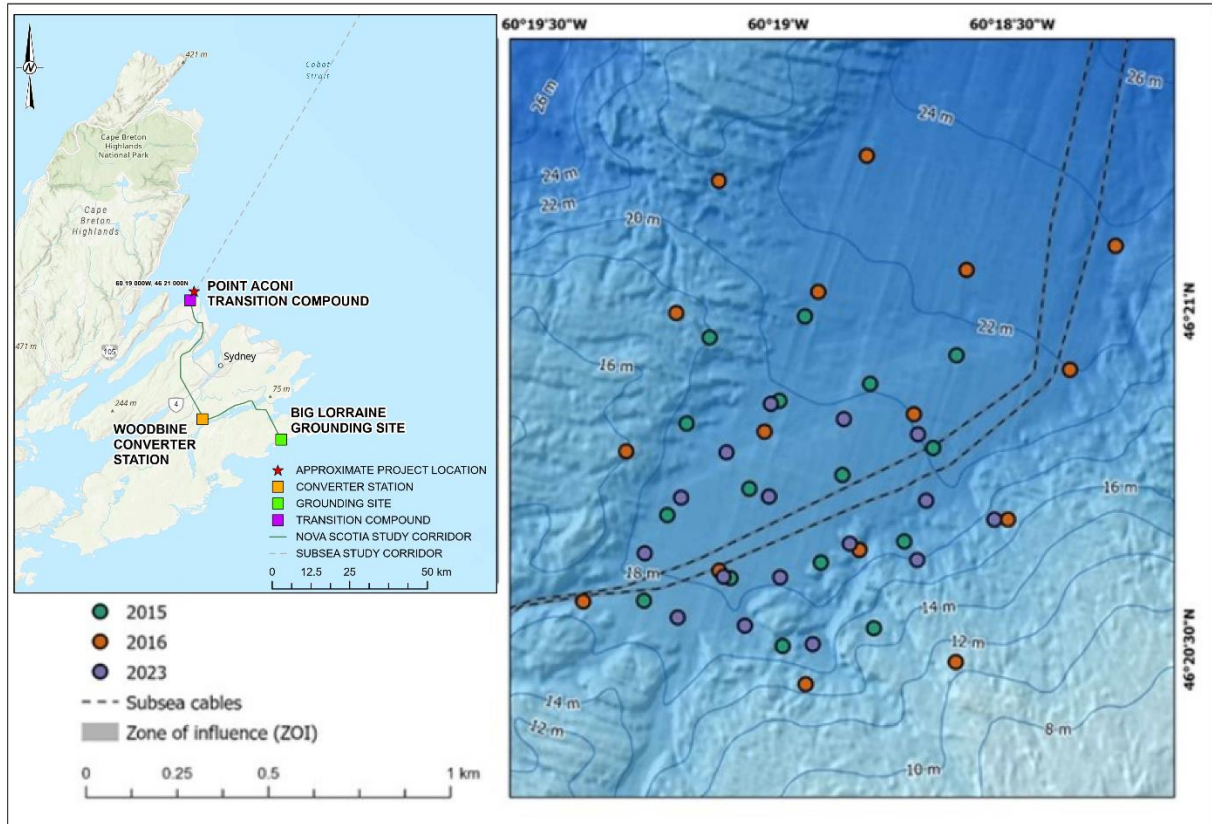


Figure 2-7 Lobster array deployment locations by study period (Baseline: 2014/2015 and 2015/2016, Operation: 2023/2024) relative to submarine cables in Cabot Strait, NS.

2.1.4 SNOW CRAB

The snow crab study area was located within a section of the submarine cable corridor that local harvesters identified as supporting high densities of adult male snow crab. This study area is situated approximately 20 km east of Ingonish, Cape Breton, at depths ranging from 100 m to 115 m. For the purposes of this study, the area is considered to consist entirely of fine substrate types, which is consistent with transect data and early geotechnical monitoring (MacGregor Geoscience Limited 2012; Amec Foster Wheeler 2018; see Section 2.1.2 for additional details). The selection of this site was based on its historical relevance, as it coincides with previous snow crab tagging efforts conducted by DFO and overlaps with commercial snow crab fishing grounds. The location of the snow crab array deployment is shown in Figure 2-8 (see Section 2.2.1 for further details on the study design and methodology).

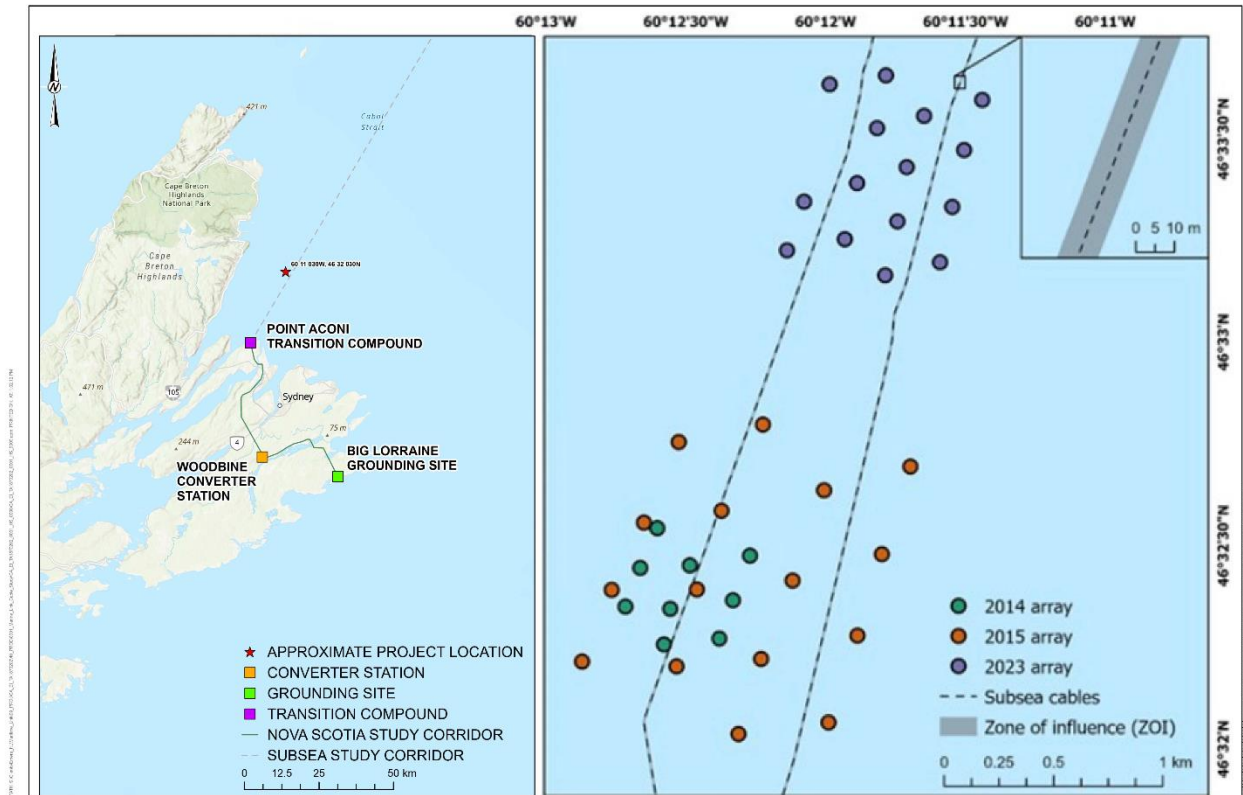


Figure 2-8 Snow crab array deployment locations by study period (Baseline: 2014/2015 and 2015/2016, Operation: 2023/2024) relative to submarine cables in Cabot Strait, NS.

2.2 TELEMETRY ARRAYS

2.2.1 SUPPORTING EQUIPMENT

Within the areas described above for American lobster and snow crab, VR2w (Innovasea, Bedford, NS, Canada) acoustic receivers were deployed four times for a period of eight months between 2014 to 2024 to enable the detection and tracking of individual lobsters and crab. In addition to receivers, other equipment was deployed within the telemetry arrays, including sync tags, calibration tags, and temperature loggers. Sync tags (internal or external) were used during this study and are used to correct for any clock drift that occurs among receivers, as precise time keeping is needed to triangulate animal positions. External sync tags were additional tags attached to a portion of the receivers in the array, while VR2AR models include internal sync tags and acoustic releases as a part of the receiver. Calibration tags are acoustic transmitters placed within the array with known positions, to assess the performance of receivers within the array. Temperature sensors within some receivers were used for constant water temperature monitoring, used as part of speed of sound calculations. The results from these devices were used during post-processing to determine animal positioning results (see section 2.4).

2.2.2 AMERICAN LOBSTER ARRAY

The array consisted of a total of 16 receivers that were individually placed on the seafloor at pre-established distances apart to allow maximum survey coverage and greatest positional accuracy using acoustic triangulation between multiple receivers. Array spacing was 250 m in 2014/2015 but was increased to 400 m in subsequent years as range testing from the 2014/2015 results was better than expected. The approach enables near-continuous monitoring of the position of tagged individuals while they remain within the array. A line of sight from the tag to the receiver is required for positioning, so animals cannot be detected while burrowing or when transmission is otherwise obstructed. The data acquired from this process was used to address study goals associated with the potential effects of the physical submarine cable on movement patterns, and habitat use.

The system consisted of VEMCO receivers with most receivers connected to their mooring with internal or Edgetech ORE (875-TD, Teledyne Benthos, North Falmouth, MA, USA) acoustic releases (Figure 2-9). The receivers were moored approximately 3 m off the seabed and suspended in the water column by a single syntactic submerged foam float (40.6 cm diameter, 17.2 kg buoyancy, DeepWater Buoyancy, Biddeford, ME, USA), where they listened for individual-specific acoustic signals of tagged animals. The mooring anchors (typically 2.5 links of 100 mm thick chain weighing approximately 80 kg) were attached to the Edgetech releases (approx. added length of 70 cm when used) by 1 m of rope, followed by 1 m of rope connecting to the float with the receiver installed above the float, though this set-up varied very slightly based on available materials (e.g. self-releasing receivers, different anchor type, different buoyancy device, etc). This acoustic receiver mooring design is similar to the standard Ocean Tracking Network (OTN) configuration which provides the best line of sight and minimizes blind spots to maximize the likelihood of animal detections. Geographic positions of tagged lobsters within the array were triangulated when a tag's signal was detected by a minimum of three acoustic receivers. The initial deployment consisted of a sixteen-receiver VPS array using moorings spaced 250 m apart, covering approximately 0.25 km². The receiver spacing was informed by prior *in-situ* range tests to optimize receiver spacing. After the first season of data collection (Oct 23, 2014 - Jan 22, 2015), the manufacturer reported that detection ranges exceeded those observed during range-testing trials. As a result, it was recommended that mooring spacing could be increased to 400 m without significantly affecting data quality. Based on this guidance, the array was redeployed using 16 receivers at 400 m spacing on September 13, 2015 (Figure 2-7). This geometry was used for the remaining duration of the project.

The American lobster telemetry array was deployed and retrieved four times: 2014/2015, 2015/2016, 2018/2019, and 2023/2024. The first two deployments were prior to the cable installation, and the last two were after installation and energization. While the cables were energized in 2018, transfers were intermittent and low until 2022 when the Maritime Link entered steady state operation. Each array was deployed in the fall (September to November) and retrieved the following spring in early May prior to the start of the commercial lobster season to avoid interference with the fishery and any gear entanglement. Table 2-1 provides a summary of each array deployment.

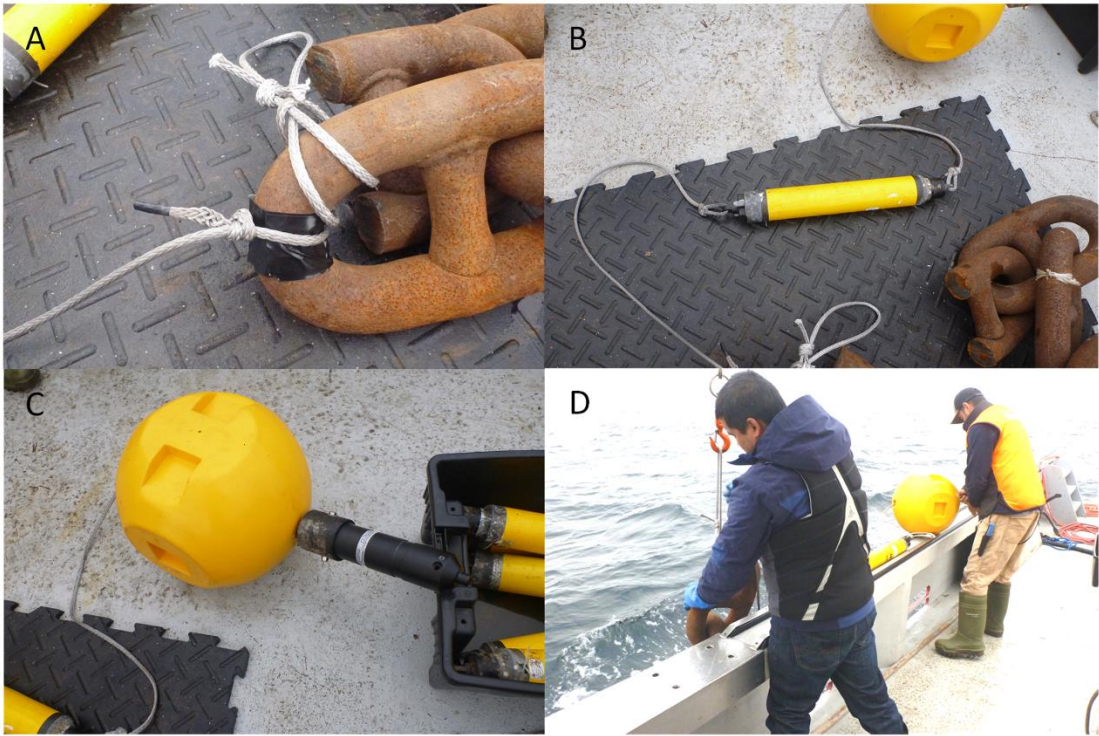


Figure 2-9 Deployment of the acoustic array receivers: A) chain anchor used, B) acoustic release, C) float with acoustic receiver, and D) deployment of a complete receiver set-up.

Table 2-1 Arrays deployed to monitor movements of American lobster off Cape Breton from 2014 to 2024

Deployment	Number of Receivers	Receiver Type	Array Configuration	Deployment Depth	Deployment Dates	Downloads
2014 / 2015	16	VR2 acoustic release	~750 m x 750 m High Resolution Positioning System array (250 m spacing)	14-21 m	October 21, 2014 February 23, 2015	January 15, 2015 May 14, 2015
2015 / 2016	16		~1200 m x 1200 m High Resolution Positioning System (400 m spacing)	14-21 m	September 13, 2015	May 16, 2016
2018 / 2019	16*			7-19 m	November 9, 2018	May 6, 2019
2023 / 2024	16			12-20 m	October 5, 2023	May 6, 2024

* Note: only 9 receivers were recovered at the end of the deployment period

2014-2015 DEPLOYMENT AND RETRIEVAL

Range testing was conducted in September of 2014 to determine the spacing at which receivers could accurately determine animal positions. The results indicated receiver spacing of 250 m, with a 4 x 4 receiver array deployed to monitoring American lobster positions. See Table 2-1 for deployment details. This represented the first year of baseline pre-project disturbance data collection.

2015-2016 DEPLOYMENT AND RETRIEVAL

The 2015/2016 deployment represented the second year of baseline conditions. Following the first year of data collection, the manufacturer advised that detection range was better than determined from equipment trials and suggested that the range could be extended without significantly compromising data integrity. Following this recommendation, and in consultation with DFO, the high-resolution positioning arrays were extended from 250 m spacing to 400 m spacing. This allowed greater survey coverage.

2018-2019 DEPLOYMENT AND RETRIEVAL

The 2018-2019 deployment was completed after cables installation. However, in this period, while the submarine cables were fully energized, power transfers between Newfoundland and Nova Scotia were intermittent and remained well below normal operating levels. Under these conditions, the resulting magnetic anomalies associated with the submarine cables were also intermittent and very low in comparison to the Earth's natural magnetic field.

Using as-built information, the geometry of the array was adjusted to reflect the position of the installed submarine cables and incorporated the increased detection range as determined during the baseline study. These minor alterations were implemented to ensure that the arrays straddled both submarine cables without changing the general location of the arrays or the area covered.

In early 2019, four receivers had washed up on shore at Point Aconi, N.S. following storms, and were returned to OTN. Given the shallow nature of the study area and damage to the equipment and ropes, it appears as though high wave action wore the acoustic release lines. Other receivers within the array were displaced, likely due to high wave action. Three additional receivers were not located within the lobster array during retrieval operations and are assumed to have washed up on shore during the same, or similar, heavy weather events. A search took place for these receivers, but they were never located. As a result, the lobster data and tracks presented herein are based on the data analysis from nine of sixteen VPS receivers (see Section 2.4.3 for discussion).

2023-2024 DEPLOYMENT AND RETRIEVAL

The 2023/2024 deployment occurred after the Maritime Link system began steady state operation during which energy transfers fluctuate according to normal operating grid load. As such, transmission levels fluctuated throughout the study as normal energy transfers increased and decreased. The 2023/2024 deployment used locations and geometry optimized for detection coverage over the area of the cables and protection of the receivers.

2.2.3 SNOW CRAB ARRAY

The original study design included a VPS array based on a 3x3 receiver geometry similar to the lobster array. However, through presentation of the study and discussions with the snow crab Fisheries Liaison Committees (FLC) and DFO, this setup was deemed insufficient. Concerns were expressed that far field crab movements would be missed by implementing only the proposed VPS array. Consequently, the study design was adjusted to include two linear arrays North of the VPS array and two linear arrays to the South (Figure 2-2 and Figure 2-8). This effectively increased the overall size of the monitoring area to approximately 10 km. Starting with the second array deployment, the crab VPS array was increased to a 4x4 receiver configuration. This approach enabled near-continuous monitoring of the position of tagged

individuals while they remain within the high-resolution positioning array (an area of approximately 500 m by 500 m in 2014/2015, and 1200 m by 1200 m in subsequent years), while the linear arrays provided presence-absence information further afield. The spacing of receivers in the presence/absence array was 500 m in 2014/2015 and increased up to 800 m in subsequent years based on the range testing completed from the first years' results. After 2014/2015, the snow crab array was deployed approximately 2 km north-east of the previous array as adjustments were made to reflect the installed location of the submarine cables. Marine survey data indicated that the habitat present at both areas was the same (i.e., soft mud substrate).

A set of Vemco receivers (e.g. VR2ARs and VR2w) were deployed for each monitoring period (Figure 2-9), similar to those deployed for the American lobster array.

The snow crab telemetry array was deployed and retrieved four times: 2014/2015, 2015/2016, 2018/2019, and 2023/2024. The first two deployments were prior to the cable installation, and the last two were after installation and energization. While the cables were energized in 2018, transfers were intermittent and low until 2021 when the Maritime Link entered a steady state reflective of operation.

Table 2-2 Arrays deployed to monitor movements of snow crab off Cape Breton from 2014 to 2024

Deployment	Number of Receivers	Receiver Type	Array Configuration	Deployment Depth	Deployment Date	Downloads
2014 / 2015	41	Tethered VR2 (n=20) + VR2 acoustic release (n=21)	~500 m x 500 m High Resolution Positioning System (n=9); 250 m spacing + Detection Lines (n=32); 500 m spacing	106 – 115 m	October 23, 2014	January 22, 2015
2015 / 2016	40	Tethered VR2 (n=27) + VR2 acoustic release (n=13)	~1200 m x 1200 m High Resolution Positioning System (n=16); 400 m spacing + Detection Lines (n=24); 500-800 m spacing	106 – 115 m	September 13, 2015	May 14, 2016
2018 / 2019	42	Tethered VR2 (n=26) + VR2 acoustic release (n=16)	~1200 m x 1200 m High Resolution Positioning System (n=16); 400 m spacing + Detection Lines (n=26); 500-800 m spacing	100 - 110 m	October 27, 2018	May 7-10, 2019
2023 / 2024	42				October 14, 2023	May 5, 2024

2014-2015 DEPLOYMENT AND RETRIEVAL

See details in Section 2.2.1 above. The snow crab array in 2014/2015 was a set up of 3x3 receivers in the VPS array area and 32 additional receivers for presence / absence detections. See Table 2-2 for deployment details.

2015-2016 DEPLOYMENT AND RETRIEVAL

See details in Section 2.2.1 above. In addition to the spacing changes in 2.2.1, the untethered receivers in the presence-absence arrays were extended to 800 m. The extended coverage enabled some presence-absence receivers to be reallocated to the snow crab positioning array, improving it from a nine-receiver array to a 1.5 km² 16-receiver array similar to that used in the American lobster area while maintaining the same coverage of the presence-absence receiver lines.

2018-2019 DEPLOYMENT AND RETRIEVAL

See details in Section 2.2.1 above. An additional receiver was added to each of the northern presence-absence arrays.

2023-2024 DEPLOYMENT AND RETRIEVAL

See details in Section 2.2.1 above.

2.3 ANIMAL TAGGING

2.3.1 AMERICAN LOBSTER TAGGING

Local harvesters or a subcontractor were employed to set traps for American lobster within the study area. Twelve standard commercial traps were set for 1-3 days to collect adult lobsters for tagging. Individuals caught were banded for safety, weighed, measured, sexed, and suitably sized individuals were retained for tagging. The goal was tagging an equal amount of male and female lobsters, though catch numbers were not always sufficient to allow for this (Table 2-3). Despite expanding the fishing area and effort in 2014/2015 to balance the sex ratio, lobsters caught were heavily skewed towards males with 2018 in particular having no females caught.

Individuals caught were held in fish pans with surface seawater circulation to prevent thermal shock and reduce stress. All individuals were tagged with carapace mounted Vemco V13-1H 69KHz acoustic transmitters with a submerged mass of 6 g (11 g, 13x36 mm, 653-day tag life; transmission frequency: 60-180 s) (Figure 2-10). The transmitter attachment methods were adapted from those described by Bowlby et al. (2007), Morrison (2014), and Zisserson & Cameron (2016). In brief, the dorsal surface of the carapace, where the transmitter was to be attached, was lightly abraded using a rotary tool with a flap-wheel sanding disc to enhance tag adhesion. A vinyl tubing (spaghetti-style) tag (Floy Tag) was then threaded through a cap incorporated into the transmitter and positioned between the first and second walking legs. A small amount of 3M® 5200 marine adhesive was applied to the abraded area, and the cap was pressed into place. Once the acoustic tag was securely mounted in the adhesive, the spaghetti tag was tightened, and the aluminum sleeve was crimped to hold it in position. Excess tubing was trimmed. To further ensure proper tag placement and adhesive contact during curing, thin wire pipe cleaners were used to secure the posterior portion of the acoustic tag. These pipe cleaners corrode rapidly and were designed to fall off shortly after the adhesive set, ensuring minimal long-term impact on the animal. The use of spaghetti tags was dropped after 2014/2015 as they provided limited addition monitoring value to the study and could hinder the moulting process of the lobsters. This minor change was not expected to affect the results of the study. Tagged lobsters were released typically within 6 hr of capture and claw bands were removed prior to placing the lobsters back into the water. Animals were released in four equal-sized

groups at the surface at four locations within the acoustic array (two releases on each side of the cable route within the area of coverage). These locations were selected to maximize the likelihood of interactions of animals with the subsea cables, to safeguard against any directional currents that may bias the outcome, and to avoid signal collisions associated with having too many animals in one location.

Table 2-3 Summary of tagged American Lobsters caught throughout the study, 2014-2024.

Deployment	Number of Tagged animals	Tag Type	Number of Male Lobster	Number of Female Lobsters	Date Deployed
2014 / 2015	40	V13	32	8	October 26, 2014
2015 / 2016	40		21	19	October 6, 2015
2018 / 2019	40		40	0	November 13, 2018
2023 / 2024	40		22	18	October 12, 2023



Figure 2-10 American lobster tagging: A) lobsters directly after removal from trap, B) banded lobster being weighed, C) V13 tag and D) tag attached to lobster with epoxy and attachment loop.

2.3.2 SNOW CRAB TAGGING

Local harvesters or a subcontractor were employed to initially set traps for snow crab within the study area. The study design called for a sample size of 40 terminal moult males, 20 females and 20 juvenile snow crab to be caught within the study area, to reduce the risk of introducing an animal translocation bias. This aspect of the study was discussed at length with the snow crab FLC and DFO, as it was understood that female and juvenile snow crabs were unlikely to be present in the study area. Like males, juvenile and female snow crabs show a clear *preferendum* for cold, soft-bottom shelf habitats, but juveniles occupy the coldest water and often slightly different depths than adult females. Juveniles are typically concentrated in near-bottom waters between about 0 and 2°C, on muddy or sandy substrates in relatively shallow shelf areas, while mature females can use somewhat broader temperature and depth ranges but still favor cold, soft sediments. Juveniles commonly inhabit continental-shelf depths on soft mud or sand, often in shallower portions of the species' depth range where food and structural shelter are abundant, but still within cold bottom water. Adult females also favor cold water and soft, muddy or sandy bottoms, typically on the shelf in depths up to roughly 200 m (and in some regions down to a few hundred meters), but they are less tightly constrained to <2°C than juveniles and can occur over a slightly wider temperature range. In the study area, females are known to occupy habitats somewhat separated from adult males for much of the year, remaining in colder, soft-substrate nursery and brood areas that provide suitable conditions for egg brooding and protection, while still overlapping with juvenile habitat along cold shelf bottoms. As a result, no female or juvenile snow crabs were captured in the study area in 2014/2015. Subsequent consultations with DFO and the FLC indicated that juveniles and females were primarily found in hard-bottom habitats, prompting modifications to the study design to include the targeted capture and translocation of these crabs. Commercial harvesters provided valuable guidance by identifying potential fishing grounds for female and juvenile snow crabs along the western slope of Sydney Bight (NS), approximately 5 km from the VPS array at depths of 70–100 m.

Two standard 1.8 m commercial pots were set for 1-3 days to capture terminally moulted male snow crab within the VPS array, while two lines of three (six total) modified rectangular, top entrance shrimp traps were set at the same time to capture juveniles and female crab due to their smaller size. Individuals caught were inspected for physical damage or signs of decreased health or viability. Animals selected for tagging were rapidly transferred (within a few minutes) and held temporarily in a 750 L insulated fish box. In 2014/2015 to 2015/2016, deep-water thermal conditions were replicated on deck by adding approximately 300 L of ice to the box and covering it with a non-permeable membrane. The remaining volume was filled with aerated surface seawater, which was chilled to 1.5°C. The holding box was then covered to minimize light exposure and help maintain stable temperatures. In 2023/2024, captured snow crab were instead held in a 70-L fish tote (63 cm × 40 cm × 26 cm) and packed with layers of saltwater ice to keep animals at appropriate temperatures prior to tagging. This method was recommended by commercial harvesters as appropriate. All tagged animals displayed active behaviour during tagging procedures and prior to release. Prior to tagging, crabs were weighed, measured, sexed. Crabs were tagged with either VEMCO (Halifax, NS) V13-1H (diameter: 13 mm; length: 36 mm, weight in water: 6.0 g, 69 KHz, estimated tag life: 653 days, transmission frequency: 60-180 s), or V9 acoustic transmitters (69kHz, diameter: 9 mm; length: 29 mm, weight in water: 2.9 g, estimated tag life: 347 days, transmission frequency: 60-180 s).

Adult male individuals were tagged with carapace mounted VEMCO 69KHz acoustic transmitters (V13-1H; 11 g; 13x36 mm; 653 days tag life; transmission frequency: 60-180 s) (Figure 2-11), and juveniles and females were tagged with smaller V9 transmitters (2.9 g; 9x21 mm; 347 days tag life; transmission frequency: 60-180 s). Crabs were individually selected for tagging and placed upright on a flat surface. To improve tag adhesion, the area of attachment on the dorsal surface of the carapace was dried with paper towel then lightly abraded using a rotary power tool. A vinyl tubing, spaghetti-style tag (Floy Tag, Seattle, Wash., USA) was attached through a cap built into the transmitter and positioned around the animal's carapace between the second and third walking legs. A small volume of 3M® 5200 marine

adhesive was then placed on the carapace area prepared with the rotary power tool and the cap pressed into the adhesive. Once the acoustic tag was mounted in the adhesive, the spaghetti tag was tightened, and the aluminum sleeve was crimped to secure it in place and excess tubing trimmed. Thin wire pipe cleaners were then used to secure the posterior portion of the acoustic tag to further ensure tag position and adhesive contact throughout curing (24 h while submerged). Similarly to the lobster releases, crabs were released in four equal groups within 6 hours of capture within the VPS array: two releases on each side of the cable route within the area of coverage. Crabs were lowered to the bottom using a cage with a swing door to ensure safe targeted delivery to the seafloor within the array. These locations were selected to maximize the likelihood of interactions of animals with the submarine cables, to safeguard against any directional currents that may bias the outcome, and to avoid signal collisions associated with having too many tagged animals in one location.

Table 2-4 Summary of tagged snow crab caught throughout the study, 2014-2024.

Deployment	Number of Tagged animals	Tag Type	Number of Male Crabs	Number of Female Crabs	Date Deployed
2014 / 2015	48	V13 (large males) or V9 (juveniles and females)	48 (adult)	0	October 31, 2014
2015 / 2016	116		101 (70 adult, 31 juvenile)	15	October 5-7, 2015
2018 / 2019	80		60 (40 adult, 20 juvenile)	20	November 13-16, 2018
2023 / 2024	80		80 (60 adults, 20 juveniles)	0	October 14, 2023



Figure 2-11 Snow crab tagging: A) snow crab pot, B) crabs in salt water ice, C) epoxy applied to a snow crab, and D) V13 tag and attachment loop on crab.

2.4 DATA PROCESSING AND ANALYSIS

As per the study design, the first two deployments (2014/2015 and 2015/2016) datasets constitute the pre-installation baseline datasets, while the 2018/2019 and 2023/2024 deployments constitute the post-installation and fully steady state operational datasets, respectively. Data preparation was conducted in a similar manner for both species with noted exceptions to account for species-specific behavior or array-specific positioning characteristics.

2.4.1 INITIAL DATA PROCESSING AND QUALITY CONTROL

All data were downloaded and the full detection dataset from each receiver was consolidated by Innovasea. The data from the sync and calibration tags was used to correct receiver positioning and enable triangulation of animal transmitter positions within the VPS arrays. As a quality check and to determine overall detectability and triangulation accuracy within the lobster array, the fixed-position calibration tags were used to estimate tag location against its known location within the array. The resulting data is a track for each tagged animal reconstituted from sequential detection positions. The 2018 dataset was excluded from the final behavioural analysis (See section 2.4.3).

2.4.1.1 AMERICAN LOBSTER ARRAYS

Fixed-position reference tags from the first lobster array deployment in the 2014/2015 study period showed that 90% of detections were within 14.6 m of the centroid while 50% of detections were within 3.7 m. During the second array deployment in 2015/2016, 90% of detections were within 6.3 m of the centroid while 50% of detections were within 1.5 m. Similarly, 90% of detections were within 5.5 m of the centroid while 50% of detections were within 1.7 m during the 2015/2016 array deployment and study period. The 2014/2015 and 2015/2016 datasets will be referred to in the analysis and discussion as the before period meaning the data was collected prior to the submarine cables being installed.

Reference tag data for the lobster array deployed in 2023/2024 during steady state operation of the submarine cables revealed the measurement error in the array to be within the range of the estimated error for the array deployments prior to the submarine cable installation. Comparing the sync and reference tag detections to their respective centroid (grouped by transmitter) showed that 90% of detections were within 7.8 m of the centroid while 50% of detections were within 2.6 m. The 2023/2024 array deployment and associated data will be referred to as the after period as the data was collected while the submarine cables were under normal operation (i.e., energized and steady state power transmission).

2.4.1.2 SNOW CRAB ARRAYS

The fixed-position reference tag located within the snow crab array revealed that measurement error in the array during the baseline study period was low during both years of acoustic array deployment. In 2014/2015, comparing the sync and reference tag detections to their respective centroid (grouped by transmitter) showed that 90% of detections were within 10 m of the centroid while 50% of detections were within 2.1 m. In 2014/2015, 90% of detections were within 31.2 m of the centroid while 50% of detections were within 4.6 m. Consistent with the lobster data, the 2014/2015 and 2015/2016 crab datasets will be referred to as the before period meaning the data was collected prior to the submarine cables being installed.

Reference tag data for the snow crab array deployed in 2023/2024 during steady state operation of the submarine cables revealed the measurement error in the array to be similar to the 2014/2015 array deployment. Comparing the sync and reference tag detections to their respective centroid (grouped by transmitter) showed that 90% of detections were within 13.6 m of the centroid while 50% of detections were within 2.6 m. The 2023/2024 array deployment and associated data will be referred to as the after period as the data was collected while the submarine cables were under steady state operation.

2.4.2 DATA PROCESSING

2.4.2.1 AMERICAN LOBSTER

BEFORE DATA

Table 2-5 Data used for ZOI analysis

Period	Species	Initial Detections	Detections in movement rate analysis	Percentage Retained for movement rate analysis
After	Crab	211250	521	0.25%
Before	Crab	136561	769	0.56%
After	Lobster	143520	400	0.28%
Before	Lobster	106634	806	0.78%

Data were filtered to remove detections where Horizontal Positioning Error (HPE) was greater than the 75th percentile of values within each array. This arbitrary percentile was selected as an appropriate threshold that balanced outlier removal (based on visual inspection) and data retention and is aligned with other peer reviewed published results. Reconstructed tracks were then segmented when the time between detections was more than 1.5 hours, and the detections were at least 50 meters apart. This is to ensure the fine-scale behaviour of individuals is captured and not interpolated over long time periods. It is not uncommon however for lobster to stay in shelters for long periods of time and therefore the tracks were only segmented when subsequent detections were at least 50 m apart. A conservative speed filter was then applied to the tracks to remove any detections where the speed was greater than 5 m/min. The detections with higher speeds typically represent aberrant position estimates in the tracks which can bias downstream analysis. The speed filter was applied iteratively until the speed between all remaining detections within track segments did not exceed the defined threshold. Track segments with ten or more detections were retained and a one-behaviour first-difference correlated random walk state-space model was applied. This model adjusts tracks by inferring underlying movement processes while accounting for drift-related measurement errors (derived from sync tags). Such an approach helps to reposition outliers to a more probable position based on recently demonstrated behavior when measurement error is likely elevated (Konecny et al. 2024). The number of initial detections retained for the movement rate analysis is summarized in Table 2-5.

AFTER DATA

After movement data was processed following the same methods as the before data however instead of filtering based on HPE, points with an RMSE (root mean-squared error) >1.3 were excluded from analysis. The RMSE measures detection time error (Shipley et al. 2024) and was not available for the before datasets. A threshold of 1.3 was selected based on the inflection point of RMSE vs speed. Visually RMSE increases with speed after an RMSE value of about 1.3. A decision was made to filter the data based on this field as it appeared to be highly effective in removing outliers in the movement tracks. This approach ensured that the best available data was being used to evaluate potential effects of the submarine cable on animal movement. The remainder of the data processing was conducted in the same way as for the before datasets (see Figure 2-12 for plots of a movement track through all stages of processing).

Figure 2-13 provides a summary over time of the post-processing detections included in the analysis. Note that several individuals were only detected immediately after release. Individuals may have left the detection range of the array, burrowed within the seabed, or dislodged the tags either mechanically or through molting.

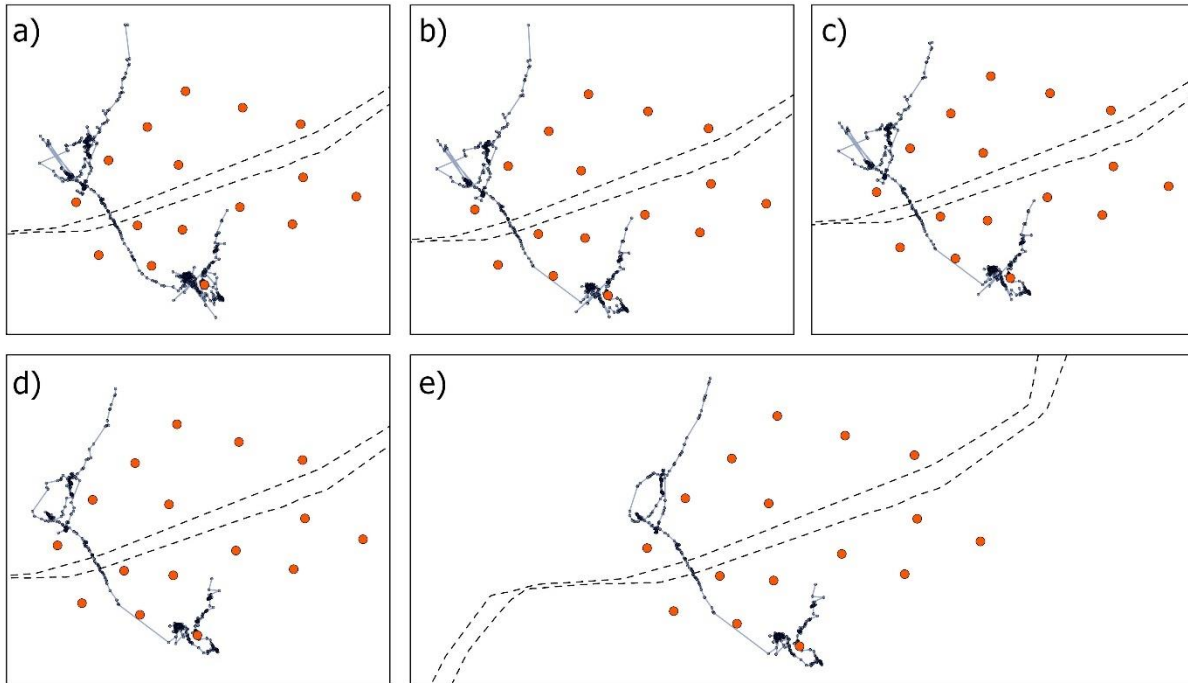


Figure 2-12 Movement track from an American lobster (2023 / 2024 array deployment) demonstrating the effect of data processing steps: A) original data provided by Innovasea processing, B) filtering based on RMSE, C) segmenting tracks where time gaps exceeded 1.5 hours and distance between subsequent points was at least 50 m, D) filtering based on speed (5 m / min), and E) applying the state-space model.

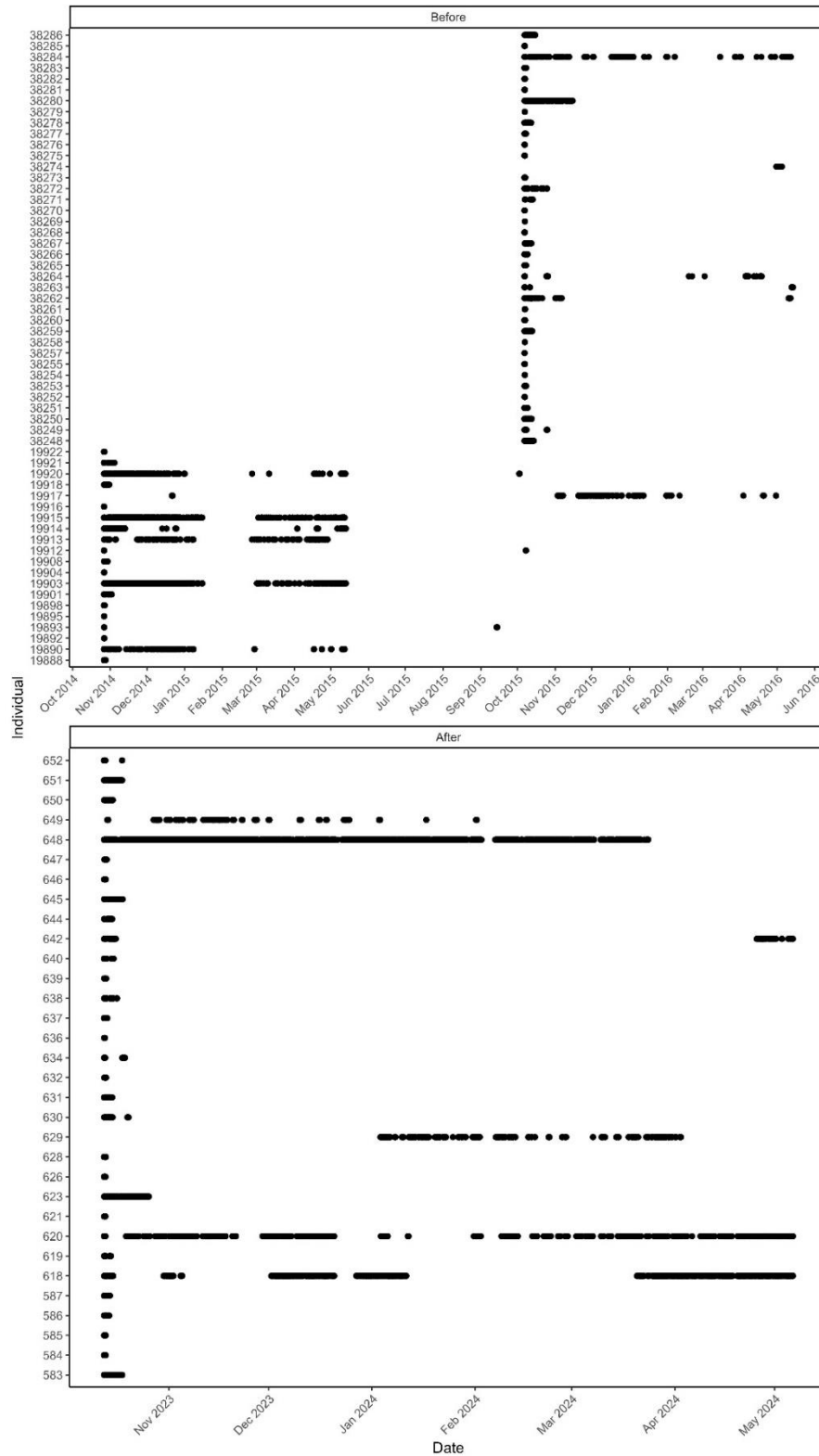


Figure 2-13 Lobster individual tags included in the analysis with observations through time (after data processing) for all array deployments separated by study period (before / after).

2.4.2.2 SNOW CRAB

BEFORE DATA

Individuals for which the tag showed no movement and remained in the array for the duration of the array deployment were assumed to be dead or have shed their tag; as such these individuals were excluded from the analysis. Data was filtered to remove detections where HPE was greater than the 75th percentile of values within each array. This arbitrary percentile was selected as an appropriate threshold that balanced outlier removal (based on visual inspection) and data retention and is aligned with other peer reviewed published results. Tracks were then segmented where time between detections exceeded 1.5 hours. This is to ensure the fine-scale behaviour of individuals is captured and not interpolated over long time periods. A speed filter was then applied to the tracks to remove any detections where the speed was greater than 10 m/min. This threshold was selected to be a conservative filter as previous studies have found maximum speeds in laboratory trials to be much lower (e.g. 2.4 m/min; Maynard 1991). The detections with speeds greater than 10 m/min typically represent aberrant detections in the tracks which can bias downstream analysis. The speed filter was applied iteratively until the speed between all remaining detections within track segments did not exceed the defined threshold. A distance filter was then applied in a similar manner to the speed filter, iteratively removing detections where the distance travelled exceeded 34.9 m (based on the 95th percentile of distance between detections in the 2023/2024 dataset) between successive locations. Track segments were retained with ten or more detections and a one-behaviour first-difference correlated random walk state-space model was applied. This model separates the tracks into segments with similar aspects, which can then be interpreted to infer the underlying movement process while accounting for the measurement errors (derived from sync tags) which further helps to remove outliers from the movement tracks. The number of initial detections retained for the movement rate analysis is summarized in Table 2-5.

AFTER DATA

The snow crab after dataset was processed using an RMSE >1.3 in the same way as the lobster after dataset following the identical rationale (see Figure 2-14 for plots of a movement track through all stages of processing). Figure 2-15 provides a summary over time of the post-processing detections included in the analysis. Note that several individuals were only detected immediately after release. Individuals may have left the detection range of the array or dislodged the tags either mechanically or through molting.

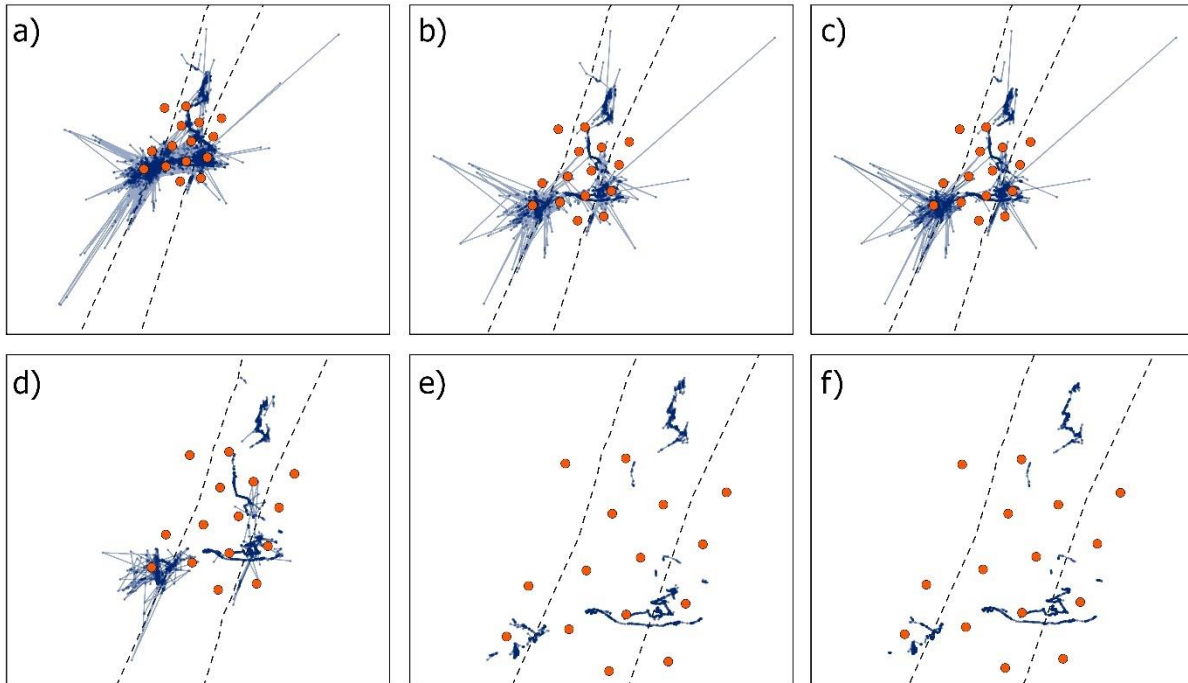


Figure 2-14 Movement track from a snow crab (2023/2024 array deployment) demonstrating the effect of data processing steps: A) original data provided by Innovasea, B) filtering based on RMSE, C) segmenting tracks where time gaps exceeded 1.5 hours, D) filtering based on speed (10 m / min), E) filtering based on distance (34.9 m, and F) applying the state-space model.

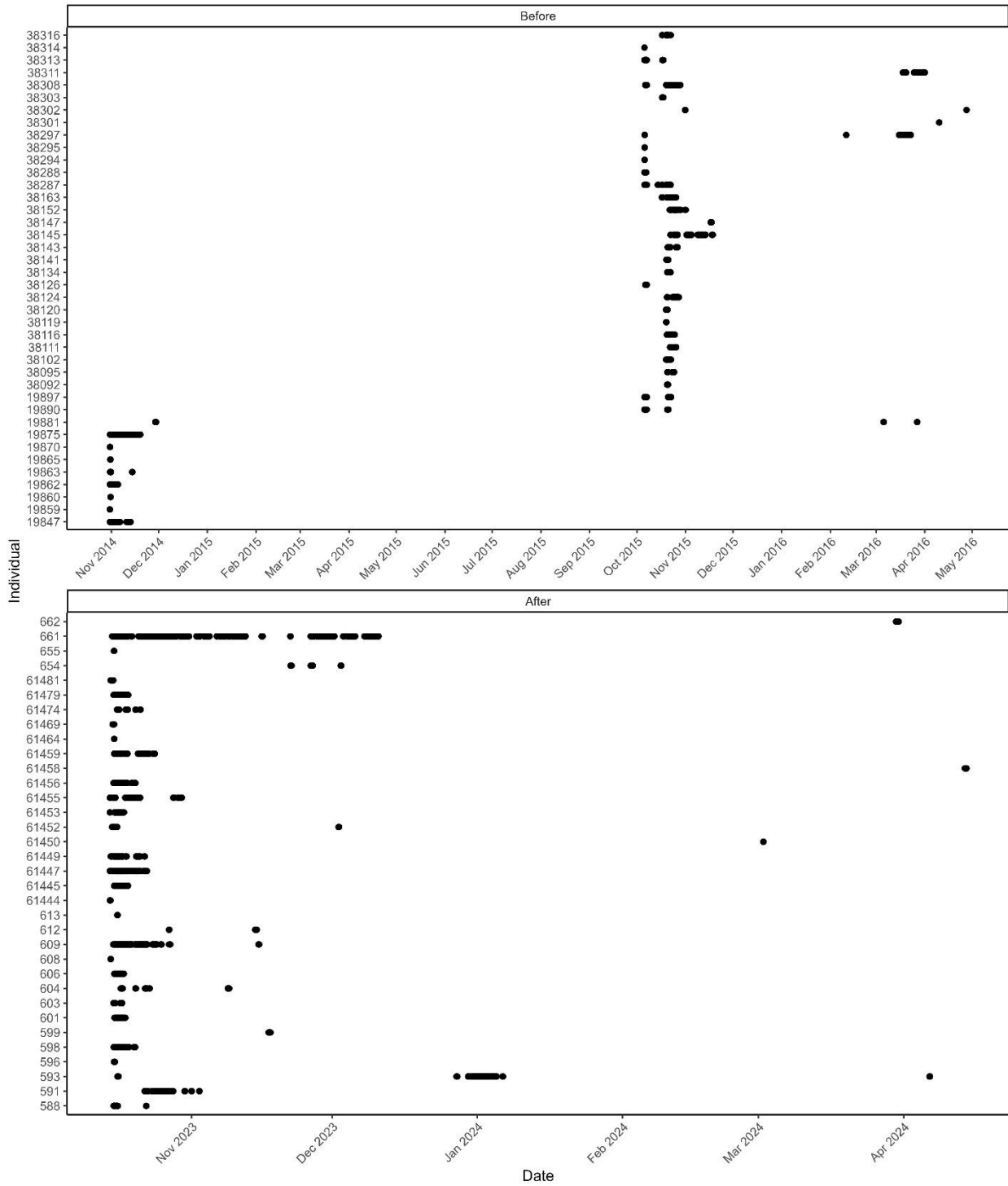


Figure 2-15 Snow crab individual tags included in the analysis with observations through time (after data processing) for all array deployments separated by study period (before / after).

2.4.3 CRITICAL ASSESSMENT OF THE 2018-2019 DATASET

Installation of the two submarine cables was completed in September 2017 and the Maritime Link entered operation (i.e. the system was energized) in January 2018. However, the Newfoundland portion of the overall Lower Churchill Project (LCP) was not complete, which meant that energy transfers across the submarine cables were intermittent and at low levels. Considering this, a discussion was held with DFO regarding the potential value of conducting a tagging study in 2018/2019. It was agreed that monitoring the behavior of American lobsters and snow crabs in the study area during the year following cable installation would be beneficial, even though energy transfer was minimal at the time. However, several factors led to the exclusion of this dataset from the final behavioural analysis:

1. Intermittent and low level energy transfers across the submarine cables,
2. Loss of half the receivers (and associated data) from the lobster VPS array (likely from storms), and
3. Displacement of several of the remaining lobster VPS receivers resulting in an alteration of the array geometry

Although a behavioural analysis was not conducted on this incomplete dataset, some qualitative findings could be drawn from the crab and lobster detections.

For American lobsters, all 40 individuals (all male) had a minimum of three detections within the array with the highest number of detections over 70,000 (average: 4,302). The distance travelled within the array on average was 4,586 m, with one individual travelling an estimated 36,493 m. Of these 40 individuals, 14 (35%) were determined to have crossed the cable path at least once.

For snow crab, 78 animals (38 adult males, 20 juvenile males, and 20 females) were detected a minimum of 1,013 times within the array, with the highest number of detections over 90,000 (average: 15,354). The distance travelled within the array was on average 14,387 m, with one individual travelling an estimated 68,856 m. Of these 78 individuals, 35 (45%) were determined to have crossed the cable path at least once. These results appear to be similar for each sex and age group, with 43% of adult males crossing once, 50% of juvenile males, and 45% of females.

Overall, these observations are consistent with the data collected during the other deployments and indicate that tagged animals were successful in travelling across the installed submarine cables.

2.4.4 ANALYSIS

2.4.4.1 CROSSING BEHAVIOUR BEFORE AND AFTER CABLE INSTALLATION

To evaluate whether the operating submarine cables act as a barrier to animal movement we identified individuals that crossed either submarine cable and the number of times that each individual crossed a cable in the 2023/2024 study period.

To evaluate if successful crossing rates differed before the cables were installed (before) vs while they were operating (after), we identified tracks in both datasets where crab or lobsters entered and exited the ZOI. We defined the ZOI as a 5 m buffer around each cable and putative cable location. This distance represented the point at which the cables' magnetic fields were expected to be of comparable strength to the Earth's (50 μ T; DFO 2013) (see Section 1.4). Successful crossings were classified as segments of the tracks where an animal started outside the ZOI, moved inside the ZOI and crossed the cable before moving back outside the ZOI. Unsuccessful crossings were classified as segments where an animal moved inside the ZOI and back outside without crossing a cable. We fit a binomial generalized linear model (GLM) with a logit link to the number of successful and unsuccessful crossings by individual to

determine whether there was an effect of the cable being energized on the rate of successful cable crossings.

2.4.4.2 CABLE CURRENT LOAD AND CROSSING BEHAVIOUR

As previously mentioned, the magnetic anomaly created by the operating cables is directly proportional to the current load travelling through the cables. As such, current load can be used as a proxy for magnetic anomaly intensity. To determine whether crossing success varied with current load when the submarine cables were operating, a weighted average of hourly current (kW) data was calculated for track segments intersecting the ZOI. In instances where energy was transferred in both directions within an hour for a cable, the maximum energy transferred across both directions was taken as the hourly current transferred through the cable for that hour. A binomial generalized linear mixed model (GLMM) logit link was fitted to the after dataset to determine the effect of average current load on crossing success with a random effect of individual to account for multiple observations by individual crab. The predictor variable for cable current was centred prior to analysis to improve model convergence by placing values on a scale more comparable with the other model variables. Results were back-transformed to the original scale for presentation.

2.4.4.3 MOVEMENT RATES WITHIN AND OUTSIDE “ZONE OF INFLUENCE”

To compare movement rates within the ZOI and outside the ZOI and compare these before the submarine cables were installed and while the cables operating we used detections from the track segments previously identified as entering and exiting the ZOI. For each track segment, detections from within the ZOI (that entered and exited the ZOI) were retained as well as detections outside of the ZOI recorded within one hour prior to the animal entering the ZOI (see Figure 2-16 and Figure 2-17 for track segments included in the analysis for lobster and snow crab, respectively).

For American lobsters, we then further filtered the data to include only track segments where lobster were in known areas of open habitat (i.e. algal cover is 0%; see Figure 2-6 for plot of algal cover). This filter was applied to as habitat has been shown to influence the behavior of American lobster (Karnofsky 1989, Konecny et al. 2024) and the submarine cables are installed in areas of open habitat.

Note that not all ZOI interactions will have one full hour of detections outside the ZOI prior to entering the ZOI. It is also possible for each track segment to have multiple interactions with the ZOI. For each track segment, a time weighted average was calculated for movement rate (m/min), bottom temperature (°C) and time since release (TSR) within and outside the ZOI. Diel period (i.e. daytime vs. nighttime) was taken as the mode across detections within and outside the ZOI. TSR was then transformed into a categorical variable (as “acclimation” status) to identify segments where individuals were in an acclimation period (average TSR ≤ 24 hours) or post-acclimation period (TSR > 24 hours) based on results from Konecny et al. (2024) for lobsters, and Cote et al. (2019) for crab, which showed an influence of time since release on animal behaviour state probabilities within the first 24 hours post-release.

A GLMM with a gamma distribution (log link) was fitted to the movement rate across track segments. Only data from male snow crab were included in the snow crab analysis as there were no females present in the after dataset. Covariates of carapace length (cm), sex (lobster only), diel period, average temperature, and acclimation status were included in the model, as well as an interaction between time period (before cables were installed/while cable was energized) and ZOI (inside/outside). A random effect of individual was included to account for multiple track segments for individual animal.

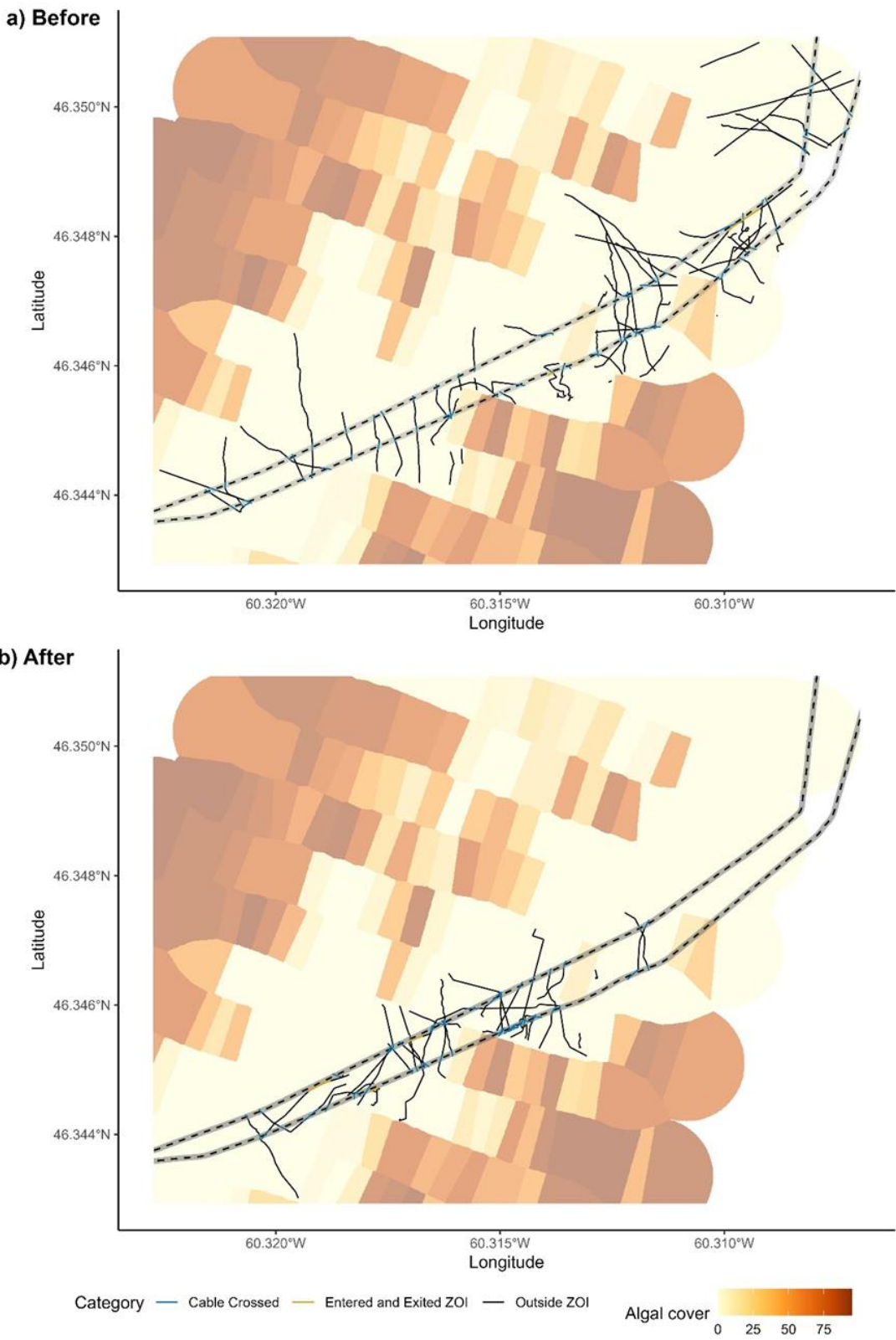


Figure 2-16 American lobster track segments included in the movement analysis

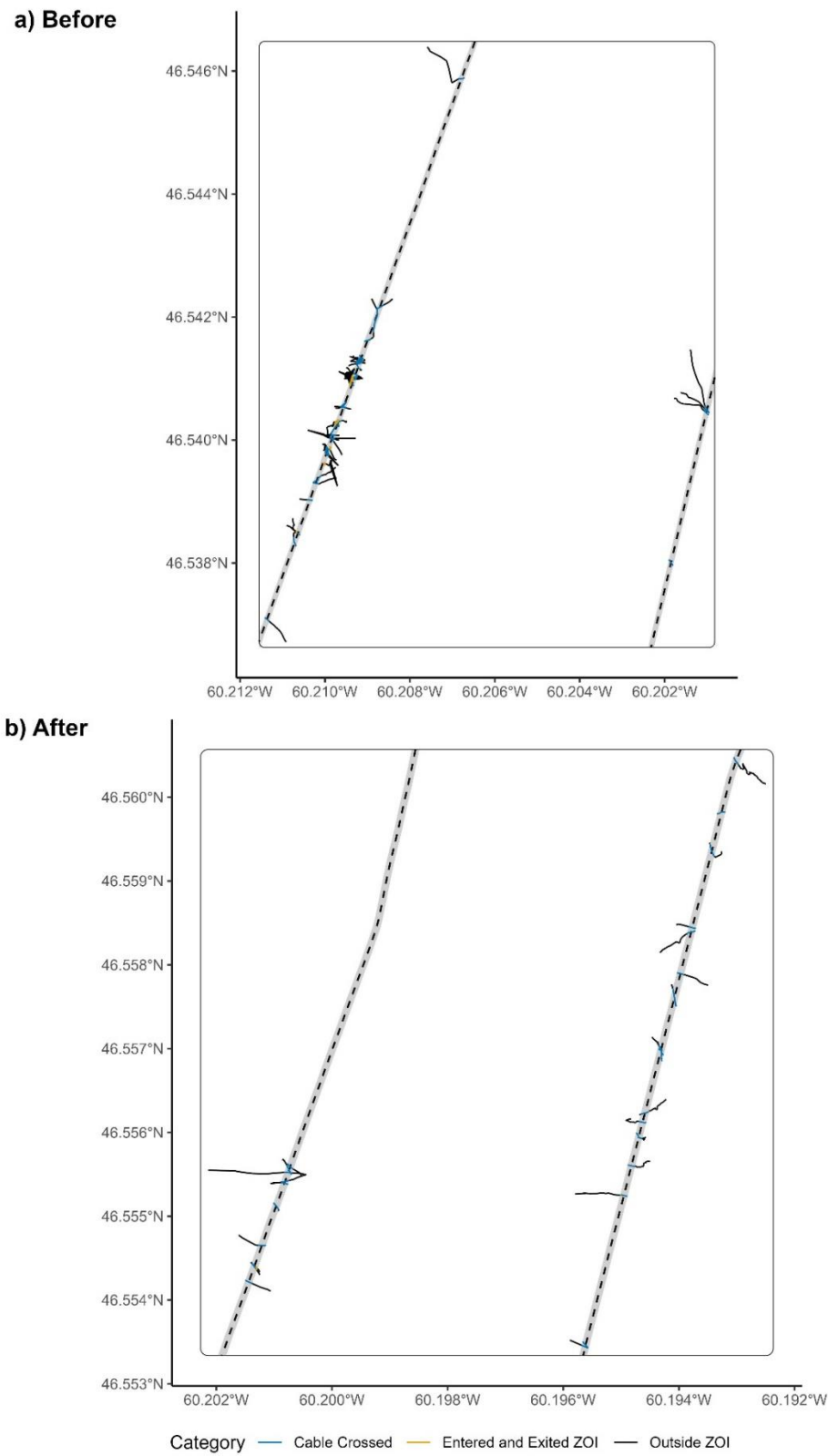


Figure 2-17 Snow crab track segments included in the movement analysis

3 RESULTS

3.1 AMERICAN LOBSTER

3.1.1 CROSSING BEHAVIOUR BEFORE AND AFTER CABLE INSTALLATION

In the two study years prior to the submarine cables being installed, there were a total of 27 individuals that entered and exited the ZOI out of the 58 individuals included in the analysis. Across the 27 individuals that entered and exited the ZOI, there were 102 successful cable crossings (91%) out of 112 interactions (Figure 3-1a). In the study period while the cables were operating, 18 individuals entered and exited the ZOI out of the 32 individuals included in the analysis. Individuals that crossed the cables, crossed a total of 1-12 times. Across the 18 individuals that entered and exited the ZOI, there were 60 successful cable crossings out of 64 interactions (93%) while the cables were operating (Figure 3-1b). GLM analysis showed no significant effect of the cable being under steady state operation on the success rate of animals crossing the cable ($p = 0.530$; Table 3-1, Figure 3-2).

Table 3-1 GLM results of the effect of study period on cable crossing success rates in American lobster

Predictor	Odds Ratio	Confidence Interval	p-value
Intercept	10.20	5.61 – 20.85	<0.001
Study Period	1.47	0.47 – 5.55	0.530
Observations	45		

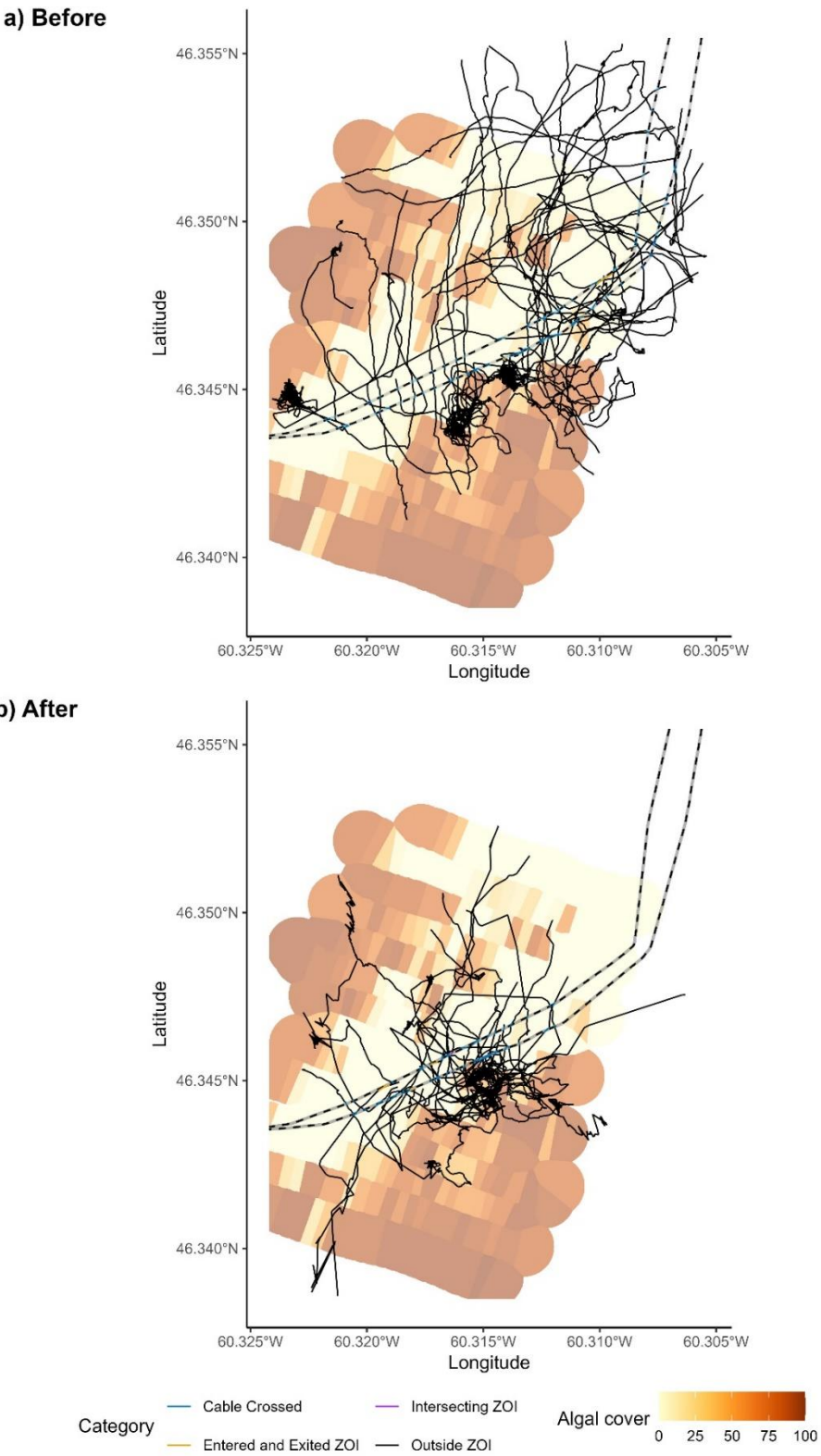


Figure 3-1 Movement track segments of lobster that entered and exited the ZOI in the study periods before the cable was installed (a) and while the cable was energized (b). Areas of the track segments that crossed one of the cables are shown in blue, areas of the track segments that entered and exited the ZOI without crossing the cable are shown in yellow, and areas of the track segments that only intersected the ZOI

(either entered or exited the ZOI) are shown in purple. The remaining areas outside the ZOI are shown in black. Algal cover (percent cover) is shown for reference.

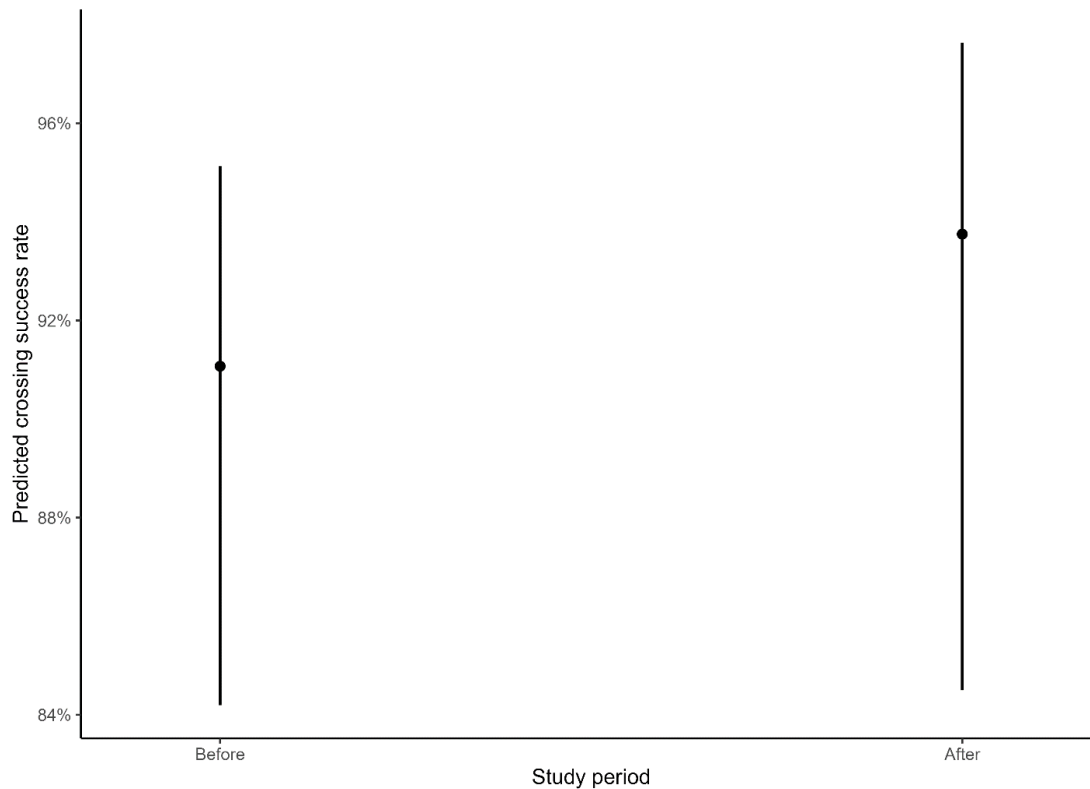


Figure 3-2 Predicted cable crossing success rate before the submarine cables were installed (before) and while the submarine cables were energized (after). Points represent GLM model estimates and error bars represents 95% confidence intervals

3.1.2 CABLE CURRENT LOAD AND CROSSING BEHAVIOUR

In the study period while the cables were operating under load, GLMM analysis showed that there was no significant effect of energy load ($p = 0.347$, Table 3-2) on the success rate of American lobster crossing the cable (Figure 3-3).

Table 3-2 GLMM results of the effect of submarine cable current on cable crossing success rates in American lobster

Predictor	Odds Ratio	Confidence Interval	p-value
Intercept	11065.44	3.87 – 31657248.79	0.022
Cable Current	5.56	0.16 – 198.95	0.347
<i>Random Effects</i>			
σ^2	3.29		
τ_{00} Transmitter	55.67		
ICC	0.94		
$N_{\text{Transmitter}}$	18		

Observations	64
Marginal R^2 / Conditional R^2	0.048 / 0.947

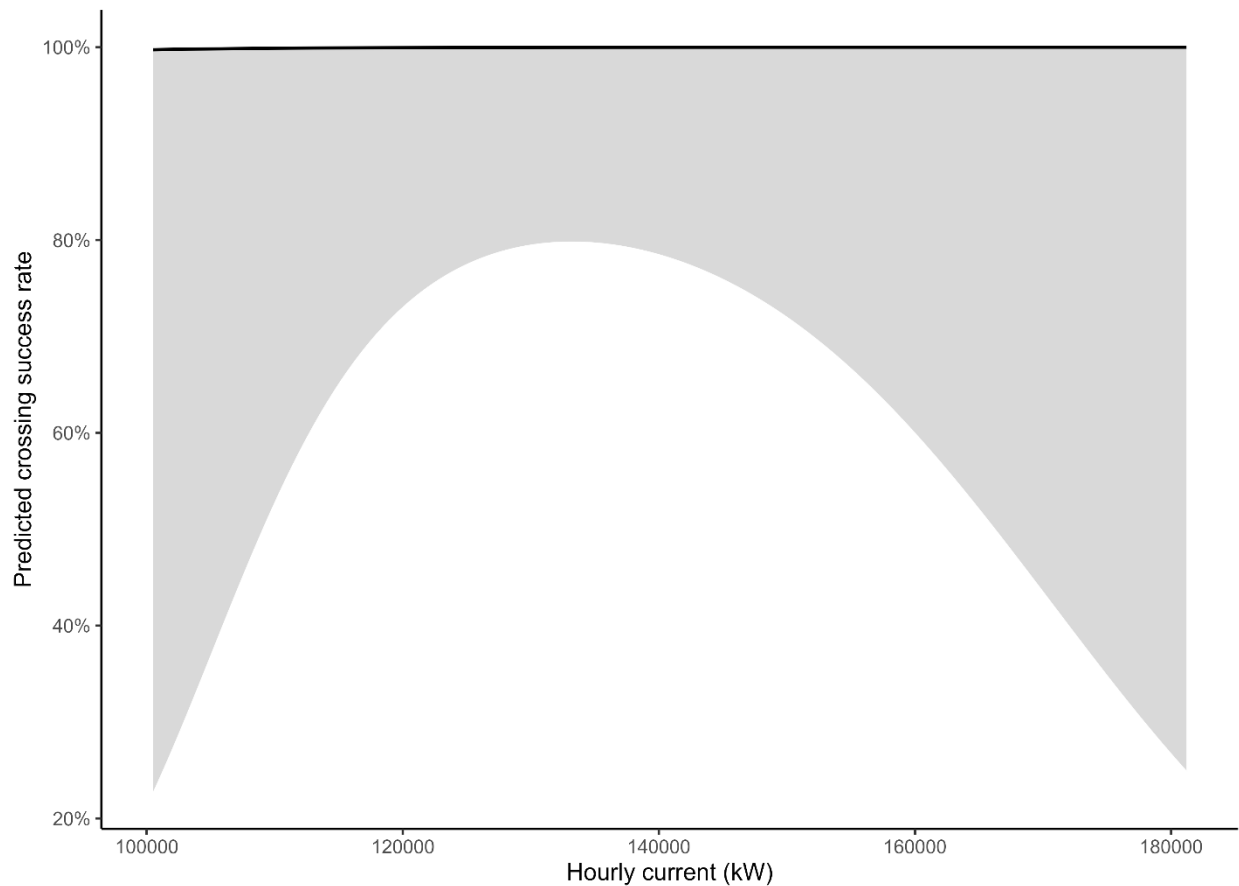


Figure 3-3 Predicted cable crossing success rate as a function of hourly current in the submarine cables. Line represents GLMM model estimate and shading represents the 95% confidence interval

3.1.3 MOVEMENT RATES WITHIN AND OUTSIDE “ZONE OF INFLUENCE”

The GLMM showed that carapace length did not statistically significantly affect movement rate ($p = 0.680$; Table 3-3, Figure 3-4a). However, there was a slight non-significant tendency for movement rates to increase as carapace length increased, i.e. larger lobsters tended to have slightly higher movement rates. Diel period ($p = 0.002$; Table 3-3, Figure 3-4b) and temperature ($p < 0.001$; Table 3-3, Figure 3-4c) significantly affected movement rates in American lobster with individuals moving faster during the day and at higher temperatures. There was a non-significant trend of higher movement rates in male compared to female lobster ($p = 0.271$; Table 3-3, Figure 3-4d). During the post-acclimation period lobster moved significantly faster ($p = 0.004$; Table 3-3, Figure 3-4e). There was no effect of study period ($p = 0.237$) on movement rates or location (inside vs outside the ZOI; $p = 0.886$, Table 3-3). There was also no significant interaction between study period and location (inside or outside the ZOI) indicating that the operating cables did not impact lobster movement rates ($p = 0.757$; Table 3-3, Figure 3-4f).

Table 3-3 GLMM results of the effect of individual-level and environmental covariates on movement rates (m / min) in American lobster. Results are also shown for the effects of the study period, the location inside or outside the “zone of influence” (ZOI), and their interaction.

Predictor	Estimates	Confidence Interval	p-value
Intercept	0.84	0.18 – 4.02	0.829
Length	1.04	0.88 – 1.22	0.680
Diel Period [night]	0.70	0.56 – 0.87	0.002
Temperature	1.06	1.03 – 1.09	<0.001
Sex [Male]	1.20	0.87 – 1.66	0.271
Acclimation status [post-acclimation]	1.37	1.10 – 1.69	0.004
ZOI [Not intersecting]	1.01	0.88 – 1.16	0.886
Study period [After]	1.21	0.88 – 1.68	0.237
ZOI [Not intersecting] x Study period [After]	0.97	0.78 – 1.20	0.757
<i>Random Effects</i>			
σ^2	0.07		
τ_{00} Transmitter	0.17		
ICC	0.72		
$N_{\text{Transmitter}}$	40		
Observations	95		
Marginal R^2 / Conditional R^2	0.208 / 0.776		

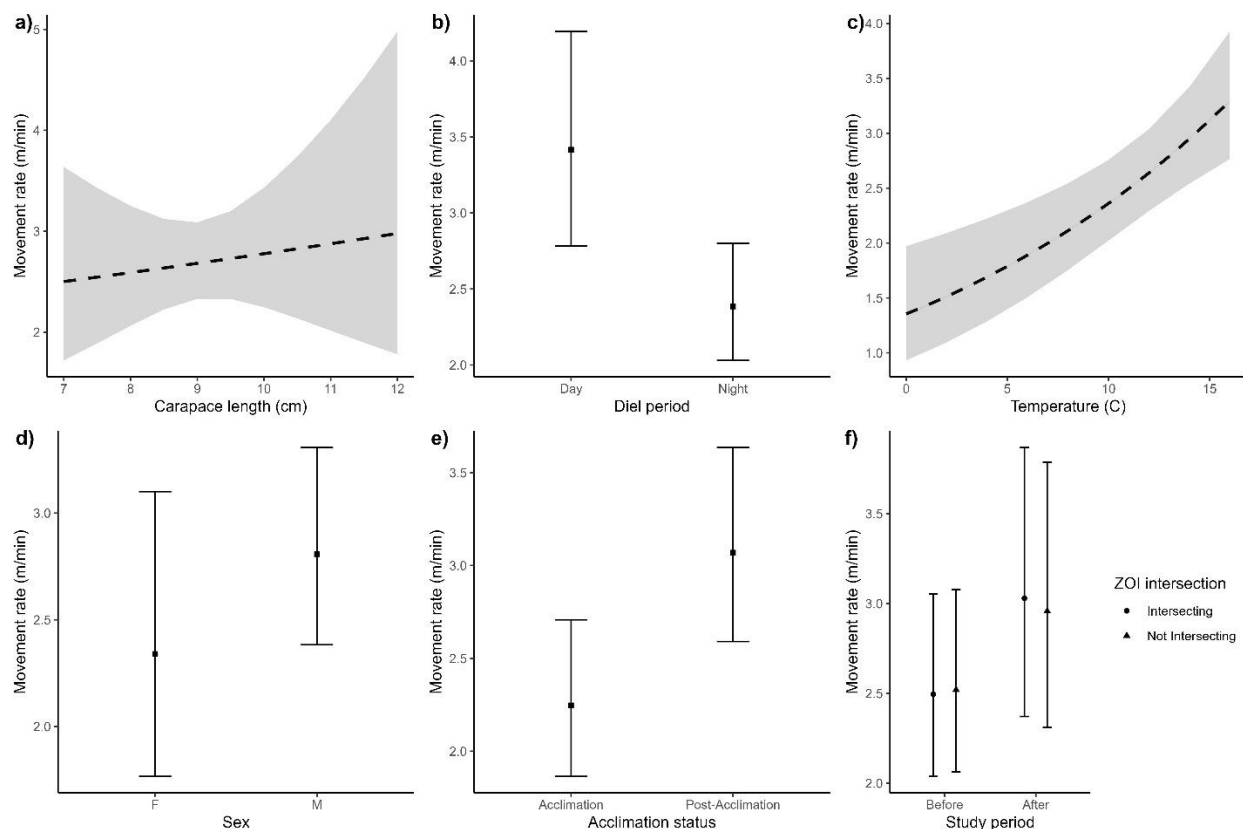


Figure 3-4 Marginal effects plots from the fitted GLMM to show the effect of: A) carapace length, B) diel period, C) temperature, D) sex, E) acclimation status, and F) the interaction between study period and lobster location on lobster movement rates (m / min). Marginal means are shown (dashed lines and points) as well as 95% confidence intervals for the predicted values (shading and error bars).

3.2 SNOW CRAB

3.2.1 CROSSING BEHAVIOUR BEFORE AND AFTER CABLE INSTALLATION

In the two study years prior to the submarine cables being installed, there were a total of 15 individuals that entered and exited the ZOI out of the 40 individuals included in the analysis. Across the 15 individuals that entered and exited the ZOI, there were 42 successful cable crossings (70%) out of 60 interactions (Figure 3-5a). In the study period while the cables were operating, 12 individuals entered and exited the ZOI out of the 34 individuals included in the analysis. Individuals that crossed the cables, crossed a total of 1-8 times. Across the 12 individuals that entered and exited the ZOI, there were 25 successful cable crossings (75%) out of 33 interactions while the cables were operating (Figure 3-5b). GLM analysis showed no significant effect of the submarine cables being under steady state operation on the success rate of animals crossing the cable ($p = 0.555$; Table 3-4, Figure 3-6).

Table 3-4 GLM results of the effect of study period on cable crossing success rates in snow crab

Predictor	Odds Ratio	Confidence Interval	p-value
Intercept	2.33	1.37 – 4.15	0.003

Study Period	1.34	0.52 – 3.68	0.555
Observations	27		

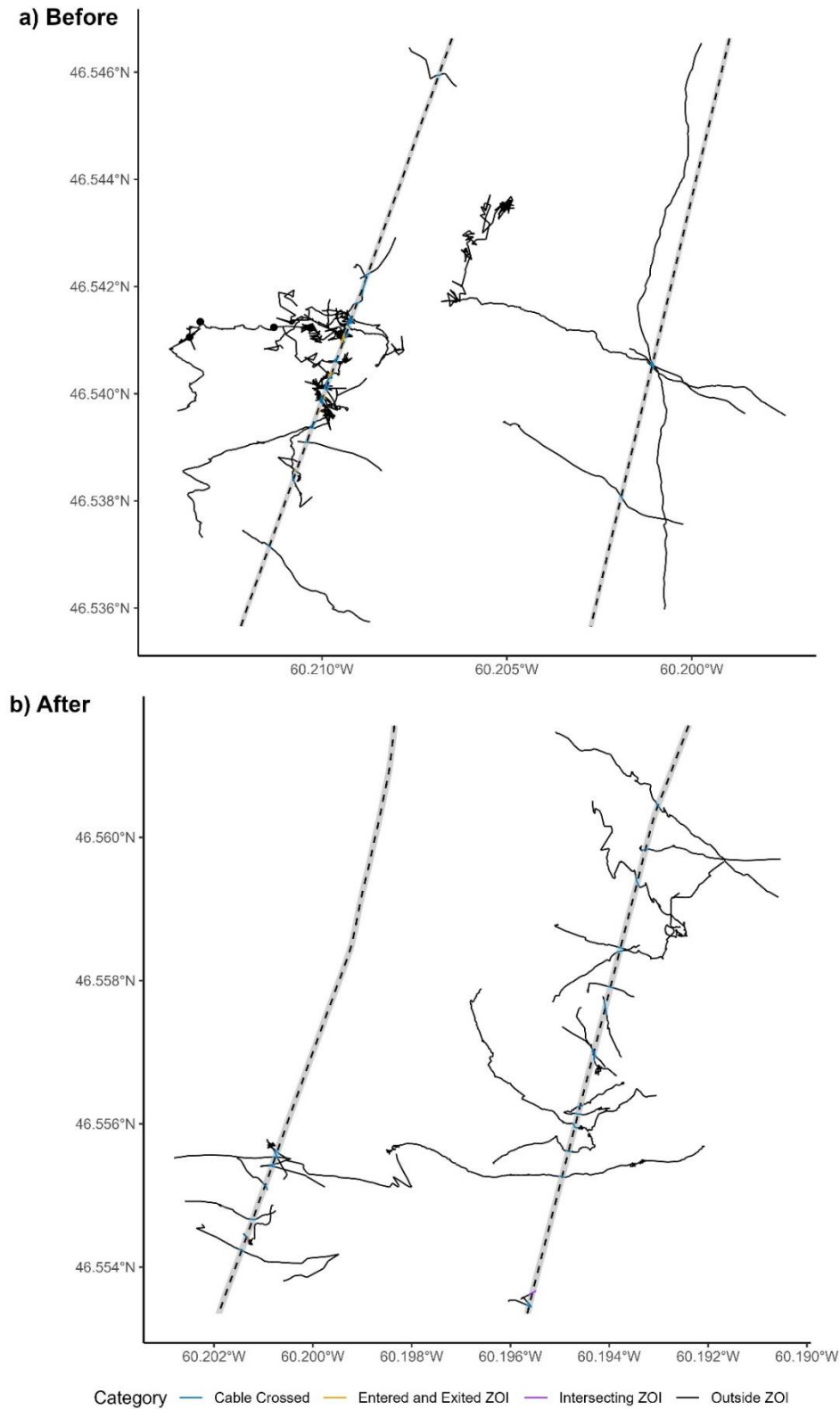


Figure 3-5 Movement track segments of snow crab that entered and exited the ZOI in the study periods before the cable was installed (a) and while the cable was energized (b). Areas of the track segments that crossed one of the cables are shown in blue, areas of the track segments that entered and exited the ZOI without crossing the cable are shown in yellow, and areas of the track segments that only intersected the ZOI

(either entered or exited the ZOI) are shown in purple. The remaining areas outside the ZOI are shown in black

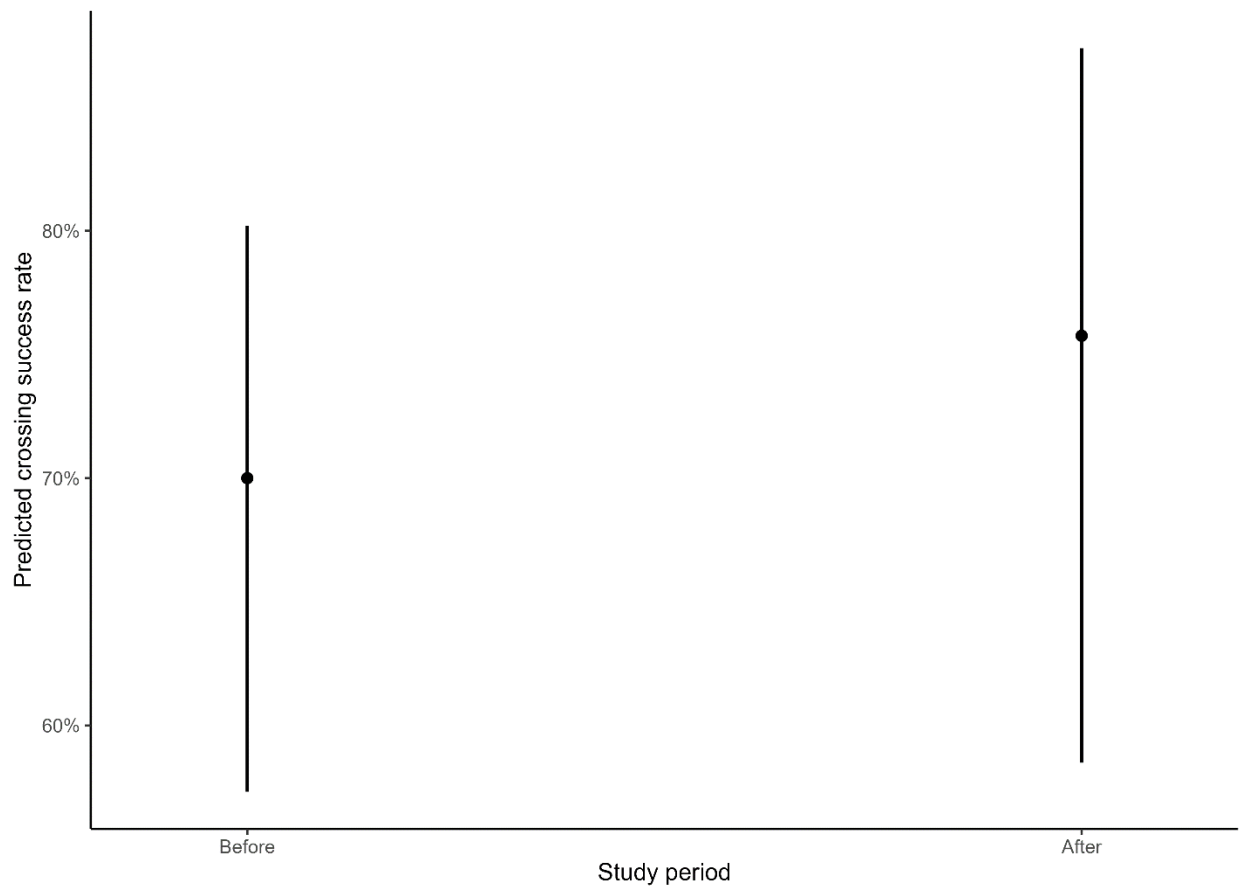


Figure 3-6 Predicted cable crossing success rate before the submarine cables were installed (before) and while the submarine cables were energized (after). Points represent GLM model estimates and error bars represents 95% confidence intervals

3.2.2 CABLE CURRENT LOAD AND CROSSING BEHAVIOUR

In the study period while the cables were operating, GLMM analysis showed that there was no significant effect of energy load ($p = 0.275$; Table 3-5) on the success rate of snow crab crossing a cable (Figure 3-7).

Table 3-5 GLMM results of the effect of submarine cable current on cable crossing success rates in snow crab

Predictor	Odds Ratio	Confidence Interval	p-value
Intercept	6.05	0.15 – 243.38	0.340
Cable Current	1.98	0.58 – 6.73	0.275

<i>Random Effects</i>	
σ^2	3.29
τ_{00} Transmitter	0.84
ICC	0.20
$N_{\text{Transmitter}}$	12
Observations	33
Marginal R^2 / Conditional R^2	0.101 / 0.283

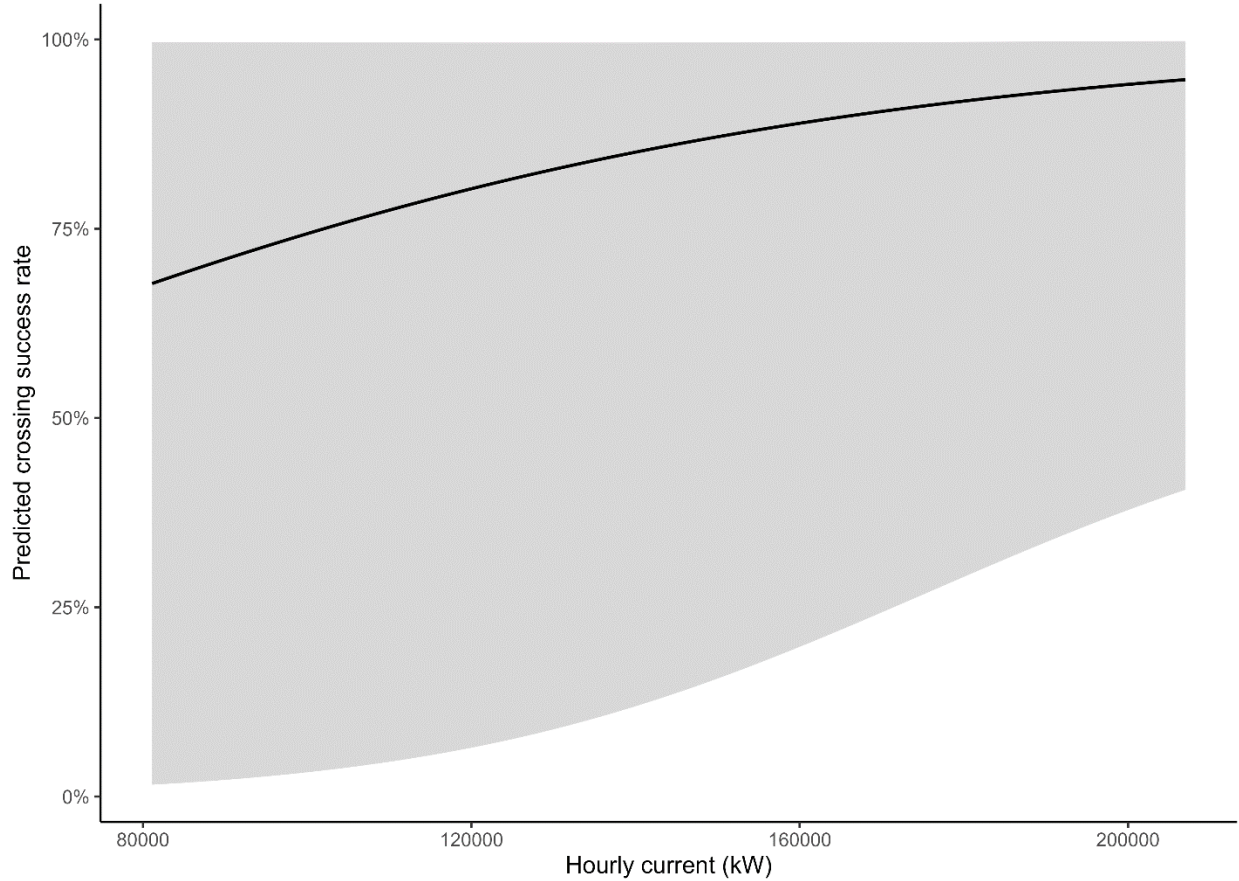


Figure 3-7 Predicted cable crossing success rate as a function of hourly current in the submarine cables. Line represents GLMM model estimate and shading represents the 95% confidence interval

3.2.3 MOVEMENT RATES WITHIN AND OUTSIDE “ZONE OF INFLUENCE”

The GLMM indicated that there was no effect of carapace length ($p = 0.795$; Table 3-6, Figure 3-8a) on movement rate. However, there was a slight non-significant tendency for movement rates to increase as carapace length increased, i.e. larger crabs tended to have slightly higher movement rates. Diel period ($p < 0.001$; Table 3-6, Figure 3-8b) and temperature ($p < 0.001$; Table 3-6, Figure 3-8c) significantly affected movement rates in snow crab with individuals moving faster at night and at higher temperatures. There was a non-significant trend of increased movement rates during the post-acclimation period ($p = 0.394$; Table 3-6, Figure 3-8d). There was a significant effect of study period ($p = 0.005$; Table 3-6) on movement rates with crab moving faster in the period before the cables were installed both inside and outside the ZOI ($p = 0.582$; Table 3-6). The interaction however, between study period and the crab's location (inside or outside the ZOI) did not significantly affect movement rates indicating that the operating cables did not impact crab movement rates ($p = 0.704$; Table 3-6, Figure 3-8e).

Table 3-6 GLMM results of the effect of individual-level and environmental covariates on movement rates in snow crab. Results are also shown for the effects of the study period, the location inside or outside the “zone of influence” (ZOI), and their interaction

Predictor	Estimates	Confidence Interval	p-value
Intercept	0.10	0.01 – 1.23	0.072
Length	1.03	0.84 – 1.25	0.795
Diel Period [night]	2.08	1.42 – 3.04	<0.001
Temperature	1.67	1.27 – 2.20	<0.001
Acclimation status [post-acclimation]	1.28	0.73 – 2.26	0.394
ZOI [Not intersecting]	0.92	0.69 – 1.23	0.582
Study period [After]	0.37	0.19 – 0.74	0.005
ZOI [Not intersecting] x Study period [After]	0.92	0.61 – 1.39	0.704
<i>Random Effects</i>			
σ^2	0.19		
τ_{00} Transmitter	0.60		
ICC	0.76		
N Transmitter	27		
Observations	79		

Marginal R ² / Conditional R ²	0.258 / 0.824
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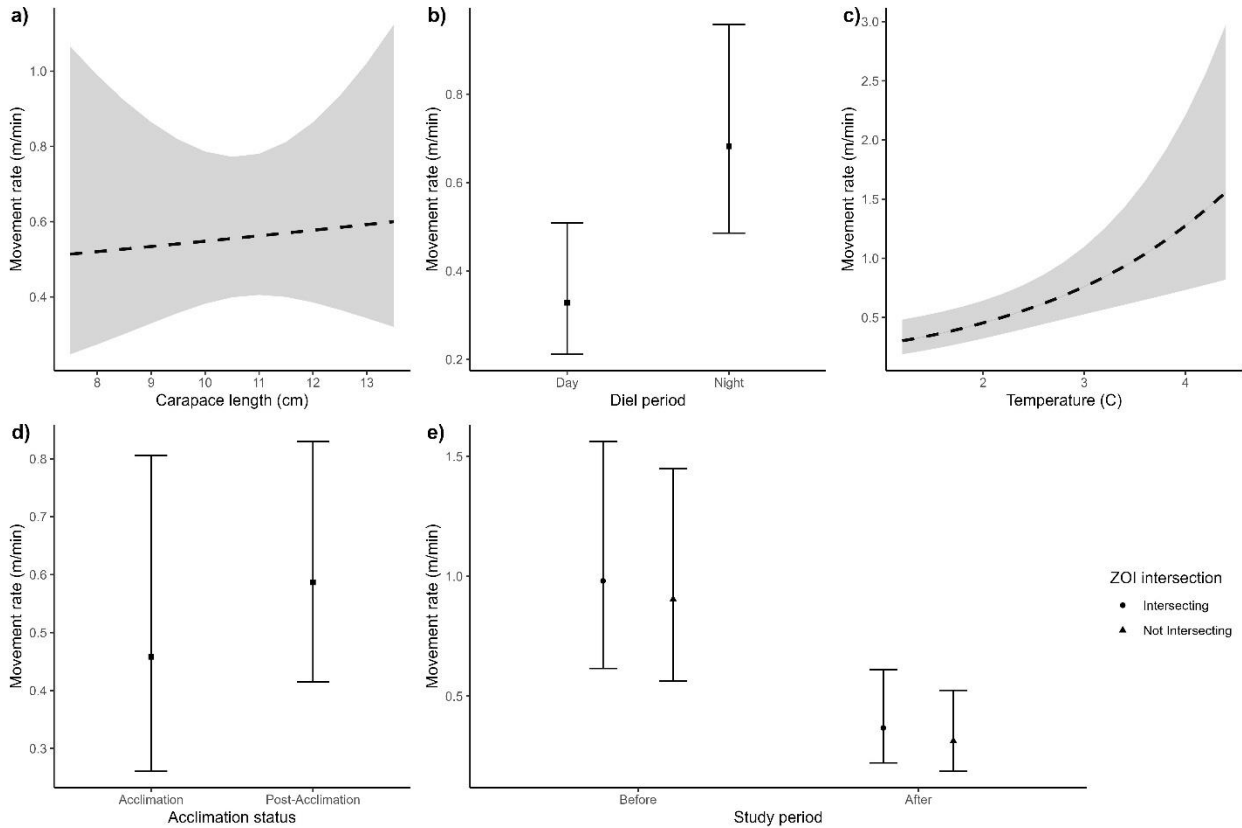


Figure 3-8 Marginal effects plots from the fitted GLMM to show the effect of: A) carapace length, B) diel period, C) temperature, D) acclimation status, and E) the interaction between study period and crab location on snow crab movement rates (m / min). Marginal means are shown (dashed lines and points) as well as 95% confidence intervals for the predicted values (shading and error bars)

4 SUMMARY AND CONCLUSION

The findings from this study represent a unique *in situ* perspective on the potential impact of magnetic fields on American lobsters and snow crabs. Long-term field studies of this nature are rare given the high cost and complexity, with the majority of studies taking place in laboratory settings (Konecny et al. 2024). However, laboratory studies typically test single variables while field studies give a more realistic and holistic view of multiple natural effects (e.g., water temperature, currents, predator presence) on animal behaviour. As the Maritime Link cables are within commercial fishing areas for American lobster and snow crab, understanding potential behavioural changes is needed for resource management as well as understanding their ecology in the region. Konecny et al. (2024) and Cote et al. (2019) give early findings from this study focused on lobster and crab movement behaviour, respectively, prior to cable energization.

4.1 AMERICAN LOBSTER

For American lobster, there was no significant change in animal behaviour between before the installation of the submarine cables and after installation and steady state operation. While not included in the analysis, results from 2018/2019 also suggested that the cables did not create a barrier as 35% of lobsters crossed over at least once. Cable current load, as a proxy for magnetic anomaly intensity, did not impact crossing behaviour. Lobster movement rates within the “zone of influence” (ZOI; within 5 m of the cables) were not significantly different from before the cables’ installation and during normal operation.

The only significant factors that influenced lobster movement within the ZOI were time of day (higher in the day compared to night), water temperature (higher as temperature increased), and acclimation (behaviour directly after being tagged and released and behaviour after one day). While lobster movement behaviour is generally higher in warmer water (within their preferred thermal range; Watson et al. 2023), lobsters are generally more active at night (Christian 1995). Further tagging studies may be needed to better understand the increase in lobster movement during the day.

Results from this study support the conclusion that the installation and operation of the Maritime Link submarine cables do not influence American lobster horizontal movement patterns in the area.

4.2 SNOW CRAB

For snow crab, some differences in animal behaviour were observed between the pre-installation period and the post-installation steady-state operation period; however, these differences were not attributable to the installation or operation of the submarine cables. In particular, this study found that the installation and operation of the submarine cables did not create an impediment to snow crabs crossing the cables area. While not included in the analysis, results from 2018/2019 also suggested that the cables did not create a barrier as 45% of crabs crossed over at least once. Cable current load, as a proxy for magnetic anomaly intensity, did not impact crossing movement patterns. Crab movement rates within the “zone of influence” (ZOI; within 5 m of the cables) were not significantly different between before the cables’ installation and during normal operation.

Although movement rates differed significantly between study periods, with higher crab movement observed during the pre-installation period, movement speeds were similarly elevated both within and outside the ZOI, and the non-significant interaction term suggests that the cables were not impacting movement speed. Other significant factors that influenced movement within the ZOI were time of day (higher in the night compared to the day) and water temperature (higher as temperature increased). These

results are typical for the species, with faster movement during the night and in warmer water (Cote et al. 2019).

Results from this study support the conclusion that the installation and operation of the Maritime Link submarine cables do not influence snow crab horizontal movement patterns in the area.

4.3 DISCUSSION

The findings from this study give a better understanding of how these two species' behaviour is potentially altered by electromagnetic fields and confirm the EA statement that the adverse residual environmental effects from the Project activities are not significant. Neither American lobster nor snow crab experienced any behavioural changes (either in crossing rate or movement within the ZOI) after the installation and energization of the Marine Link. These findings generally agree with past studies, such as Hutchison et al. (2018) which studied lobster movement near electrified cables in seabed enclosures. They found no movement differences between treatments, though lobsters exposed to the electromagnetic field did exhibit more burrowing behaviours. While no studies to date have tested the behaviour of snow crab exposed to electromagnetic fields, findings from other crab species generally show no behavioural changes (Woodruff et al. 2013, Love et al. 2015).

Some limitations of this research include the life history stages tested, animal sex, and timing. For lobsters, only adults were used in this study and findings from other lobster species indicate potential effects on early life stages (Harsanyi et al. 2002). While lobster sex did not significantly impact movement, few female lobsters were caught in 2014/2015. While snow crab did use male, female, and juvenile individuals, the majority of the tagged animals were adult male crab as few female crabs were caught in most study years. Array deployments were generally from the fall until spring and thus may not give the full context of movement effects year-round.

While few subsea electrified cables exist in Atlantic Canada, these findings are important for the future of the region as addition cables are added for offshore wind power production. Lobster and crab are Canada's most valuable sea fisheries (DFO 2025), and the creation of potential barriers to movement could impact migratory behaviour, settlement, and other life history events. These results add to the body of research around the effect of electromagnetic fields on lobster and crab and gives key insights for future work in the region.

4.4 FUTURE RECOMMENDATIONS

It was noted that a large portion of tagged individuals were only detected immediately after being returned to the water and remained undetected for the remainder of the array deployment. Future surveys should consider the effective sample size if large portions of the tagged animals depart the array and do not provide usable data.

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