# An Evaluation of the Effects of Simulator Training on Ice Management Performance

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# Abstract

This research offers practical insights into the relationship between amount of training and ice management performance. In a previous experiment, it was found that, on average, experienced seafarers performed better in an ice management simulator than inexperienced cadets (Veitch, 2018). In a current experiment, two additional groups of inexperienced cadets were trained for ice management in either one or two sessions. The training included viewing examples of expert performance and completing practice scenarios in a simulator. After training, the cadets completed two ice management simulator scenarios, one of which was the same as that used in the previous experiment. Training was found to have a positive effect on ice management performance in most scenarios. In the scenario used in both experiments, ice management performance improved with increasing amounts of training and the results demonstrate a proposed method for estimating the amount of training required to reach a performance target.

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# List of Abbreviations

AHTS – Anchor Handling Tug Supply

ANOVA – Analysis Of Variance

DNV – Det Norske Veritas

FPSO – Floating Production Storage Offloading facility

ICEHR – Interdisciplinary Committee on Ethics in Human Research

IMO – International Maritime Organization

ISO – International Organization for Standardization

MARPOL – International Convention for the Prevention of Pollution by Ships

MUN – Memorial University of Newfoundland

POLARIS – Polar Operational Limit Assessment Risk Indexing System

SOLAS – Safety Of Life At Sea

TEMPSC – Totally Enclosed Motor Propelled Survival Craft

VHF – Very High Frequency

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# Chapter 1: Introduction

## 1.1 Overview

Ice management is relied upon for offshore operations to continue year round in the presence of sea ice (Dunderdale and Wright, 2005; El Bakkay et al., 2014; Keinonen, 2008). Many of the seafarers conducting these ice management operations have had little or no formal training in ice management (Veitch, 2018a). Instead, it is assumed they have expertise in ice management based on both their own experience and experience inherited from other seafarers (Sellberg, 2017; Veitch, 2018a; Veitch et al., 2019). However, since the level of experience in ice management amongst seafarers is highly variable, an uncertainty exists in the ability of each individual seafarer to successfully complete safety critical ice management operations (Veitch, 2018a; Veitch et al., 2019). The objective of the research presented in the present thesis was to study how different amounts of direct training affect the ability of inexperienced seafarers to successfully complete ice management operations.

The research associated with the present thesis consisted of two experiments. Experiment 1 studied the effects of experience on the success of ice management operations. The results of Experiment 1 were reported in Veitch (2018a). In Experiment 1, a group of experienced seafarers and a group of inexperienced cadets conducted ice management operations in a bridge simulator. It was found that, on average, the experienced seafarers performed better in ice management operations than the inexperienced cadets. The performance amongst both groups was found to be highly variable (Veitch, 2018a; Veitch et al., 2019). The results of Experiment 1 are used in the present thesis as a performance benchmark of both experienced seafarers and inexperienced cadets with no training.

Experiment 2 studied the effects of training on ice management performance. The results of Experiment 2 are the primary focus of the present thesis. In Experiment 2, a training curriculum was developed using the results of Experiment 1 and the training recommendations in the International Maritime Organization (IMO) Polar Code (IMO, 2017a). Using the curriculum, two groups of inexperienced cadets were trained in three ice management techniques:

(1) pushing,

(2) prop wash, and

(3) leeway.

The Training I group received one training session. This included completing three training scenarios in the ice management bridge simulator, one for each of the three ice management techniques. The Training II group received two training sessions, which included completing each of the three training scenarios twice. Two testing scenarios were used to assess the ice management performance of the cadets after training. These were the precautionary and emergency ice management scenarios. The emergency ice management scenario was also used in Experiment 1 and the scenario was used to compare ice management performance across both experiments.

## 1.2 Purpose

The purpose of this research was to offer practical insights into the relationship between amount of training and the performance of inexperienced cadets in ice management operations. The research aimed to demonstrate the ability of simulators as a training tool for ice management operations and estimate how much training is needed for novice inexperienced cadets to reach targeted performance levels.

## 1.3 Hypotheses

For the emergency ice management scenario, the hypotheses, as illustrated in Figure 1, were:

(1) inexperienced cadets with increasing amounts of training would have higher average ice management performance levels in a bridge simulator (the median performance in each box of Figure 1 is higher with successive training),

(2) the variability in performance in an ice management bridge simulator amongst the inexperience cadets would decrease with increasing amounts of training (the spread of each box in Figure 1 is less with successive training), and

(3) the relationship between amount of training and ice management performance would provide a method of estimating the amount of training an inexperienced cadet would need to reach a specified performance target (Figure 1 shows a trend created from the hypothetical median ice management performance of the inexperienced cadets. The trend is the basis to extrapolate the amount of training needed to reach the target level.).

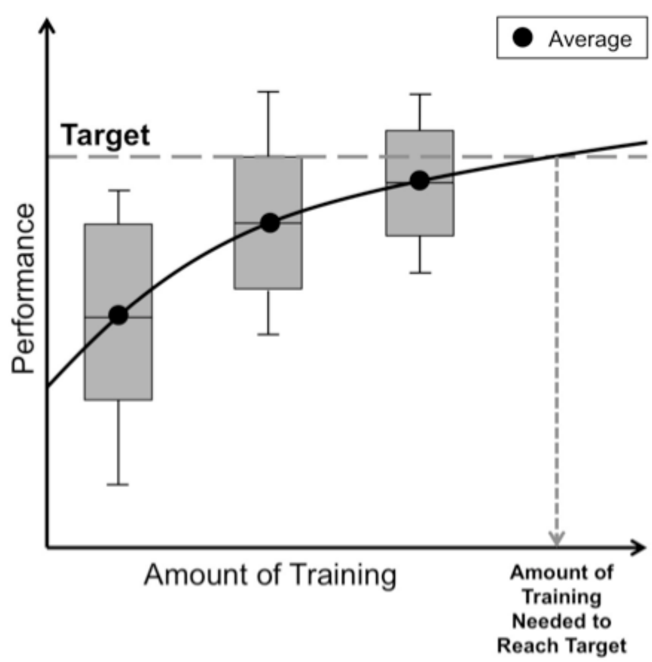



**Figure 1: Hypothesized Results**

For the precautionary ice management scenario, the hypotheses were:

(1) the inexperienced cadets with more training would perform better on average in the ice management bridge simulator than the inexperienced cadets with less training and

(2) the variability amongst the performances of the inexperienced cadets with more training would be lower than the cadets with less training.

For each of the three training scenarios, it was hypothesized that:

(1) the cadets with more training would have a better average ice management performance in the bridge simulator in their second attempt of the scenarios than the cadets with less training had in their first attempt of the scenarios (i.e. between subject comparison) and

(2) the cadets with more training would have a better average ice management performance in the bridge simulator in their second attempt of the scenarios than in their own first attempt of the scenarios (i.e. within subject comparison).

# Chapter 2: Literature Review

## 2.1 Sea Ice and Ice Management

### 2.1.1 Definition of Ice Management

The term *'Ice management'* has various definitions (Eik, 2008; Haimelin et al., 2017). In the context of this research, ice management is defined as:

> "… a general term that is often used to describe the support activities a stationary vessel or platform may require to allow it to maintain position and continue operations in moving ice." (Dunderdale and Wright, 2005)

This definition fits within the scope of ice management covered under the International Standard Organization (ISO) standard, *ISO 35104*, which covers ice management for Arctic operations in the petroleum and natural gas industries (ISO, 2018).

Ice management typically encompasses the management of both sea ice and icebergs (Dunderdale and Wright, 2005; Eik, 2008; El Bakkay et al., 2014; Haimelin et al., 2017; ISO, 2018). However, iceberg and fast ice management is not covered under the scope of this research and the term ice management is used to refer only to the management of pack ice.

The term ice management can also refer to a full ice management system, which would include:

(1) ice forecasting, detection, and tracking,

(2) threat evaluation and risk assessment,

(3) ice alert procedures, and

(4) physical ice management (El Bakkay et al., 2014; Keinonen, 2008).

This research focuses only on physical ice management. Many of the other steps within an ice management system are controlled within the experiments.

### 2.1.2 Properties and Conditions of Pack Ice

The stages of sea ice development are:

(1) new ice - very thin newly formed ice,

(2) nilas – elastic ice up to ten centimeters thick that bends with waves,

(3) young ice – ten to thirty centimetre thick ice between the stages of nilas and first-year ice,

(4) first-year ice – ice greater than thirty centimeters thick in its first winter, and

(5) multi-year ice – ice that has survived at least one melt season (Canadian Ice Service, 2005).

Pack ice is sea ice that is not attached to land (fast ice). The form of pack is usually floes, which are independent pieces of ice of varying sizes. Pack ice is defined by its concentration (the ratio of an area covered by ice to the entire area), ice thickness, ice type (first-year or multi-year), and floe size (width) (Canadian Ice Service, 2005).

The physical properties and strength of pack ice vary due to its thickness, width, salinity, and granular structures (Timco and Weeks, 2010). Multi-year ice is higher in strength and size and is therefore the most difficult to mange (Maddock et al., 2011; Taylor et al., 2012). The management of first-year pack ice is also required for offshore operations to continue through the ice season and is what is most often required for operations in offshore Newfoundland (Dunderdale and Wright, 2005).

Ice drift is defined by the speed and direction that pack ice is traveling. Factors affecting ice drift include wind drag, ocean current drag, pack ice mechanics, and Coriolis forces. An offshore facility's heading is generally in the direction of drift but keeping this position can become difficult and ice loads can become high when ice management operations cannot keep up with changes in drift direction (Rossiter and McKenna, 2013).

### 2.1.3 Ice Management on the Grand Banks of Newfoundland

Dunderdale and Wright (2005) described the pack ice conditions on the Grand Banks off the east coast of Newfoundland. Ice on the Grand Banks comes from the ice cover on the east coast of Canada. Ice does not occur annually on the Grand Banks but is common farther north. The White Rose oil field is farther north and therefore experiences more ice cover than the Hibernia or Terra Nova fields. Ice usually reaches the Grand Banks in January to mid-February and lasts until May with maximum coverage in March and April (Dunderdale and Wright, 2005; C-CORE, 2005). Concentrations are usually one to six tenths, what is known as drift ice, but concentrations of seven to nine plus tenths occur 30% of the time during pack ice intrusions. Floe sizes are small at twenty to 100 meters but can be up to 500 meters or larger. Ice thicknesses of 30 to 70 centimeters occur 90% of the time and 70 to 120 centimeters thickness occur 10% of the time. It is unlikely that ridges, rubble field, or raft ice will occur on the Grand Banks. However, remnants of old ice floes and small glacial ice masses can occur. The drift speed on the Grand Banks is usually half a knot but can increase to several knots in short bursts of a few hours. Drift direction is typically south or southeast but can be in any direction. Factors that make pack ice management on the Grand Banks complex include whether a fixed of floating platform is used, the function of the platform (such as drilling, production, storage, or loading), the level of ice strengthening on the platform, how station is kept, and the ice environment (Dunderdale and Wright, 2005).

### 2.1.4 Ice Management Vessels

The IMO's Polar Code gives guidelines for ships operating in ice-covered waters. The code is written with a goal and risk based approach and covers issues under the Safety of Life at Sea (SOALS) Convention and International Convention for the Prevention of Pollution by Ships (MARPOL) (IMO, 2017a; Kendrick, 2014).

Choosing the vessel to be used in an ice management operation is important for allowing a facility to stay on station in an ice drift and maintain minimal loads on the facility. The use of multiple vessels in an ice management operation can improve an ice management operation but the number of vessels is often limited by how many vessels can operate in a limited space (Hamilton et al., 2011).

One key aspect of ice management on the Grand Banks is the difference between using an ice transit and an ice management vessel. An ice transit vessel is designed to go through ice. However, it can avoid major hazards on its way to its destination. An ice management vessel needs to deal with all ice in the path of a facility. For this reason it is essential that a vessel being used for ice management operations on the Grand Banks be properly assessed for its ability to mange ice. If an ice transit vessel is used and damage occurs this can impair the success of an operation (Dunderdale and Wright, 2005).

### 2.1.5 Ice Management Techniques

There are five techniques used in typical pack ice management operations. These include the:

(1) linear,

(2) sector,

(3) circular,

(4) ice pushing, and

(5) prop wash techniques.

The goal of each of these techniques is to reduce the number and size of floes coming in to contact with the facility in order to reduce the ice loads and allow the facility to maintain its position or reduce the risk of structural damage. The selection of which technique to use is dependent on the pack ice conditions during a given time period (Dunderdale and Wright, 2005; Hisette, 2014).

The linear technique involves an ice management vessel moving in lines parallel to the ice drift. This technique is performed up drift of the facility when the drift speed is fast and the drift direction is consistent. The linear pattern is used to reduce the size of larger floes, there by keeping a channel of ice with reduced floe size around the vicinity of the facility. Since this technique is performed parallel to the ice drift and facility and creates a relatively narrow channel, it is difficult to adjust to changes in drift direction (Dunderdale and Wright, 2005; Hisette, 2014).

The sector technique is conducted in ice drifts with slow speed and variable direction. A sector shaped pattern is created perpendicular to the drift direction that is narrower closer to the facility and wider farther from the facility. This technique is used to reduce the floe sizes in the vicinity of a facility, similarly to the linear technique. However, the wider sector pattern accounts for changing drift direction by covering a wider area of the ice field. Also, as the time to complete a rotation in the sector pattern is shorter than in the linear pattern, it is easier to adjust and account for changes in drift direction (Dunderdale and Wright, 2005; Hisette, 2014).

The circular technique is conducted in either thin ice of high concentration or thick ice in small floes with variable drift direction. For this technique, many circles are created up drift of the facility. The diameter of the circular pattern is dependent on the speed of the ice drift. This technique is flexible and can be easily adjusted for changes in drift direction. The circular pattern can also be made around the vicinity or a facility to reduce ice pressure by redistributing ice and reducing floe sizes (Dunderdale and Wright, 2005; Hisette, 2014).

The pushing technique is used to push medium or large floes out of the path of the facility. By moving larger floes out of the path of the facility, collision and large ice loads are avoided. For this technique, floes are generally pushed in a direction ninety degrees to the drift direction. It is beneficial to push a large floe rather than break it because the broken floe can still pose a threat to the facility depending on its size and thickness. The pushing technique is best performed in near constant ice drift direction because any changes in drift direction may cause the floe to be back in line with the facility, therefore increasing the risk (Dunderdale and Wright, 2005).

The prop wash technique, also called the propeller wash technique, involves a vessel up drift of the facility using its propellers to deflect the ice away from the facility. This technique is typically conducted in thick ice in the form of small floes and works best when a vessel is equipped with azimuth propulsion. The prop wash technique is effective because it allows a vessel to clear almost all the ice around the facility, eliminating ice forces, and requires minimal maneuvering once the vessel is in position (Dunderdale and Wright, 2005). The prop wash technique was not widely used until the introduction of azimuth thrusters.

Propeller shaft speed and initial ice concentration are the most significant factors affecting the prop wash technique (Ferrieri et al., 2013).

It is not efficient to implement these techniques without considering the specific ice hazards around the facility. The most effective way to implement pack ice management is to identify what hazards pose a risk to the facility, prioritize them from greatest to least risk, and address them in order from greatest to least hazardous (El Bakkay et al., 2014).

### 2.1.6 Ice Management Risks

Pack ice management is a safety critical task. The high loads associated with ice pose a risk of damage to the facility and the ice management vessel. An ice management operation occurs twenty-four hours a day. If the ice management operation does fail at anytime, the facility has little time to react. This poses a risk for damage (Haimelin et al., 2017).

One of the greatest needs for ice management is during emergency response (Taylor et al., 2012). Survival craft cannot operate or launch in ice. In case of emergency evacuation, if an ice management operation cannot clear a path from the facility there is a risk that the people on the facility will not be able to evacuate. Ice management operations often occur in remote areas, meaning if the ice management vessel cannot keep up with the ice in an emergency, it can be a long time before additional support can arrive. This means the entire operation has to be independently stable at all times. For past operations in ice-covered waters, effective use of ice management made it possible to complete these operations. Without it, the risk to the facility and of not being able to evacuate is too high for the operation to occur (Eik, 2008).

ISO 35104 (ISO, 2018) lists the factors that contribute to ice management hazard levels, which include:

(1) size and thickness of ice,

(2) drift speed and wave motions,

(3) how close the ice is to the facility,

(4) ice encroachment,

(5) pack ice pressure, and

(6) the manageability of ice.

In order to identify and classify hazards, factors such as ice type, origin, and other unexpected influences should also be considered.

Haimelin et al. (2017) discuss the risks associated with every aspect of ice management and emphasize the lack of background knowledge related to ice management and how this increases the associated risks. The consequences of the risks of ineffective ice management include:

(1) environmental damage,

(2) health effects,

(3) poor safety, and

(4) economic loss.

### 2.1.7 Ice Management Training

Ice management performance is influenced largely by the performance of the seafarer operating the vessel. This means that good ice management training is essential for a successful ice management operation. Past experience with ice management operations has shown that training is an essential factor when developing an ice management plan (Keinonen, 2008).

Traditional ice management training is administered primarily through practical experience. Cadets spend time on vessels and learn from experienced seafarers conducting ice management operations. While ship based experience remains an essential aspect of ice management training, with an increase in the amount and complexity of the technology used on ships, more traditional methods, such as lectures, are also used for training. In recent years, the use of ice management simulators for training has become common practice (Sellberg, 2017). This allows for practical training of the safety critical task of ice management in a zero risk environment and allows for training year round rather than being limited by the availability of ice.

The IMO has developed model courses in order to standardize global training for ice management. The use of simulator training is not required for these courses but is strongly encouraged and highlighted as something that would improve the effectiveness of the training (IMO, 2017b; IMO, 2017c). Studies on the use of simulators for training in ice management operations have shown positive results. One study on the use of simulator training for ice covered waters found that novices training in a simulator were more than three times more likely to correctly navigate in ice and were more confident about their ability to correctly navigate in ice in the future than those trained using standard methods (Power-MacDonald, 2012).

Simulator training has become standard for seafarers conducting ice management operations in Sweden. Until the year 2000, Swedish ice management operations were conducted by the Navy, who gave seafarers extensive ice management training. However, when the government began contracting ice management, seafarers were not getting the same level of training and were not performing adequately. To address this, courses were developed for training in ice management, which included time spent in ice management simulators. This is expected to improve ice management performance overall (Bostrom, 2010).

## 2.2 Training and Learning

### 2.2.1 Learning and Cognition

Operating a vessel, especially in ice, requires seafarers to take in larges amounts of complex information and make quick decisions on what courses of action to take. Making these decisions requires the cognitive process (Cohen et al., 2015). The cognitive process relates to how people perceive, interpret, remember, and think about the information they are taking in and subsequently create mental maps of the given situation (Ormrod, 2012). Operating a vessel is considered a complex task because it requires both the cognitive process and physical action (Neerincx et al., 2009; Peeters et al., 2013).

Trainees when learning a skill also use the cognitive process. The ability of a trainee to learn effectively is largely dependent on having the right amount of cognitive task loading (Clark and Mayer, 2008; Neerincx et al., 2009). Cognitive task loading is influenced by the amount of time required to complete a task, the amount of information that is being processed, and the frequency at which someone is switching between tasks. If training has too high of a cognitive task load, trainees become overwhelmed. If training has too low of a cognitive task load, trainees become bored. Both of these levels of cognitive task loading have negative effects on a trainee's ability to learn (Clark and Mayer, 2008; Neerincx et al., 2009).

High cognitive task loading is common in training because trainees have a limited amount of working memory that can be used in the cognitive process at any given time (Clark and Mayer, 2008). However, while the working memory is limited, the long-term memory has a much higher capacity. With the appropriate amount of cognitive task loading, trainees can store information in their long-term memory and learn more effectively (Billings, 2012).

Active learning is effective in providing trainees at different skill levels the right amount of cognitive task loading (Billings, 2012). Active learning involves a trainee making active choices when learning a skill, as opposed to passively being told information. As a result of having an appropriate level of cognitive task loading, active learning also leads to improved skill retention (Lee et al., 2017).

Lee et al. (2017) list ten strategies that can be incorporated into training in order to have an appropriate amount of cognitive task loading for effective training. These strategies are:

(1) training support and error prevention,

(2) task simplification,

(3) part-task training,

(4) active learning,

(5) multi-media instruction,

(6) feedback,

(7) practice and overlearning,

(8) distribution of practice,

(9) appropriate training for experience level, and

(10) training-transfer.

### 2.2.2 Learning Curves

Learning in relation to practice has been found to have a period of fast skill improvement that eventually plateaus after repeated practice (Champney et al., 2006; Pusic et al., 2011). The trend created based on this relationship between training and amount of practice has been described as an exponential curve, exponential decay, or power function but generally resembles a three-phase curve of learning development as represented in Figure 2 (Champney et al., 2006; Kim et al., 2013; Lee et al., 2017; Malysuz and Pem, 2014; Pusic et al., 2011).

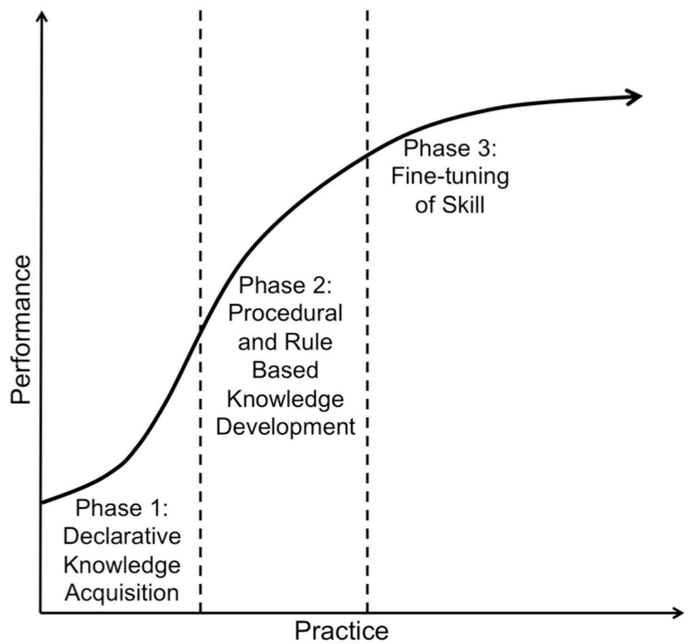



**Figure 2: Three-Phase Curve of Learning Development (Based on Figures From: Kim et al., 2013, Lee et al., 2017, and Pusic et al., 2011)**

As shown in Figure 2, the three-phase curve of learning development involves the transformation of a skill from a level of declarative knowledge, where information is stored as facts, to a level of procedural knowledge, where connections and associations can be formed in relation to the skill (Lee et al., 2017). Phase one of the three-phase curve of learning development is a period of acquiring initial declarative knowledge. In this phase, skill level improves at a rapid pace. In phase two, development of procedural knowledge begins and knowledge is often rule based. In this phase, the rate of skill improvement begins to slow, but real world implementation of the skill is more effective than in phase one. Phase three is considered a phase of fine-tuning of the skill. At this phase, knowledge acquisition rate decreases rapidly and plateaus as the skill becomes almost automatic and requires little attention (Kim et al., 2013; Lee et al., 2017).

There are several factors that can affect the rate of learning associated with the three-phase curve of learning development. For complex skills, there can be temporary plateaus in the curve as trainees learn better methods of approaching the skill (Lee et al., 2017). Those more novice to a skill will have a steeper rate of improvement than those more familiar with a skill because they are starting from a lower skill level and therefore have more room for improvement (Dammerer et al., 2018).

### 2.2.3 Experts and Novice Decision Making

Experts can perform more effectively than novices by making fewer errors (Hutton and Klein, 1999). While making decisions can be dynamic and complex, especially with time constraints, experts are able to make better decisions because of improved situational awareness (Hutton and Klein, 1999; Randel and Pugh, 1996). Experts are able to use their familiarity with a skill to quickly determine if a situation is typical or abnormal and make decisions accordingly. Becoming an expert is dependent on experience, which is not the same as time (Hutton and Klein, 1999). This means that practical training can be used to provide experience and shorten the time required to become an expert (Lee et al., 2017).

When approaching an area of expertise, experts are able to see information in patterns instead of as individual pieces of information (Hutton and Klein, 1999;

Randel and Pugh, 1996). In this way, experts can “chunk” information in a way that novices cannot (Lee et al., 2017). Experts can see differences between situations that affect the action they select (Freeman et al., 2009). Experts think of information in terms of rules and constraints, but when these rules are taught directly to novices, they overgeneralize and do not recognize conflicts in the rules. Experts tend to consider one course of action for a given situation because they spend more time trying to understand the situation whereas novices spend more time picking a course of action and can become side tracked. When experts make errors, they are able to course correct, while novices may not recognize their own limitations (Hutton and Klein, 1999; Randel and Pugh, 1996).

The transition from knowing a skill at a novice level to an expert level requires practice and can take several years. However, direct training can be used to speed up the transition from novice to expert (Lee et al., 2017). Expert knowledge can be used to train novices to become experts themselves. This is not as simple as asking experts how they perform a task because people do not usually have a good level of understanding of their own expertise and cannot vocalise how they make decisions (Tomlinson et al., 2009). Simulation can be used to model expert performance and identify the expert patterns that work most effectively (Freeman et al., 2009; Tomlinson et al., 2009). It may be possible to compare expert patterns to novice patterns in order to help novices progress more rapidly through the three-phase curve of learning development (Schnell et al., 2009).

### 2.2.4 Competency – Based Training

Training traditionally requires a trainee to complete a set number of scenarios and/or hours of practice (Walsh et al., 2013). An issue that arises with this type of 'one size fits all' training is that trainees at different skill levels end up with different abilities to perform the given skill (Guskey, 2007; Walsh et al., 2013). Varying the amount of training that trainees at different skill levels receive results in more effective learning over all (Guskey, 2007).

Competency-based training requires that trainees reach a certain performance level rather than complete a set amount of training. Trainees with higher skill levels or more experience receive less training while trainees with lower skill levels or less experience receive more training. Competency-based training results in better skill performance, less total training time and equivalent skill retention and transferability (Walsh et al., 2013).

### 2.2.5 Simulators as a Training Tool

Simulators are an effective training tool. They allow for direct practical training for complex skills in a zero risk environment. Advantages of training with simulators include the ability to train to specific learning objectives, the ability to control the complexity and level of difficulty of a task and adjust difficulty throughout training, and the ability to create realistic and relevant job related scenarios (House, Smith, et al., 2014; Peeters et al., 2013; Sellberg, 2018). The use of simulators in training has been shown to improve task performance (McGaghie et al., 2006). McGaghie et al. (2006) list the advantages that come with training using simulators, which include:

(1) feedback provided during learning,

(2) repetitive practice,

(3) the ability to integrate into the curriculum,

(4) practice with increasing levels of difficulty,

(5) adaptation to multiple learning strategies,

(6) the ability to capture variation,

(7) controlled environment,

(8) individual learning,

(9) clearly defined and measurable learning objectives, and

(10) representation of real world scenarios.

Training for complex skills requires the trainee to be knowledgeable about the skill, be able to coordinate the skill, and be able to transfer the skill to different problems and situations (Peeters et al., 2013). The use of simulators in training can provide the trainee the opportunity to rehearse the cognitive process required for the skill. By doing this, they are increasing their confidence and ability to perform the skill (Cohen et al., 2015). The practical training involved with using simulators allows the trainee to create mental models in order to comprehend and remember the information they are learning (Billings, 2012).

Another advantage of simulators is the ability to train for high stress and emergency situations. Under high stress, people often have difficulty making decisions and can make decisions without considering all the options and consequences. Training with simulators allows trainees to prepare for these stressful emergency situations so that they can perform to a high level if the situations are encountered. Training with simulators can also help trainees make better decisions in other unknown situations (Cohen et al., 2015).

It is often believed that higher fidelity simulators provide better training. This has not proven to be true. Higher fidelity in the physical properties of a simulator does not necessarily lead to better learning (Sellberg et al., 2018). This is because increasing task complexity can lead to high cognitive loads. Simplified simulators and tasks have been shown to lead to better performance. Having high fidelity in simulators is not necessary for the skills being learned to be transferable (Haji et al., 2016; Tichon and Wallis, 2010).

### 2.2.6 Training with Simulators

Simulators by themselves are not effective in training (Sellberg, 2017). In fact, simulators are often poorly implemented in seafarer training because there is little information about how to design simulator training and how this relates back to real world implementation of a skill (Sellberg et al., 2018). In order for training with simulators to be effective, they should allow both experience and instruction that ensures learning is taking place (Billings, 2012). As listed by Dieterle and Murray (2009), in order for simulators (or any technology) to be effective in training they should provide:

(1) learning in real-world contexts,

(2) connections to experts and other trainees,

(3) the ability to visualize and analyze information,

(4) problem solving with complex reasoning, and

(5) opportunities for feedback, reflection, and revision.

Simulator training curricula should include a description of the training structure, methods of learning, methods of teaching, methods of feedback, and methods of supervision (Barsuk et al., 2016). The development of a training curriculum includes a needs assessment, curriculum design, and evaluation of curriculum effectiveness (Barsuk et al., 2016; Lee et al., 2017). The eventual curriculum should provide the best training with the longest retention in the shortest amount of time and least expense (Lee et al., 2017).

A common method used in simulator training is a three-phase method of:

(1) briefing,

(2) scenario, and

(3) debriefing (Sellberg, 2017; Sellberg 2018; Sellberg et al., 2018).

This method should incorporate information, demonstration, practice, and feedback (Grossman et al., 2015). The briefing phase is used to introduce the learning objectives and information about the skill being trained, the scenario phase allows practice of the skill being trained, and the debriefing phase allows feedback and reflection on the scenario (Sellberg et al., 2018).

Effective training has a balance of both examples and practice in order to have an appropriate cognitive load and mental model of the skill being trained (Clark and Mayer, 2008). Trainees often do not think strategically about how they are learning and therefore benefit from being guided to effective learning strategies (Brydges et al., 2016). Training that incorporates deliberate practice has been found to result in better learning due to high motivation, appropriate level of difficulty, feedback, evaluation of performance, and advancement (McGaghie et al., 2011). Creating multiple scenarios representing different aspects of a skill with varying levels of difficulty provides effective training and allows trainees to distinguish between scenarios and learn to respond to them in the way experts do (Freeman et al., 2009). Repetitive practice has been shown to lead to better performance especially when that practice is distributed over multiple training sessions (Lee et al., 2017; McGaghie et al., 2006).

The use of feedback can help increase motivation in training, reduce uncertainty in performance level, and help the trainee correct mistakes. The feedback can aid in learning by allowing the trainee to identify and understand relevant information about the skill and integrate the information into better performance. The more specific feedback is, the better the learning of the skill (Billings, 2012). Feedback can be administered either immediately (during a scenario) or delayed (after the scenario). Immediate feedback can interrupt thinking and contribute to high cognitive loading, while delayed feedback can be administered too late to be incorporated in the trainee's mental map of the situation (Billings, 2012; Lee et al., 2017). Incorporating expert feedback in training is important in order for trainees to understand the relevant real-world information (Sellberg et al., 2018). Having novices view expert solutions to scenarios has been shown to be more effective than providing corrective feedback (Tomlinson et al., 2009).

# Chapter 3: Methodology

## 3.1 Experimental Overview

Two Experiments were used in this research, both of which adopted a formal design of experiments approach. Both experiments were conducted following an ethics protocol approved by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) at Memorial University of Newfoundland (MUN). Experiment 2 studied the effects of training on ice management performance and is the primary focus of this research. Experiment 1 studied the effects of experience on ice management performance and was conducted by Veitch (2018a) in Fall 2017. The results of Experiment 1 where reported in Veitch (2018a) and are used in this research only as a baseline of performance with no training. All results from Experiment 1 used in this research were reanalyzed using the same methods as Experiment 2.

In Experiment 1, a group of experienced seafarers and a group of inexperienced cadets conducted two thirty-minute ice management operations in a bridge simulator. It was found that, on average, the experienced seafarers performed better in the ice management operations than the inexperienced cadets. The performance amongst both groups was found to be highly variable (Veitch, 2018a; Veitch et al., 2019).

Experiment 2 was conducted from November 2018 to April 2019. In Experiment 2, a training curriculum was developed using the results of Experiment 1 and the training recommendations in the IMO Polar Code (IMO, 2017a). Using this curriculum, two groups of inexperienced cadets were trained using an ice management bridge simulator. The Training I group received one training session and the Training II group received two training sessions. After training, both groups completed two thirty-minute ice management testing scenarios in the bridge simulator.

Each cadet who participated in Experiment 2 attempted five unique scenarios: three training scenarios and two testing scenarios. Participants in the Training II group attempted each training scenario twice and completed a total of eight scenarios. The three training scenarios were:

(1) the pushing scenario,

(2) the prop wash scenario, and

(3) the leeway scenario.

Each training scenario took fifteen minutes and allowed the cadets to practice, in succession, one of the three ice management techniques identified from Experiment 1. The training scenarios were completed as part of the scenario phase of the three-phase briefing, scenario, and debriefing method used to train the cadets for each ice management technique (Sellberg, 2017; Sellberg, 2018; Sellberg et al., 2018).

In both Experiment 1 and Experiment 2, two thirty-minute testing scenarios were used:

(1) the precautionary ice management scenario and

(2) the emergency ice management scenario.

In the testing scenarios, a factor of ice conditions was used with a high level of severe ice conditions and a low level of mild ice conditions. While the precautionary ice management scenario was used in both experiments, the objective of the scenario was changed for Experiment 2. Only the results from Experiment 2 for the precautionary ice management scenario are reported here. The emergency ice management scenario was the same in both experiments and results are directly compared in this research.

Performance in all scenarios was quantified using three performance metrics:

(1) average change in ice concentration,

(2) end change in ice concentration, and

(3) clearing to distance ratio.

Additionally, in the emergency ice management scenario, a fourth lifeboat launch zone performance metric was used. The lifeboat launch zone performance metric used in this research represents the *longest* consecutive time that the lifeboat launch zone was clear of ice during the scenario. The results for the *total* time the lifeboat launch zone was clear of ice during the scenario are also reported because this is the metric originally used in the analysis of Experiment 1.

## 3.2 Experimental Design

Experiment 2 was designed so that the results of the testing scenarios would be a $2^2$ fixed effects factorial design with the factors and levels listed in Table 1. There were nine replicates at three of the four levels and eight replicates at the Low-Low level of Training I with mild environmental conditions. The total sample size for Experiment 2 was 35.

**Table 1: Experimental Factors for Experiment 2**

| Factor | Low | High |
|---|---|---|
| Training | **Training I**<br>1 training session<br>*consisting of:*<br>1.5 hours of training<br>3 practice scenarios | **Training II**<br>2 training sessions<br>*consisting of:*<br>3 hours of training<br>6 practice scenarios |
| Ice Conditions | **Mild Conditions**<br>4 tenths ice concentration<br>0.6 knot drift | **Severe Conditions**<br>7 tenths ice concentration<br>0.5 knot drift |

For the training scenarios in Experiment 2, the ice conditions factor was not used; meaning training was the only factor. Seventeen cadets were in the

Training I group and eighteen cadets were in the Training II group. Participants were not informed of which level of the ice conditions factor they would be completing the testing scenarios in until after training was completed. Since the same training scenarios were used in the first and second training sessions, the results are analyzed both between subjects (comparing the first attempt of the scenarios by the Training I group to the second attempt of the scenarios by the Training II group) and within subjects (comparing the first and second attempt of the scenarios by the Training II group).

Experiment 1 was a $2^2$ factorial experiment with the factors and levels listed in Table 2. There were nine participants in each group for a total sample size of 36. Experiment 1 was designed as a split-plot experiment because of logistical concerns with scheduling participants. The hard to change factor in the split-plot design was experience (Veitch, 2018a; Veitch et al., 2019).

**Table 2: Experimental Factors for Experiment 1**

| Factor | Low | High |
|---|---|---|
| Experience | **Inexperienced Cadets** enrolled in a nautical sciences program with ~0-2 years at sea | **Experienced Seafarers** masters and mates with at least 10 years experience at sea |
| Ice Conditions | **Mild Conditions** 4 tenths ice concentration 0.6 knot drift | **Severe Conditions** 7 tenths ice concentration 0.5 knot drift |

The ice conditions factor was kept the same in both experiments. To change the ice conditions factor, two similar versions of the test scenarios were created with different properties for ice concentration and drift speed. Participants completed either the mild or severe ice conditions version of the test scenarios based on a random assignment by coin flip.

As each cadet in Experiment 2 could be randomly assigned to either training group, this was not considered a hard to change factor. Therefore, Experiment 2 was treated as a completely random design (Kowalski and Potcner, 2003). A random number generator was used to assign each volunteer to the Training I or Training II group before being contacted to schedule participation. The cadets were told which training group they were assigned to before participating in the experiment to avoid scheduling conflicts with the Training II group's second sessions and so that the cadets knew how long their first session would be.

Participants in both experiments were volunteers recruited following a protocol approved by the ICEHR at MUN. The cadets in both training groups of Experiment 2 were in years one, two, or four of the same nautical sciences program as the inexperienced cadets in Experiment 1. Experiment 1 had six cadets from each of year one, two, and four (Veitch, 2018a). Experiment 2 had four to five cadets from year one and four to five cadets from either years two or year four at each factor level. In the early stages of Experiment 2, a second factor of experience was to be used in the analysis of the training scenarios. This would have had a low level of year one, for cadets who had no experience at sea, and a high level of years two to four, for cadets who had at least two months experience at sea. Early results of Experiment 2 did not show any significant difference in the results between the experience levels. Therefore, this factor was not used in further analysis. The results comparing the experience factor of the training scenarios are not reported here, but are mentioned because of their affect on the random assignment to each training group.

The number of cadets enrolled in the nautical sciences program that volunteered to participate limited the sample size of Experiment 2. The experiment aimed to study the effects of amount of training on ice management performance. Therefore, instead of repeating a baseline of inexperienced cadets with no training, the inexperienced cadets from Experiment 1 were treated as a third level, Training 0, for the factor of training for the emergency ice management scenario, as listed in Table 3. Since the objective of the precautionary ice management scenario was changed in Experiment 2, the results of the two experiments could not be compared in this scenario and the training factor had two levels as listed in Table 1.

**Table 3: Levels of the Training Factor**

| | **Experiment 1** | **Experiment 2** | |
|---|---|---|---|
| | Level 1 | Level 2 | Level 3 |
| **Training** | **Training 0**<br>0 training sessions<br>*consisting of:*<br>0 hours of training<br>0 practice scenarios | **Training I**<br>1 training session<br>*consisting of:*<br>1.5 hours of training<br>3 practice scenarios | **Training II**<br>2 training sessions<br>*consisting of:*<br>3 hours of training<br>6 practice scenarios |

The experienced seafarers from Experiment 1, who also received no training at the Training 0 level, were used as a baseline for comparison, but were not directly compared to the results of Experiment 2 in the emergency ice management scenario. Since only one of the levels of the whole plot factor of Experiment 1 was used in the analysis of this research, the restricted randomization of the split-plot design was not considered in the analysis. As discussed further in the Statistical Analysis Methods section of this chapter, directly comparing the results of Experiment 1 to the results of Experiment 2 violates the randomization of the experimental analysis, making this a quasi-experiment (Shadish et al., 2002).

### 3.2.1 Sample Size Determination

The sample size for Experiment 2 was estimated assuming a $2^2$ fixed effects factorial experiment. Sample size was estimated using the results of the average change in ice concentration performance metric from Experiment 1 (Veitch, 2018a; Veitch et al., 2019). Using Equation 1 (Montgomery, 2005), assuming a p-value of 0.05 and an 80% power level, a $\Phi$ value of 2 was needed for statistical significance. The estimated standard deviation was assumed to be the standard deviation from the cadets in the emergency ice management scenario of Experiment 1. The estimated difference between means was assumed to be two-thirds of the difference between means in the emergency ice management scenario of Experiment 1 as the difference between means was expected to be somewhat lower in Experiment 2 than in Experiment 1. As shown in Table 4 and Table 5, the sample size was estimated for both the mild and severe ice conditions. A sample size of 36 was estimated to obtain statistical significance using the mild ice conditions results and this sample was also sufficient for statistical significance using the severe ice conditions results. Based on this, the planned sample size for Experiment 2 was 36.

$$\Phi = \sqrt{\frac{nD^2}{2\sigma^2((a-1)(b-1)+1)}}$$

Where:

$n - sample\ size$
$D - estimated\ difference\ between\ means$
$\sigma - estimated\ standard\ deviation$
$a - number\ of\ levels\ of\ factor\ A$
$b - number\ of\ levels\ of\ factor\ B$

**Equation 1: Sample Size Estimation**

**Table 4: Sample Size Estimation Mild Ice Conditions**

| n | $\sigma$ (tenths) | D (tenths) | a | b | $\Phi$ |
|---|---|---|---|---|---|
| 32 | 0.6 | 0.4 | 2 | 2 | 1.89 |
| 36 | 0.6 | 0.4 | 2 | 2 | 2.00 |
| 40 | 0.6 | 0.4 | 2 | 2 | 2.11 |
| 44 | 0.6 | 0.4 | 2 | 2 | 2.21 |

**Table 5: Sample Size Estimation Severe Ice Conditions**

| n | $\sigma$ (tenths) | D (tenths) | a | b | $\Phi$ |
|---|---|---|---|---|---|
| 32 | 0.8 | 0.6 | 2 | 2 | 2.12 |
| 36 | 0.8 | 0.6 | 2 | 2 | 2.25 |
| 40 | 0.8 | 0.6 | 2 | 2 | 2.37 |
| 44 | 0.8 | 0.6 | 2 | 2 | 2.49 |

Only 35 of the planned 36 sample size was completed for Experiment 2 because there were not enough volunteers to participate in the experiment.

## 3.3 Description of Participants

The participants in Experiment 2 were seafaring cadets enrolled in years one, two, or four of a nautical sciences program. Participants were expected to be familiar with ship controls, the concept of ship handling, and ship vernacular, but have little experience operating a ship. Participants were between the ages of eighteen and forty and, while there were no requirements for gender, all of the 35 participants identified as male. Participants were required to be healthy, have normal or corrected to normal (20/20) vision, not be prone to simulator sickness, and to not have consumed alcohol or recreational drugs twenty-four hours prior to participation. Participants were excluded from the experiment if they had background knowledge of the simulator and/or if they had participated in a previous research study using the same ice management simulator. A description of the participants from Experiment 1 can be found in Veitch (2018a). The cadets in Experiment 1 were also in years one, two, or four of the same nautical science program as the cadets in Experiment 2, and the experienced seafarers had at least ten years experience at sea.

## 3.4 Simulator

The ice management bridge simulator used in these experiments, shown in Figure 3, included a simple bridge console surrounded by a 360-degree panoramic projection screen. The PhysX software is used to model the physics in the simulator (NVIDIA Corporation, 2008). The PhysX software can calculate real-time physics for thousands of dynamic rigid bodies as well as advanced particle and fluid simulation and vehicle dynamics, allowing for accurate modeling of the physical interactions of pack ice and ship-ice interaction (Kumar, 2013; Lubbad and Loset, 2011). As with any simulator, there were differences from reality in the physics and virtual environment, but none that were considered to negate the results of this research in terms of ice management performance or the observed methods and techniques used to manage ice.

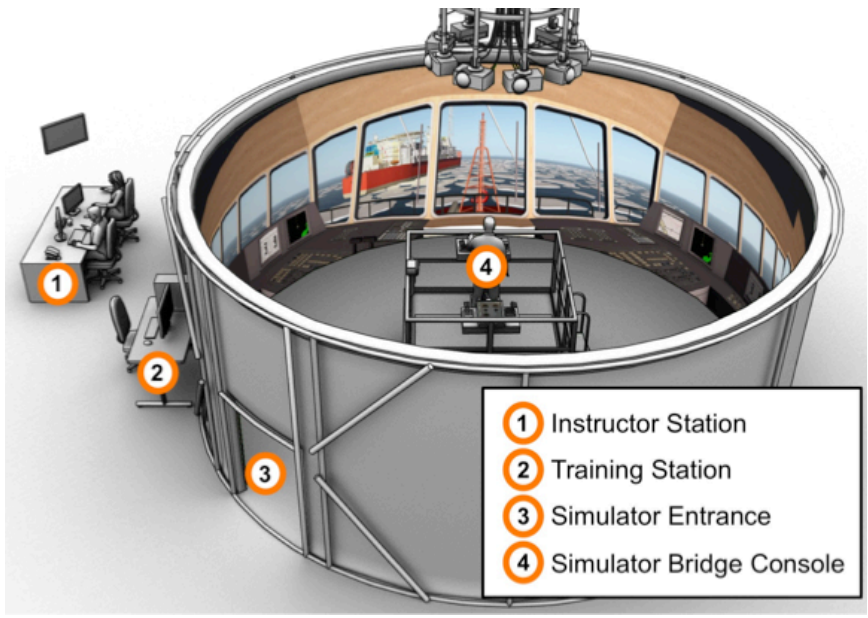



**Figure 3: Ice Management Simulator Schematic**

The virtual ship used for these experiments was a 75-metere twin-screw Det Norske Veritas (DNV) class 1A1 and ice class ICE-C Anchor Handling Tug Supply (AHTS) vessel with the principal particulars listed in Table 6. The ship was modeled after the vessels used for ice management operations in offshore

Newfoundland. The ship has two 5369 kilowatt engines and an 895 kilowatt tunnel thruster in both the bow and stern.

**Table 6: Vessel Principal Particulars**

| Parameter | Value |
|---|---|
| Length Overall | 75 m |
| Length Between Perpendiculars | 64 m |
| Moulded Breadth | 18 m |
| Moulded Depth | 8 m |
| Draft | 6 m |
| Gross Tonnage | 3157 tonnes |

The simulator used in this research was built for research purposes and the bridge was kept intentionally simple to minimize confusion and task complexity for participants less familiar with a ship's bridge and controls. While it is often assumed that simulators and simulator tasks closer to reality provide the best training, research has shown that simplified task complexity and simulators result in better performance after training because of easier skill acquisition with a lower cognitive load (Haji et al., 2016; Tichon and Wallis, 2010).

The simplified bridge consisted of a fore and aft console that participants could toggle between at any time. The control arrangement of the fore console is shown in Figure 4. Each console included four control sticks that could separately control power to each of the two engines and the fore and aft tunnel thrusters. The consoles also included a steering wheel that was used to control the angles of the two rudders conjointly. The controls on the aft console were inversed of those on the fore console. This is the same control arrangement as on the AHTS vessels the virtual ship was modeled after. Each control station also had an indicator screen displaying vessel heading, change of heading, speed over ground, rudder angles, engine power, and thruster power. As the simulator did not include radar, participants were told to use the Very High Frequency (VHF) radio (connected directly to the instructor station) to ask for distance from objects when they had trouble approximating depth in the simulator.

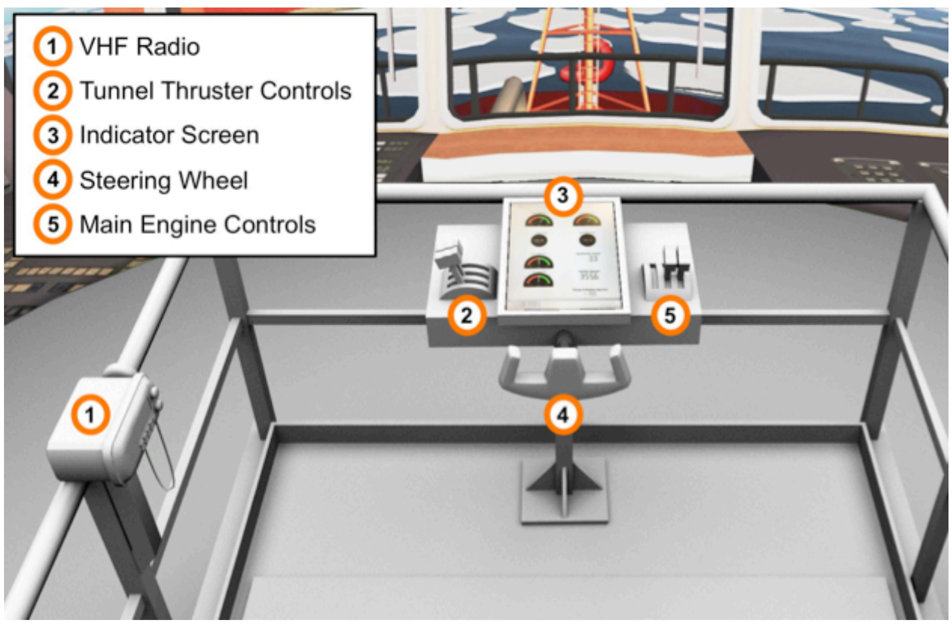



**Figure 4: Fore Bridge Console Arrangement**

To habituate participants to the simulator, virtual environment, and controls, all participants completed the same three habituation scenarios at the beginning of their participation. These scenarios were designed so that different levels of familiarity with the simulator and controls would have minimal effects on the results between training groups (i.e. the effects observed were not because the Training II group was more familiar with the simulator than the Training 0 group).

Diagrams of the habituation scenarios are shown in Appendix E: Scenario Instructions. In the first habituation scenario, participants were asked to round a bergy bit at a distance of 100 meters and return towards their starting position. This scenario was designed to help participants get used to the virtual environment and simulator controls. In the second habituation scenario, participants were asked to come up alongside a Floating Production Storage Offloading facility (FPSO) parallel with a distance of thirty meters between them and the FPSO. This scenario was designed to help participants get used to slow maneuvers and operating near another vessel. Both the first and second habituation scenarios took approximately ten minutes to complete and were stopped if the participant did not finish them in twenty minutes. The third habituation scenario was designed to make sure participants could switch between the fore and aft console and introduce participants to prop wash and what it looked like in the simulator. In this scenario, the vessel started with its bow against a large ice floe and participants were asked to switch to the aft console and use prop wash to clear the pack ice to their aft. This scenario took approximately one to two minutes to complete.

Participants filled out simulator sickness questionnaires throughout the experiment. This questionnaire was based of the questionnaire of Kennedy et al. (1993). An example of the simulator sickness questionnaire used in Experiment 2 can be found in Appendix B: Simulator Sickness Questionnaire. During the experiment, no participants reported severe simulator sickness symptoms, which would have ended their participation. Any time that moderate symptoms were reported, the participant was asked to take a break until symptoms subsided.

## 3.5 Data Acquisition

The data collected and used in this research is archived in Thistle (2019). During experiments, data collected from each participant were labelled using a randomized alphanumeric code (e.g. A00) in order to keep data anonymous and confidential.

Data was recorded from the simulator for the training and testing scenarios. No data was saved from the habituation scenarios. Two forms of data were recorded from the simulator:

(1) a log file including information such as speed over ground, longitude, latitude, and heading at each time step and

(2) a replay file that could be used to replay the scenario at the instructor station at real speed. Screenshots of this replay were later taken and used to determine ice concentrations and make a replay video of each run of each scenario.

In addition to the data recorded from the simulator, each participant completed an experience question at the beginning of their participation that was meant to collect information about the participant's experience at sea and using simulators. A copy of the experience question can be found in Appendix C: Experience Questionnaire. Additionally, after each testing scenario, the researchers asked the participants questions about the scenario in an exit interview. Some of the questions in this exit interview covered topics such as the participant's strategy in the scenario, whether or not they would do anything differently if they were to do the scenario again, and if they felt training helped prepare them for the scenario. The questions used in the exit interview are listed in Appendix G: Exit Interview Questions. The researchers also recorded observations during the experiments.

## 3.6 Training Curriculum Development

When observing the results of Experiment 1, bad ice management performances were found to use no distinct or identifiable techniques while good ice management performances typically used one of three distinct techniques:

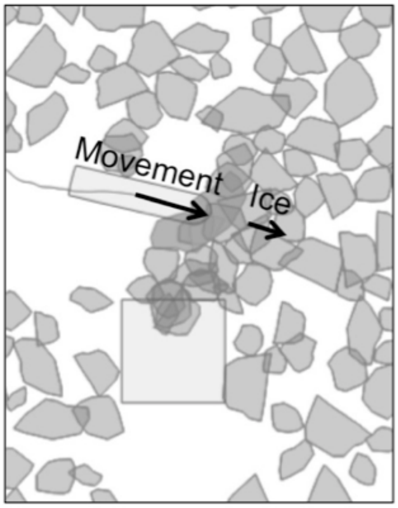
(1) pushing,

(2) prop wash, and/or

(3) leeway.

The basis of the training curriculum for Experiment 2 was these three techniques so that the cadets had methods of effectively approaching the testing scenarios.

A diagram of the pushing technique is shown in Figure 5. The pushing technique involves using the bow or side of the ice management vessel to push ice away from an area. This technique represents a combination of both the pushing and circling technique identified in the literature (Dunderdale and Wright, 2005; Hisette, 2014). A diagram of the prop wash technique is shown in Figure 6. The prop wash technique involves using the force created by the propellers of the ice management vessel to clear an area of ice. The prop wash technique was identified in the literature as a method used for managing pack ice (Dunderdale and Wright, 2005; Hisette, 2014; Ferrieri et al., 2013). A diagram of the leeway technique is shown in Figure 7. The leeway technique involves creating a lee or a barrier with the ice management vessel to block ice from flowing into a small area. This technique was not identified in any of the literature, but was used and identified by several of the experienced seafarers in Experiment 1 (Veitch, 2018b).



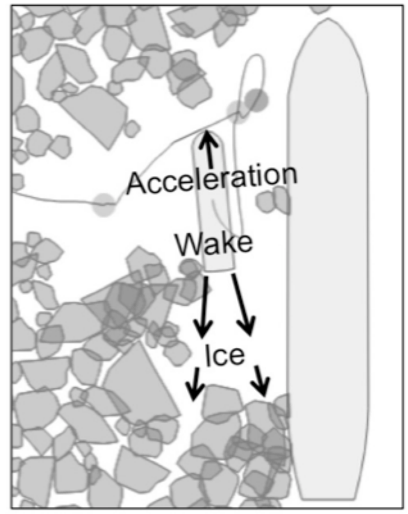




**Figure 5: Pushing Technique Diagram**

**Figure 6: Prop Wash Technique Diagram**

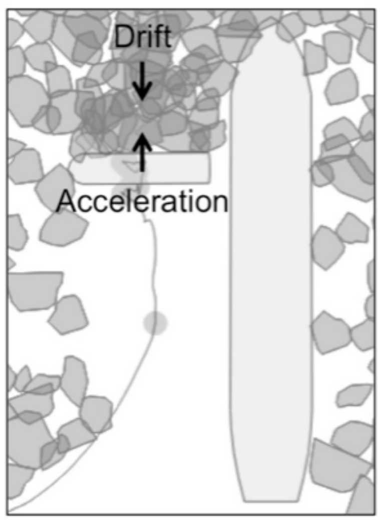



**Figure 7: Leeway Technique Diagram**

The training curriculum used in Experiment 2 was designed using the results of Experiment 1 and the training recommendations from the IMO Polar Code (IMO, 2017a) and associated model courses (IMO, 2017b; IMO, 2017c). The learning objectives for the curriculum were:

(1) demonstrate the three applicable ice management techniques (pushing, prop wash, and leeway),

(2) demonstrate Polar Operational Limit Assessment Risk Indexing System (POLARIS) recommended speeds in ice (IMO, 2016), and

(3) demonstrate how to keep the lifeboat launch area clear of ice for evacuation.

The format of the training incorporated information, demonstration, practice, and feedback in a commonly used three-phase method consisting of:

(1) briefing,

(2) scenario, and

(3) debriefing phases (Grossman et al., 2015; Sellberg, 2017; Sellberg, 2018; Sellberg et al., 2018).

The briefing phase is used to introduce trainees to the learning objectives and gives any required information about the relevant skill. The scenario phase offers trainees the ability to gain practical practice for the skill in a zero risk environment. The debriefing phase offers feedback on performance in the scenario so that trainees can reflect and improve on future application of the skill (Sellberg et al., 2018).

The three-phase method was used for each of the three ice management techniques identified in Experiment 1. The researcher acted as an instructor and used a script during training to minimize differing instructor influence between participants. The training was not meant to tell participants exactly what to do in each situation, rather, for them to make their own decisions on what would work best in a given situation based on the successes and failures of others and their own experience in practice. In this way, the participants were using active learning (Lee et al., 2017). In addition to its proven effectiveness in training comprehension, active learning was used for this training so that the trainees would not have to follow the advice of the researchers, who were not expert seafarers. Other than a brief introduction to the simulator controls at the beginning of the experiment, participants were not given any instruction on how to use the controls to implement the ice management techniques. In total, the training took approximately 1.5 hours per training session.

In the briefing phase for each technique, participants went through five examples from Experiment 1. The examples allowed the participants to learn by observing how seafarers managed ice rather than being told how to mange ice by an instructor who was not an experienced seafarer. These examples were selected to demonstrate different aspects and approaches to the technique and represented both good and bad performances. To select the examples, each run from Experiment 1, was systematically classified as using the pushing, prop wash, leeway, or no distinct technique based on a combination of log information and observations by the researchers. Each run could be split into more than one technique if it was evident that multiple techniques were used (e.g. the pushing technique was often implemented before the leeway technique). Each run was segmented into sections representing each technique that was used. These segments were a minimum of five minutes in length. Each of the technique segments were given a performance score, calculated using Equation 2. The time steps were at thirty-second intervals and ice concentration was measured in the specified zone. The performance score was used to determine what was a good or bad implementation of the technique.

$$Performance\ Score = \frac{\sum_{n=2}^{N}(Concentration_{n-1} - Concentration_{n})}{N-1}$$

Where:

$N - number\ of\ time\ steps$

**Equation 2: Technique Performance Score**

In the first training session, for each example in the briefing phase of training, participants would first watch a top down replay video of the example sped up to thirty times real speed. These example videos looked similar to the still shot shown in Figure 8. Next, the instructor pointed out aspects of the example that were both effective and ineffective. Finally, the participant would watch the sped up replay of the example again. Participants were not told directly which performances represented good or bad performances. Instead, participants were told to use their own judgment on what aspects of each example were effective and ineffective. This format of briefing allowed the participants to first make their own judgments about the effectiveness of each example, then allowed the instructor to highlight some things to do or not do when implementing the technique (e.g. making sure participants knew not to reverse in ice because the propellers and rudders were not ice protected), and finally allowed participants to view the example again having a better understanding of what happened and greater ability to think critically about what they can do to effectively implement the technique themselves.

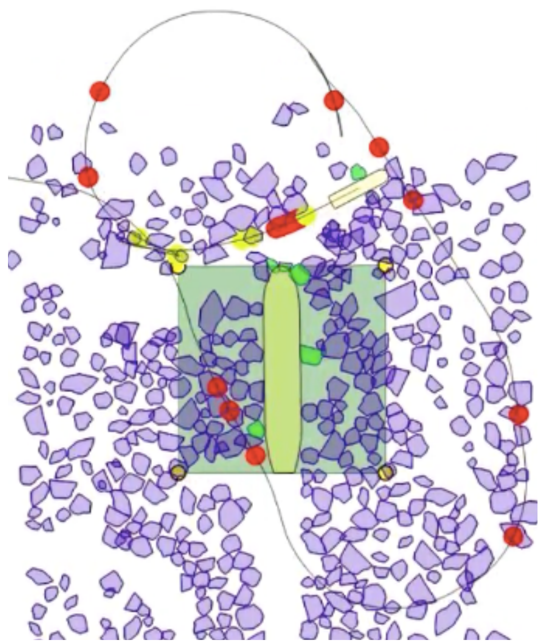


**Figure 8: Example Replay Video Still Shot**

In the scenario phase for each technique, the participants completed a fifteen-minute practice scenario in the ice management bridge simulator. A scenario was designed for each technique that was realistic to something that could be encountered in offshore Newfoundland and was suited to using the particular technique being trained. Each scenario was designed to prepare participants for the testing scenarios without being the exact same situation. There was minimal instructor influence during the scenarios, as participants were not given any feedback until the scenario was completed. This allowed participants to make their own judgments and corrections during the scenario. A description of each training scenario can be found in the Experimental Scenarios section of this chapter.

In the debriefing phase for each technique, the participants received feedback on their performance in the scenario. This included comparisons to the performance of an experienced seafarer in the same scenario. To get these comparisons, six seafarers who did not participate in Experiment 1, had experience with ice management, and had at least ten years experience at sea were asked to complete each training scenario in the ice management bridge simulator using the recommended technique. The best performance out of the six in the average change in ice concentration performance metric for each technique was used as feedback during training. The feedback was standardized using a template so that it was the same, relative to performance, for each participant. Feedback was given on ice concentration at the end of the scenario, speed during the scenario, whether or not there were collisions, and the path traveled during the scenario. The participant was also able to watch a sped up top down replay video of the experienced seafarer completing the scenario. The feedback template used in Experiment 2, along with all other training content can be found in Appendix F: Training Content Overview. The feedback in Experiment 2 was given immediately after the scenario in order to avoid both the high cognitive loads associated with concurrent feedback and the reduced temporal contiguity associated with feedback that is too far delayed (Lee et al., 2017).

After completing the training outlined above, the Training I group immediately completed the testing scenarios. The Training II group instead left and returned on another day for a second training session. This training session was within one to three days of the first training session, which allowed participants enough time to consolidate their skills without having different levels of long-term memory loss, which could be encountered if differing periods between sessions were allowed (Ormrod, 2012). To ensure the results of the experiment represented the effects of *amount* of training on ice management performance and not the effects of *type* of training on ice management performance, the same three-phase training method was used again for each technique in the second training session.

In this second training session, the debriefing phase for each technique included additional feedback on performance from the first session. This included a replay video of the participant's own performance in the first training session. Additionally, the participants watched the five sped up example replay videos for each technique used in the first session once each. In the scenario phase, the same fifteen minute training scenario used in the first session for each technique was repeated. The debriefing phase included feedback in the same format as the first session with comparisons to both the experienced seafarer performance and each participant’s own performance in the first training session.

## 3.7 Experimental Scenarios

Experiment 2 was designed to train participants for pack ice management operations such as those used by the offshore oil industry off the east coast of Canada. All of the scenarios were designed to be situations that may be encountered for ice management in offshore Newfoundland. The training scenarios were designed to prepare participants to complete the testing scenarios without being the exact same situations. The instructions used to introduce participants to each scenario can be found in Appendix E: Scenario Instructions.

All of the scenarios used in this research were kept intentionally simple to minimize the effects of confounding factors on the experiment. Ice in each scenario was first-year ice of 0.4 meters thickness with no multi-year inclusions and drift direction and speed were kept consistent through the entire scenario. The size and shape of ice floes was randomized but consistent in each repeat of the scenario.

The training scenarios were fifteen minutes in length and the participants were required to complete the full fifteen minutes of the scenario. In the pushing training scenario, shown in Figure 9, an offshore oil platform is in four-tenths first-year ice that is drifting at 0.4 knots to the south. The participant is asked to use the pushing technique to keep a 75 meter zone around the platform as clear as possible for fifteen minutes in order to reduce any ice pressures that might build up, and so that if there was an emergency, the lifeboats would be able to evacuate.

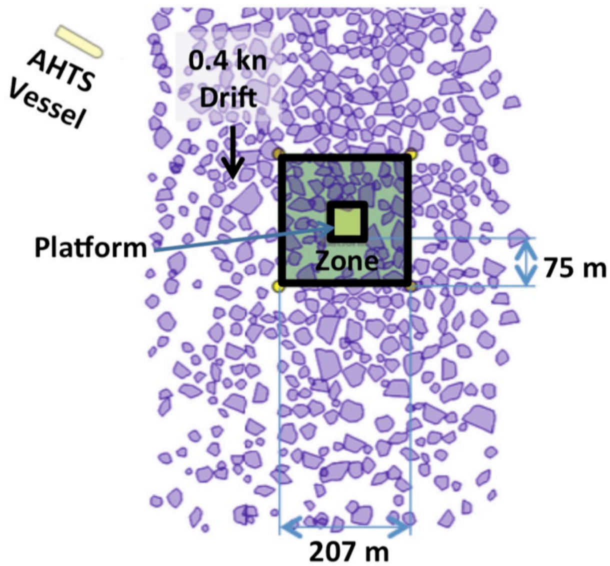



**Figure 9: Pushing Training Scenario Diagram**

In the prop wash training scenario, shown in Figure 10, a stationary tanker has seven-tenths first-year ice concentration on its port side. There is no drift in this scenario. The participant is asked to use the prop wash technique to clear the zone along the side of the tanker out to a distance of 75 meters in order to clear a berth for another vessel to dock alongside the tanker with reduced risk of damage due to ice.

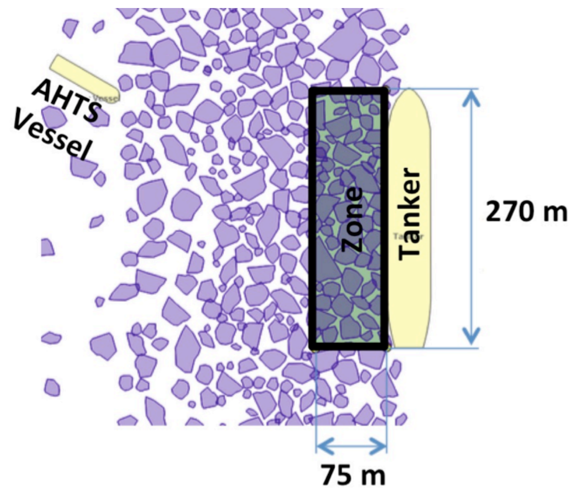



**Figure 10: Prop Wash Training Scenario Diagram**

In the leeway training scenario, shown in Figure 11, a stationary tanker is facing north in five-tenths first-year ice concentration that is drifting at one knot to the south. The participant is asked to use the leeway technique to keep the zone aft of midships as clear as possible during the scenario as if someone was using the pilot ladder or there was research equipment being launched off the side of the vessel.

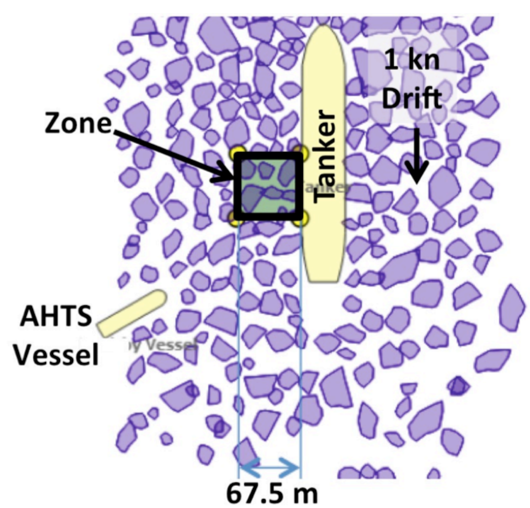



**Figure 11: Leeway Training Scenario Diagram**

A diagram of the severe ice conditions version of the precautionary ice management scenario is shown in Figure 12. In this scenario, a moored FPSO is facing north in either four or seven-tenths first year ice concentration that is drifting at 0.6 or 0.5 knots to the south. The participant is asked to use whichever techniques or methods they feel are most appropriate to keep the port side of the FPSO clear of ice in order to alleviate any ice pressures that might build up, and so that if there was an emergency, the lifeboats would be able to evacuate. The participant is told that in this type of operation typically another support vessel would be responsible for clearing the starboard side of the FPSO.

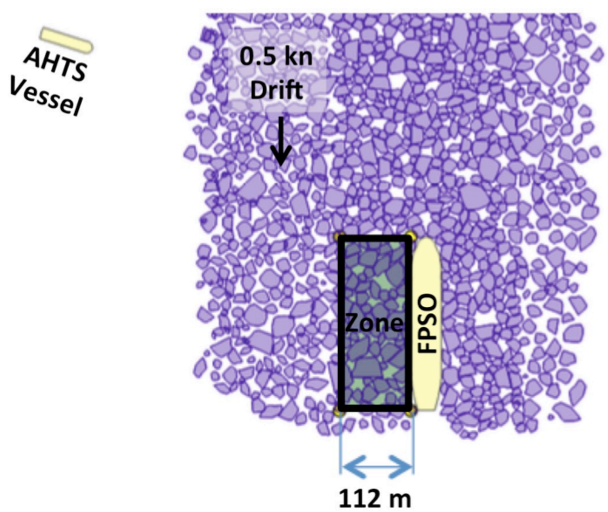



**Figure 12: Precautionary Ice Management Scenario in Severe Ice Conditions Diagram**

A diagram of the severe ice conditions version of the emergency ice management scenario is shown in Figure 13. In this scenario, a moored FPSO is once again in either four or seven tenths concentration of first-year ice that is drifting at 0.6 or 0.5 knots to the south. In this scenario, the FPSO has turned against the drift, so that the starboard lee side is clear for lifeboat launch in ice-free water. The participant is asked to use whichever techniques or methods they feel are most appropriate to keep the port aft of the FPSO free of ice so that the port lifeboat can also launch in ice-free water. As with every scenario, the participants were shown the zone, as highlighted in Figure 13, that was to be cleared during the scenario.

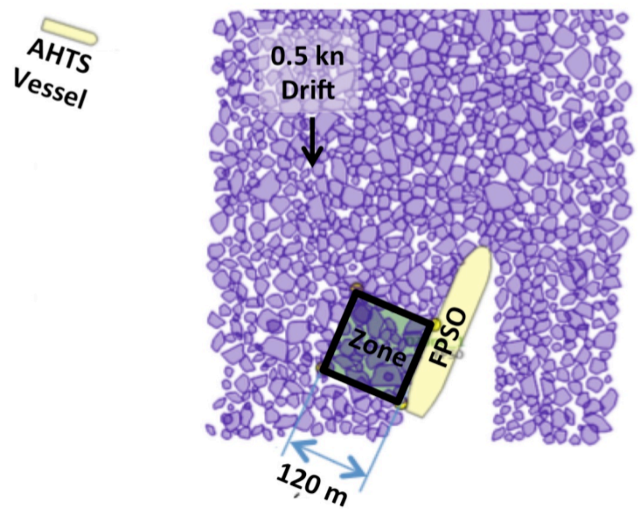



**Figure 13: Emergency Ice Management Scenario in Severe Ice Conditions Diagram**

## 3.8 Experimental Procedure

Participants in Experiment 2 were recruited following a protocol approved by the ICEHR at MUN. Most participants were recruited during visits to their classrooms. During the classroom visits, the researchers told students about the experiment and students were given a copy of a recruitment poster, which included information on how to contact the researchers if they were interested in participating in the experiment. Students were also given the option to fill out a participation questionnaire so that the researchers could contact them if they were interested in participating. After contacting the researchers or filling out a participation questionnaire, volunteers were randomly assigned to either the Training I or Training II group and contacted to schedule participation. When being contacted to schedule participation, volunteers were sent a copy of the experiment's informed consent form, which can be found in Appendix A: Informed Consent Form, and told to which training group they were randomly assigned. After scheduling participation, each participant was randomly assigned to either mild or severe ice conditions and randomly given an alphanumeric code.

Figure 14 outlines the procedure followed during Experiment 2. There were three people present for each session:

(1) the principal researcher,

(2) an undergraduate co-op engineering student working on the project, and

(3) the participant.

In addition to the tasks described in the procedure, the co-op student was responsible for loading and starting the simulator scenarios, saving the data from training and testing scenarios, and VHF radio communications with the participant during the simulation scenarios.

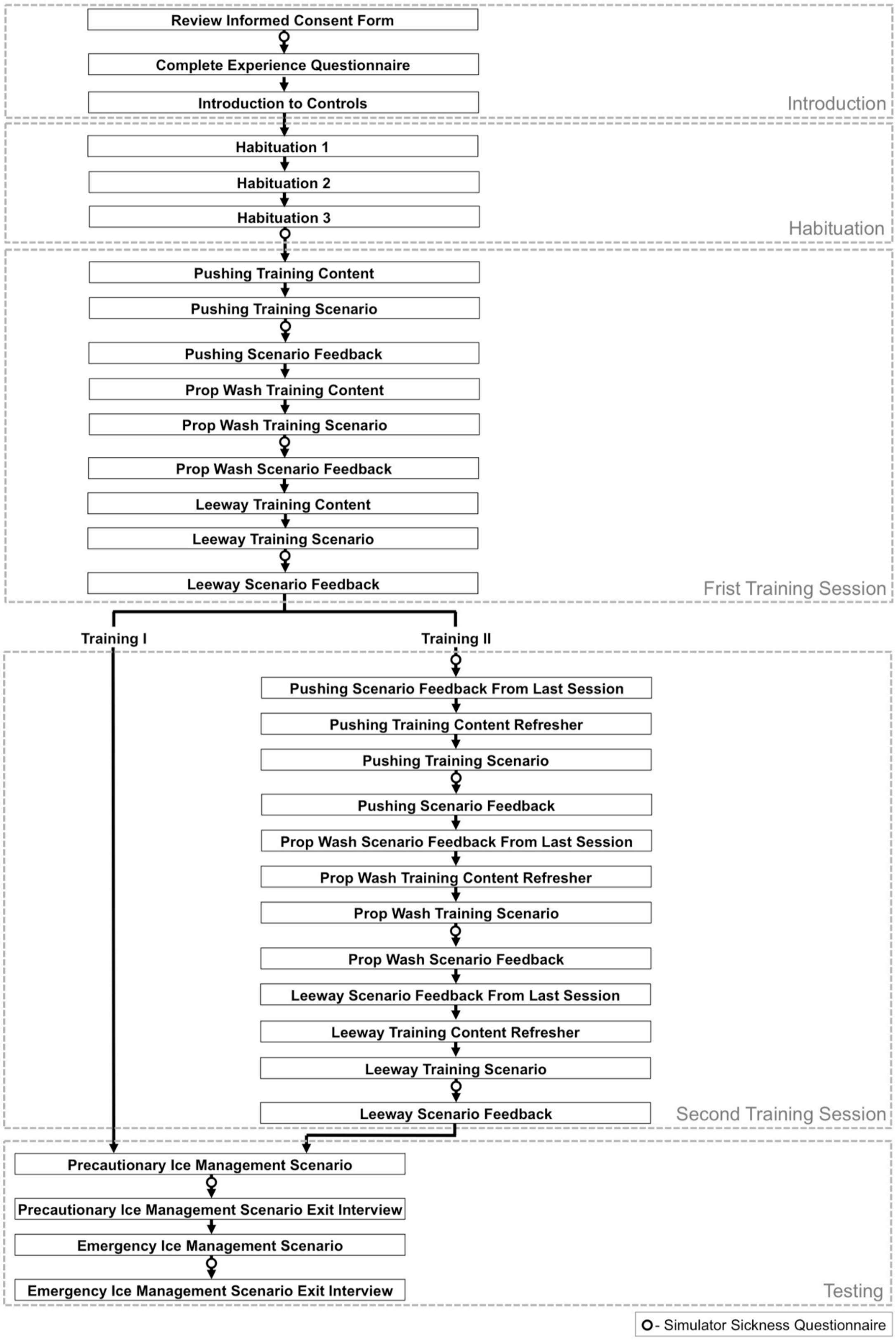



**Figure 14: Experimental Procedure Flow Chart**

The introduction, habituation, and first training session sections were identical for the Training I group and the first session of the Training II group. The introduction section occurred when the participant first arrived at the simulator to participate in the experiment and took approximately fifteen minutes. At the training station, the principal researcher reviewed the informed consent form with the participant and ensured that they understood what was involved in participating. Once they had both signed the informed consent form, the principal researcher introduced the participant to the simulator sickness questionnaire and asked them to fill out a first questionnaire as a baseline of any symptoms they had before participating. Then, the participant filled out the experience questionnaire. Once this was completed, the participant entered the simulator and the co-op student introduced them to the simulator and controls following the script found in Appendix D: Introduction to Controls Script.

Next, the participant exited the simulator and the principal researcher introduced them to the first habituation scenario. The participant then completed the first habituation scenario and exited the simulator to the training station where the principal investigator explained the second habituation scenario and so on for all three habituation scenarios. In total, the habituation section of the experiment took approximately 45 minutes. At the end of the habituation section, the participant filled out a second simulator sickness questionnaire. After each section the participant was asked if they wanted to take a break before continuing.

Next, the participant moved onto the first training session at the training station. The principal researcher first introduced the participant to the replay videos and explained what the symbols in the video represented. Then, the training started with the pushing technique, followed by the prop wash and leeway techniques. For each technique, the instructor went through the training briefing with the participant and then introduced them to the relevant training scenario. The participant then entered the simulator and completed the fifteen-minute training scenario. During the training scenario, the researchers updated the feedback template according to the participant's performance. After completing the training scenario, the participant returned to the training station, filled out a simulator sickness questionnaire, and went through the feedback from the scenario. After the training for each technique, the principal researcher asked if the participant wanted to take a break and directed them to the available refreshments. The training content for each technique took approximately thirty minutes. In total, the first training session took approximately 90 minutes.

After the first training session, the Training I group immediately completed the testing section. The Training II group left and returned within one to three days for their second session. Before the participant returned for their second session, the researchers made the replay videos and prepared the feedback from the first training session.

The second training session was similar in format to the first training session. Before starting training, the participant completed a simulator sickness questionnaire at the training station. Then, in the training content for each of the three techniques, the participant went through the feedback from last session and the principal researcher went through a training content refresher with them. Next, the principal researcher re-introduced the training scenario for the relevant technique and the participant entered the simulator and repeated the fifteen-minute scenario. Finally, the participant returned to the training station, filled out another simulator sickness questionnaire, and went through the feedback from their second attempt of the training scenario. Once again in this training session, the training for each technique took approximately thirty minutes for a total of 90 minutes of training.

In the testing section, the principal investigator introduced the precautionary ice management scenario to the participant at the training station. Then, the participant entered the simulator and completed the thirty-minute precautionary ice management scenario. After the participant completed the scenario, they returned to the training station and completed another simulator sickness questionnaire. The principal researcher then asked the participants questions about the scenario in an exit interview. This same procedure was then followed for the emergency ice management scenario. The testing section took approximately 75 minutes to complete.

## 3.9 Performance Metrics and Analysis Methods

### 3.9.1 Performance Metrics

There were four performance metrics used in the analysis of this research:

(1) average change in ice concentration,

(2) end change in ice concentration,

(3) clearing to distance ratio, and

(4) lifeboat launch zone.

The first three performance metrics apply to every scenario, while the lifeboat launch zone performance metric applies only to the emergency ice management scenario. The performance metrics are similar to those used in Veitch (2018a).

The performance target for the trained inexperienced cadets in the emergency ice management scenario was set at the median performance of the experienced seafarers from Experiment 1. This target was assumed to be the best representation of a reasonable target performance because it is how the average experienced seafarer is expected to perform.

#### 3.9.1.1 Average Change in Ice Concentration

The average change in ice concentration performance metric is used to represent performance based on the amount of ice the participant was able to clear during the scenario. Equation 3 was used to calculate the average change in ice concentration performance metric. The concentration was measured in the scenario's specified zone. To measure the change in ice concentration, the concentration at each thirty-second time step was subtracted from the baseline concentration. The baseline concentration is defined as what the concentration in the zone would have been if no ice management had occurred.

$$Average\ Change\ in\ Ice\ Concentration = \frac{\sum_{n=1}^{N}(Baseline\ Concentration_n - Concentration_n)}{N}$$

Where:

$N - number\ of\ time\ steps$

**Equation 3: Average Change in Ice Concentration**

The simulated ice used in each scenario was randomly generated initially, but was the same for each repeated run of the same scenario. However, there was randomness in the ice interaction and therefore the baseline concentration is not the same for every run of the same scenario. It is not possible to determine what the baseline concentration would have been for a specific run. Instead, it is assumed that the baseline concentration is normally distributed and random across each run and subsequently random across all training groups. To estimate the mean value of the baseline concentration, the concentration was measured for five separate runs of each scenario without ice management influence. Using these runs the average baseline concentration was calculated on a 95% confidence interval at each thirty-second time step. The range of this confidence interval was up to 0.85 tenths at some time steps, indicating a significant difference in the nominal average of the baseline concentration. All results for the average change in concentration performance metric were analyzed at the maximum, minimum, and mean of the baseline concentration confidence interval. However, only the results of the mean are reported here. The results from the maximum and minimum of the confidence interval can be found in Thistle (2019).

#### 3.9.1.2 End Change in Ice Concentration

The end change in ice concentration performance metric is used to represent how the participant was able to perform by the end of the scenario rather than over the course of the entire scenario. Throughout training, the participants in Experiment 2 were given feedback on the concentration in the zone at the end of the scenario and were likely trying to improve in this area specifically.

The end change in ice concentration performance metric was calculated using Equation 4. The calculation is similar to the average change in ice concentration performance metric, except only the change in ice concentration at the last time step of the scenario is used rather than an average over the entire scenario. This performance metric was also calculated at the maximum, minimum, and mean of the baseline concentration 95% confidence interval, but only the results from the mean are reported here.

$$End\ Change\ in\ Ice\ Concentration = Baseline\ Concentration_N - Concentration_N$$

**Equation 4: End Change in Ice Concentration**

### 3.9.1.3 Clearing to Distance Ratio

The clearing to distance ratio performance metric is calculated using another performance metric: average clearing. The results of the average clearing performance metric are reported along with the clearing to distance ratio performance metric, but are not analyzed separately because this metric is essentially equivalent to the average change in ice concentration performance metric converted to an area in square kilometers.

The average clearing performance metric is calculated using Equation 5. This metric represents the mean area of ice cleared for every thirty seconds. Equation 5 converts to Equation 6 using the trapezoidal rule for numerical integration to estimate the area under the curve of change in ice concentration with resect to time. While the units of average clearing should be [$km^2$ x tenths x seconds / thirty seconds] they are represented as square kilometers since tenths is a unit-less ratio and the seconds cancel out, noting the definition of average clearing is the mean area of ice cleared for every *thirty seconds* and not the mean area of ice cleared for every *one second*.

$$Average\ Clearing = A * \frac{\int_{t=0}^{T} Cdt}{N}$$

Where:

$A - area\ of\ zone$
$C - baseline\ concentration - concentration$
$N - number\ of\ time\ steps$
$T - length\ of\ scenario$

**Equation 5: Average Clearing**

$$Average\ Clearing = A * \frac{T * \sum_{n=1}^{N-1}(C_n + C_{n+1})}{2 * N * (N-1)}$$

**Equation 6: Average Clearing – Trapezoidal Rule**

The clearing to distance ratio performance metric is calculated using Equation 7 and is measured in kilometers. Once again for this performance metric, the results were calculated at the maximum, minimum, and mean of the 95% baseline concentration confidence interval, but only the results from the mean are reported here.

$$Clearing\ to\ Distance\ Ratio = \frac{Average\ Clearing}{Distance\ Traveled}$$

**Equation 7: Clearing to Distance Ratio**

While the average change in ice concentration performance metric is used to represent the *amount* of ice the participant was able to clear during the scenario, the clearing to distance ratio performance metric gives a representation of how much *effort* was used to clear the ice. In Experiment 1, the experienced seafarers were found to clear more ice compared to the distance traveled than the inexperienced cadets (Veitch, 2018a). Traveling less distance for the amount of ice cleared likely resulted in less unnecessary maneuvering in ice and more focused ice management, indicating a better performance.

#### 3.9.1.4 Lifeboat Launch Zone

The lifeboat launch zone performance metric is only applicable to the emergency ice management scenario. While the participants were asked in the emergency ice management scenario to keep the entire zone clear, an area this large is not required for lifeboat launch. The lifeboat launch zone was a small sixteen meter by 8.2 meter rectangle as shown in Figure 15. The size of the lifeboat launch zone was estimated to be the minimum required area needed for the lifeboat to launch. This is based on the findings of Simoes Re et al. (2002) that a davit launched Totally Enclosed Motor Propelled Survival Craft (TEMPSC) could usually be launched within two meters of its targeted launch location. For the analysis of this research, an extra one meter clearance on each side of the lifeboat was given for a total of three meters of clearance, except on the side closest to the FPSO where it is assumed only 1.5 meters of clearance exists. As shown in Figure 16, the sixteen meter by 8.2 meter lifeboat launch zone is found based on 1.5 meters of clearance on the starboard side and three meters of clearance on all other sides of a ten meter by 3.7 meter TEMPSC lifeboat.

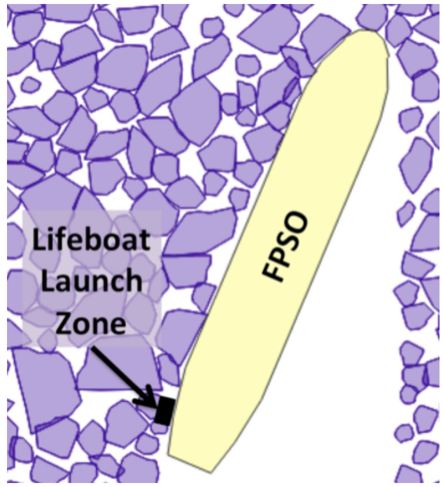



**Figure 15: Location of Lifeboat Launch Zone**

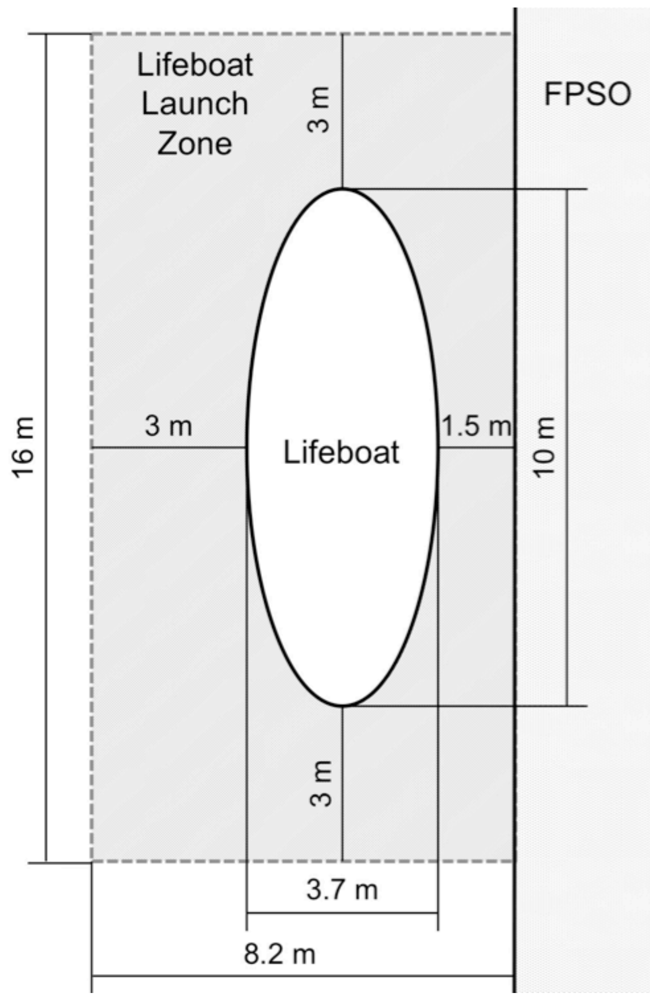



**Figure 16: Lifeboat Launch Zone Diagram**

The primary lifeboat launch zone performance metric used in this research is the longest time the lifeboat launch zone is clear. This is a measure of the longest consecutive time during the scenario that the lifeboat would have been able to launch without colliding with ice. Since Veitch (2018a) used a lifeboat launch metric measuring the total time during the scenario that the lifeboat launch zone was clear, the results are also reported using this metric. The longest time the lifeboat launch zone is clear performance metric is preferred in this research because for this entire time the lifeboat could have been given the go ahead to launch whereas with the total time the lifeboat launch zone is clear performance metric, an ice floe could enter the zone in the middle of the lifeboat launching even though the zone could be clear again in a few minutes. Unless specific reference is made to the total time the lifeboat launch zone is clear performance metric, any time the lifeboat launch zone performance metric is discussed the longest time the lifeboat launch zone is clear performance metric is being referred to.

The longest time the lifeboat launch zone is clear performance metric was determined based on the longest consecutive time during the thirty-minute emergency ice management scenario that no ice was in the lifeboat launch zone. The total time the lifeboat launch zone is clear performance metric was determined based on the total time during the thirty-minute emergency ice management scenario that no ice was in the lifeboat launch zone. For the longest time the lifeboat launch zone is clear performance metric, if an ice floe entered the lifeboat launch zone, the count time would restart at zero the next time there was no ice in the zone. For the total time the lifeboat launch zone is clear performance metric, if an ice floe entered the lifeboat launch zone the count time would continue from the last time the zone was clear the next there was no ice in the zone. For both lifeboat launch zone performance metrics, the status of ice in the lifeboat launch zone was measured at every ten-second time step over the course of the thirty-minute scenario.

### 3.9.2 Technique Analysis Methods

#### 3.9.2.1 Ice Management Method Breakdown

Throughout the training used in Experiment 2, the researchers observed that many of the cadets used similar methods when approaching the training scenarios. To analyze which methods were most effective, and if cadets were more likely to implement a certain method, each attempt of the scenario was observed and similar methods were classified together.

For the pushing scenario, there were four different approaches commonly used by the cadets. The first method is illustrated in Figure 17. This method involves clearing the port side of the platform by pushing the ice down drift with the broadside of the ice management vessel. The second method is illustrated in Figure 18. This method involves clearing the ice from the north of the platform by pushing with the bow of the ice management vessel. The third method is illustrated in Figure 19. Similarly to the second method, it involves clearing near the north of the platform, this time by pushing with the broadside of the ice management vessel. The final method for the pushing scenario is shown in Figure 20. This method involves circling the platform and pushing the ice with the bow of the ice management vessel.

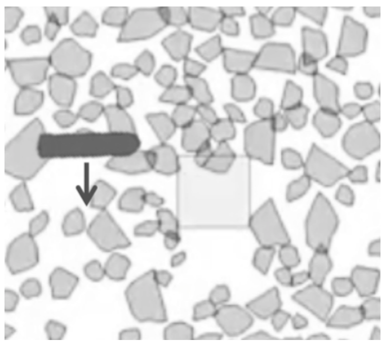


**Figure 17: Pushing Scenario – Port Side Method**

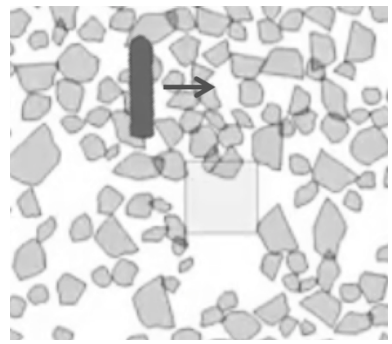


**Figure 19: Pushing Scenario – Top Side Method**

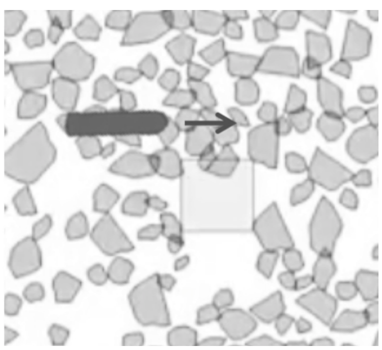


**Figure 18: Pushing Scenario – Top Bow Method**

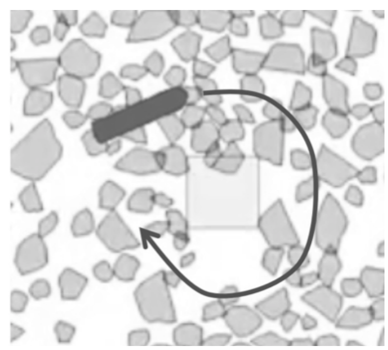


**Figure 20: Pushing Scenario – Circling Method**

The cadets used four different methods to approach the prop wash scenario. The first method is shown in Figure 21. This method involves starting above the zone and prop washing so that the stern of the ice management vessel is at an angle to the tanker. The second method it illustrated in Figure 22. This method also involves prop washing with the stern of the ice management vessel at an angle to the tanker, but this time starting from the side of the zone. The third method is shown in Figure 23. This method involves starting above the zone and prop washing straight down parallel to the tanker. The final method is shown in Figure 24. This method involves starting at the side of the zone and prop washing straight down parallel to the tanker.

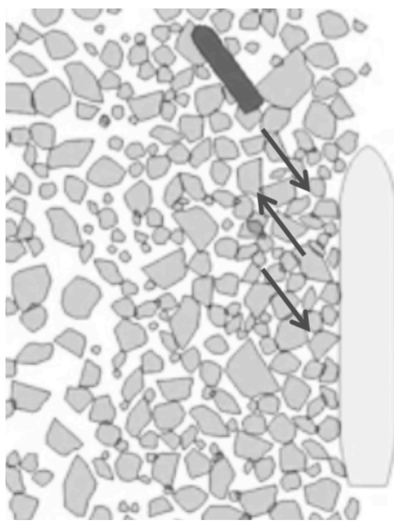


**Figure 21: Prop Wash Scenario – Above Angle Method**

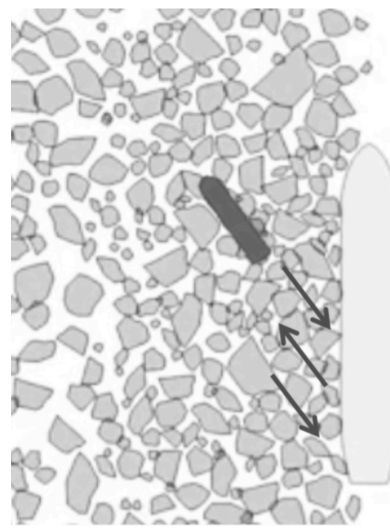


**Figure 22: Prop Wash Scenario – Side Angle Method**

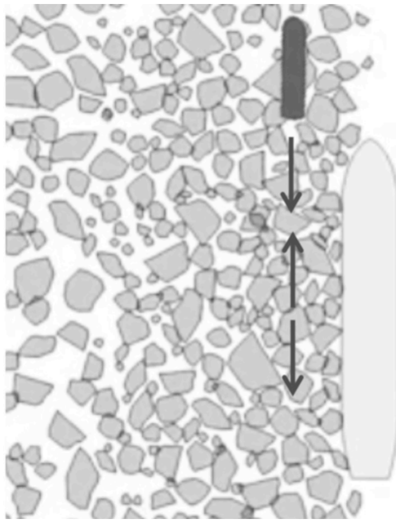


**Figure 23: Prop Wash Scenario – Above Straight Method**

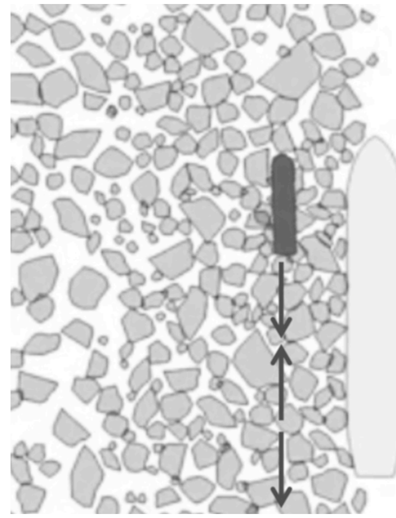


**Figure 24: Prop Wash Scenario – Side Straight Method**

There were two different methods commonly used in the leeway training scenario. The first method is shown in Figure 25 and involves creating a lee with the stern of the ice management vessel facing the tanker. The second method is shown in Figure 26. This method involves creating a lee with the bow of the ice management vessel facing the tanker.

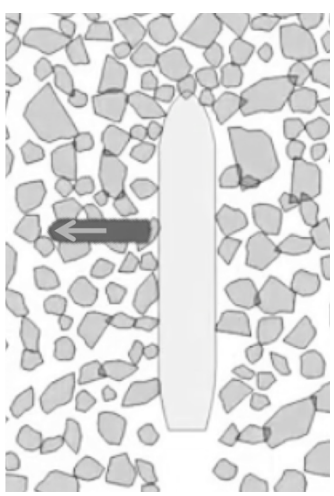


**Figure 25: Leeway Scenario – Stern in Method**

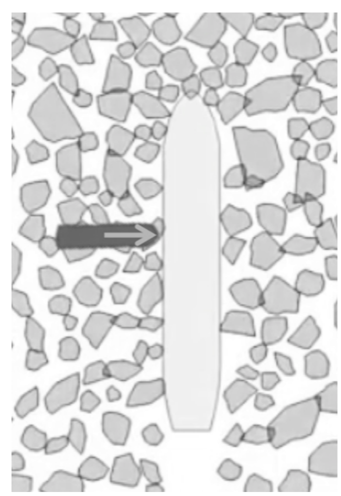


**Figure 26: Leeway Scenario – Bow in Method**

#### 3.9.2.2 Ice Management Technique Analysis

The ice management techniques used during the testing scenarios were analysed to determine how training affected what the cadets did during the scenarios. A technique was determined at each thirty-second time step during the scenarios using data from the log file. A leeway technique was defined as any time the ice management vessel was traveling at below 0.25 knots and in contact with ice. A prop wash technique was defined as any time the ice management vessel was traveling at above 0.25 knots, the engines were in the forward position, and the course of the vessel was relatively opposite (within 45 degrees) of its heading. Additionally, because of the nature of moving back and forth when implementing the prop wash technique, any time step that was sandwiched between two prop wash techniques was also considered the prop wash technique. A pushing technique was classified as any time the ice management vessel was traveling at above 0.25 knots, in contact with ice, and the engines were in the forward direction. Any time step that did not fall into one of these three categories was considered to have no distinct technique. The use of these classifications was validated against a visual estimation of what technique was being used to ensure the techniques were being correctly classified.

The dominant technique was the technique with the highest percent of time in the scenario. As traveling in ice was often classified as the pushing technique, 20%

was subtracted from the percent of time the pushing technique was used in each scenario (e.g. instead of a scenario being 70% pushing and 30% leeway it would be 50% pushing and 30% leeway). This was done so that the technique classification was not biased towards the pushing technique. A scenario was only classified as using no distinct technique if none of the three techniques were used more than 20% of the time during the scenario. As the information collected in the log files was updated between experiments, the technique classification could only be completed for Experiment 2.

### 3.9.3 Speed Analysis Methods

The POLARIS recommended speed for the vessel and ice conditions used in these experiments was three knots. The calculation of this speed can be found in Appendix H: POLARIS Calculations. Throughout the experiments, participants were informed of the three knot recommendation of maximum speed in ice. To analyze whether or not this recommendation was followed, the speeds of each training group were analyzed to see the number of participants who went above the three knot limit and the mean percent of time the participants spent above the limit. Additionally, to look at by how much participants went above the recommended speed, the number of participants that went above four knots and the average percent of time spent above four knots was also calculated.

### 3.9.4 Rankings

In order to compare performances of groups and individuals across the different performance metrics and scenarios, the performance of each participant in each scenario was ranked in each performance metric. A ranking of one represented the worst performance and the highest ranking (e.g. 36) represented the best performance. If more than one participant had the same performance score, they would be given the same ranking and the next ranking would be skipped (e.g. 1,2,3,3,5).

For the training scenarios, only the second attempt of the scenarios by the Training II group was ranked because the mix of between and within subject design and factor levels meant the results of the Training I group and first and second attempt of the scenarios by the Training II group could not be compared simultaneously.

## 3.10 Statistical Analysis Methods

The normal probability plots of residuals for each scenario and performance metric are shown in Appendix J: Normal Probability Plots of Residuals. As examples, the normal probability plots for the average change in ice concentration and lifeboat launch zone performance metrics for the emergency ice management scenario are shown in Figure 27 and Figure 28. In Figure 27, the residuals are approximately linear and a normal distribution is assumed. In Figure 28, the residuals are not linear and the distribution is assumed to be non-normal (Montgomery, 2005).

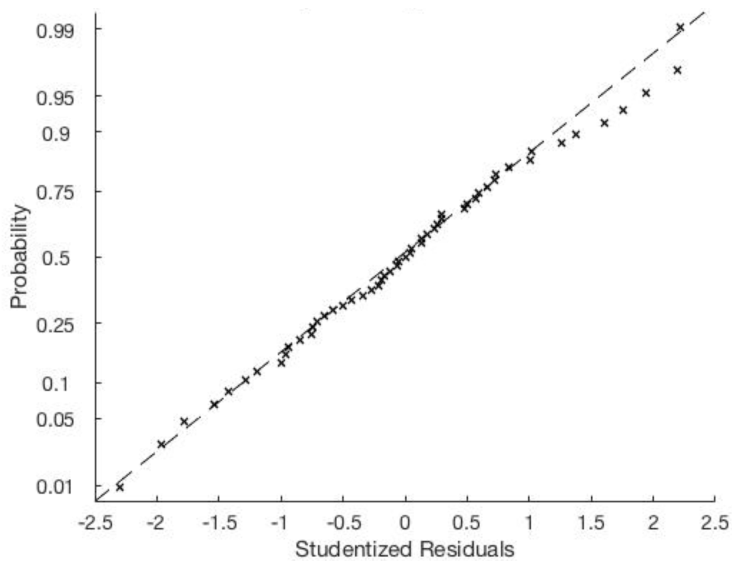



**Figure 27: Normal Probability Plot of Residuals for the Average Change in Ice Concentration Metric of the Emergency Ice Management Scenario**

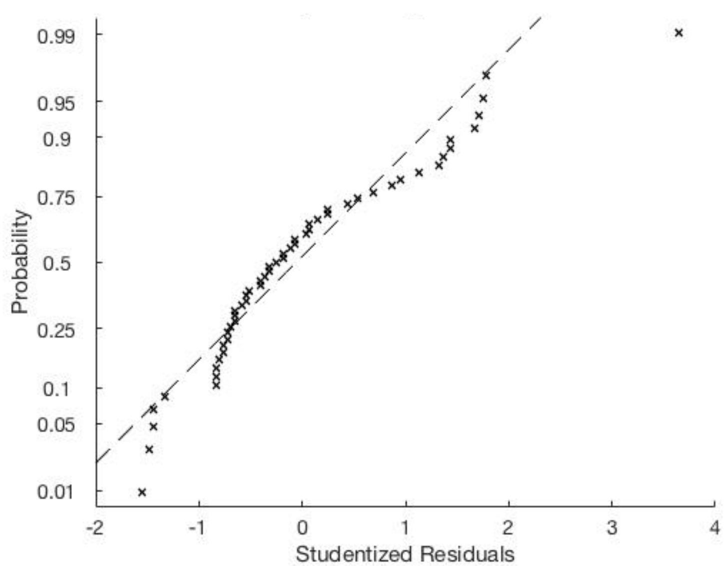



**Figure 28: Normal Probability Plot of Residuals for the Lifeboat Launch Zone Metric of the Emergency Ice Management Scenario**

The linear assumptions are confirmed using a Lillefors Test. A p-value > 0.05 for a Lillefors Test indicates that the null hypothesis, that the results are normally distributed, cannot be rejected and a p-value < 0.05 indicates that the null hypothesis can be rejected (Abdi et al., 2009). The Lillefors p-values from the results of each scenario in all performance metrics are listed in Table 7. The results for the leeway scenario in every performance metric, the precautionary ice management scenario in the average chance in ice concentration metric, and the emergency ice management scenario in the clearing to distance ratio and longest time lifeboat launch zone is clear performance metrics are assumed to be non-normally distributed.

**Table 7: Lillefors p Values**

| | Average Change in Ice Con. | End Change in Ice Con. | Clearing to Distance Ratio | Longest Time Lifeboat Launch Zone Clear | Total Time Lifeboat Launch Zone Clear |
|---|---|---|---|---|---|
| **Pushing Scenario (Between Subjects)** | 0.18 | 0.88 | 0.42 | - | - |
| **Pushing Scenario (Within Subjects)** | 0.79 | 0.43 | 0.81 | - | - |
| **Prop Wash Scenario (Between Subjects)** | 0.38 | 0.17 | 0.2 | - | - |
| **Prop Wash Scenario (Within Subjects)** | 0.32 | 0.31 | 0.35 | - | - |
| **Leeway Scenario (Between Subjects)** | **0.002** | **0** | **0** | - | - |
| **Leeway Scenario (Within Subjects)** | **0.035** | **0** | **0.007** | - | - |
| **Precautionary Ice Management Scenario** | **0.013** | 0.37 | 0.45 | - | - |
| **Emergency Ice Management Scenario** | 0.88 | 0.36 | **0.004** | **0.015** | 0.51 |

For the results that were approximately normally distributed, effect size was calculated using Cohen's d. A Cohen's d value of 0.2 - 0.5, 0.5 - 0.8, and above 0.8 were considered relatively small, medium, and large effects respectively (Cohen, 1988; Cohen, 1992; Lan and Lian, 2010).

For the within subjects results for the leeway scenario, the effect size was calculated using the Wilcoxon Signed Rank Test Statistic (Corder and Foreman, 2014). For the other non-normally distributed results, which were all between subjects, the effect size was calculated using the Mann Whitney U-Test Statistic (Corder and Foreman, 2014). For both the Wilcoxon Signed Rank Test and Mann Whitney U-Test, an effect size of 0.1 - 0.3, 0.3 - 0.5, and above 0.5 represented relatively small, medium, and large effects, respectively (Corder and Foreman, 2014; Cohen, 1988; Cohen, 1992).

The statistical significance of all the results was also calculated assuming a p-value $< 0.05$ represented statistically significant results. For the pushing and prop wash training scenarios, a one factor Analysis Of Variance (ANOVA) was used to calculate statistical significance for the between subjects results and a within subjects one factor ANOVA was used to calculate statistical significance for the within subjects results. Both of these ANOVAs had the null hypothesis that training had no effect on ice management performance.

In addition to the assumption of normality, an ANOVA has an assumption of homoscedasticity (approximately equal variance) (Abdi et al., 2009; Montgomery, 2005). To check for homoscedasticity an O'Brien's Test, which does not require that the data be normally distributed, was used. As shown in Table 8, for all results that were assumed to be normally distributed, the p-value from O'Brien's test were above 0.05 and the null hypothesis that the results from each group come from a population with the same variance was not rejected (Abdi et al., 2009). Based on this, it is assumed the homoscedasticity assumption is reasonably satisfied for every scenario that also had normally distributed results.

**Table 8: O'Brien's p-Values**

| | Average Change in Ice Con. | End Change in Ice Con. | Clearing to Distance Ratio | Longest Time Lifeboat Launch Zone Clear | Total Time Lifeboat Launch Zone Clear |
|---|---|---|---|---|---|
| **Pushing Scenario (Between Subjects)** | 0.16 | 0.53 | 0.4 | - | - |
| **Pushing Scenario (Within Subjects)** | 0.81 | 0.1 | 0.55 | - | - |
| **Prop Wash Scenario (Between Subjects)** | 0.08 | 0.38 | 0.23 | - | - |
| **Prop Wash Scenario (Within Subjects)** | 0.59 | 0.45 | 0.98 | - | - |
| **Leeway Scenario (Between Subjects)** | **0** | **0** | **0** | - | - |
| **Leeway Scenario (Within Subjects)** | 0.14 | 0.11 | 0.036 | - | - |
| **Precautionary Ice Management Scenario** | **0.014** | 0.69 | 0.1 | - | - |
| **Emergency Ice Management Scenario** | 0.62 | 0.07 | 0.09 | 0.31 | 0.34 |

For the between subjects leeway training scenario results, the statistical significance was calculated using the Mann Whitney U-Test Statistic. The Mann Whitney U-Test is the non-parametric equivalent to a one-way ANOVA with two factor levels for samples that are independent of each other (Corder and Foreman, 2014). For the within subject leeway training scenario results, the statistical significance was calculated using the Wilcoxon Signed Rank Test Statistic. The Wilcoxon Signed Rank Test is also a non-parametric equivalent to a one-way ANOVA, but for two factor levels that are related to each other, such as within subject results (Corder and Foreman, 2014). Both of these statistical tests use rankings instead of means to calculate statistical significance.

For the precautionary ice management scenario in the average change in ice concentration performance metric, statistical significance was calculated using the Mann Whitney U-Test Statistic. Since the Mann Whitney U-Test is a one-way test, the results for mild and severe ice conditions are separated for this metric. To avoid Type I error (rejecting the null hypothesis when it is true) inflation a Bonferroni corrected p-value $< 0.025$ is considered statistically significant for this metric and scenario (Corder and Foreman, 2014; Abdi et al., 2009). For all other performance metrics for the precautionary ice management scenario, a two-way fixed effects ANOVA was used to calculate statistical significance and a p-value $< 0.05$ was considered statistically significant.

For the emergency ice management scenario, the statistical significance is reported for the combined results of all three levels of training and both ice conditions. However, it must be noted that the statistical assumption of independence is violated for this scenario. Since the results were collected in two different experiments that were a year apart, they are not random. The residual versus run order plots for all scenarios and performance metrics are shown in

Appendix K: Residuals vs. Run Order Plots. The Residual versus Run Order Plot for the clearing to distance ratio performance metric for the emergency ice management scenario is shown as an example in Figure 29. In Figure 29, the violation of the independence assumption is evident because the Training 0 residuals at the beginning are visibly lower than the later Training I and Training II residuals (Montgomery, 2005).

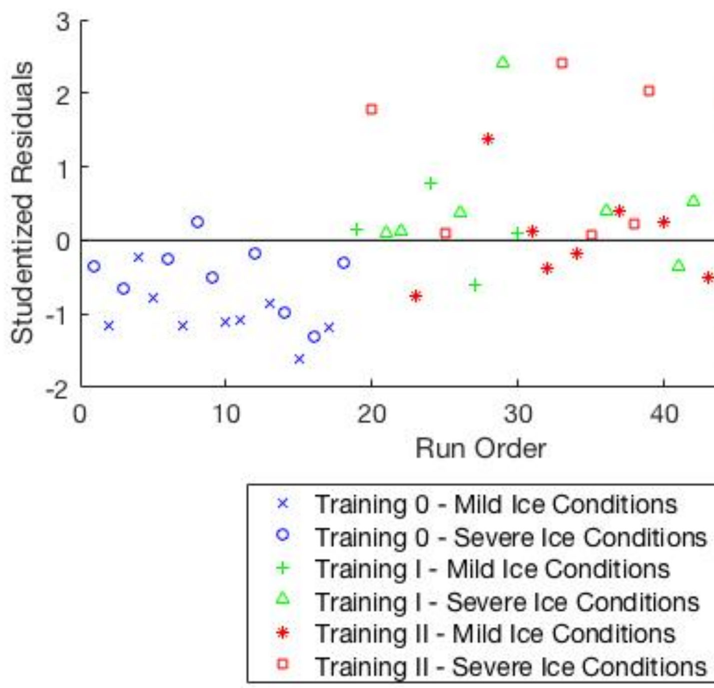



**Figure 29: Residual vs. Run Order Plot for the Clearing to Distance Ratio Metric of the Emergency Ice Management Scenario**

Experiments that are not random are considered quasi-experiments. It is theoretically possible to make practical inferences from the results of quasi-experiments, but the assumptions of a causal relationship must be satisfied (Shadish et al., 2002). For this research, the assumption that there are no alternative causes for the observed effects is violated (Shadish et al., 2002).

Although measures, such as using an experimental script and the same habituation scenarios, were taken to minimize the effects of alternative causes, the fact that there were two different experimenters is a possible partial cause of any observed effects. The results for statistical significance are still reported for the emergency ice management scenario, but the violation of the independence assumption must be noted in reporting these results.

For the average change in ice concentration, end change in ice concentration, and total time the lifeboat launch zone is clear performance metrics in the emergency ice management, scenario a two-way fixed effects ANOVA with the null hypothesis that training had no effect on ice management performance was used to determine the statistical significance of the results. For the clearing to distance ratio and longest time the lifeboat launch zone is clear performance metrics, the non-parametric Kruskal-Wallis Test was used instead of an ANOVA. Similarly to the Mann-Whitney U-Test, the Kruskal-Wallis Test uses a ranking of results to determine significance of independent results except the Kruskal-Wallis test allows for more than two factor levels. Since the Kruskal-Wallis Test is a one-way test, the results for mild and severe ice conditions are separated (Corder and Foreman, 2014). Once again, to avoid Type I error inflation a Bonferroni corrected p-value $< 0.025$ is considered statistically significant for the clearing to distance ratio and longest time the lifeboat launch zone is clear performance metrics of the emergency ice management scenario (Corder and Foreman, 2014; Abdi et al., 2009).

# Chapter 4: Results

## 4.1 Performance Metric Results

### 4.1.1 Training Scenarios

#### 4.1.1.1 Average Change in Ice Concentration

The results for the training scenarios for the average change in ice concentration performance metric are listed in Table 9 and shown in the form of box plots in Figure 30, Figure 31, and Figure 32 for the between subject results of the pushing, prop wash, and leeway scenarios, respectively.

**Table 9: Training Scenarios Average Change in Ice Concentration Results**

| | | | Mean (tenths) | Median (tenths) | Max (tenths) | Min (tenths) | Standard Deviation (tenths) |
|---|---|---|---|---|---|---|---|
| **Pushing Scenario** | 1st Attempt | **Training I** | 0.15 | 0.06 | 0.82 | -0.17 | 0.28 |
| | | **Training II** | 0.30 | 0.34 | 1.05 | -0.24 | 0.39 |
| | 2nd Attempt | **Training II** | 0.61 | 0.60 | 1.50 | 0.05 | 0.41 |
| **Prop Wash Scenario** | 1st Attempt | **Training I** | 0.60 | 0.44 | 1.50 | -0.18 | 0.54 |
| | | **Training II** | 0.74 | 0.62 | 2.84 | -0.07 | 0.76 |
| | 2nd Attempt | **Training II** | 1.80 | 1.99 | 3.66 | 0.39 | 0.87 |
| **Leeway Scenario** | 1st Attempt | **Training I** | 1.72 | 1.59 | 3.99 | -0.83 | 1.65 |
| | | **Training II** | 2.69 | 2.91 | 3.97 | -0.79 | 1.16 |
| | 2nd Attempt | **Training II** | 3.80 | 3.77 | 4.51 | 2.98 | 0.47 |

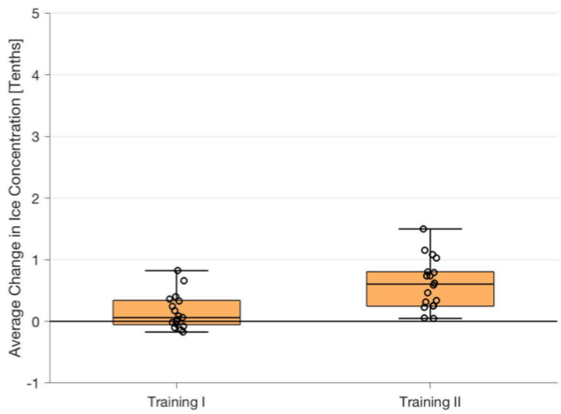



**Figure 30: Pushing Scenario Average Change in Ice Concentration Box Plot**

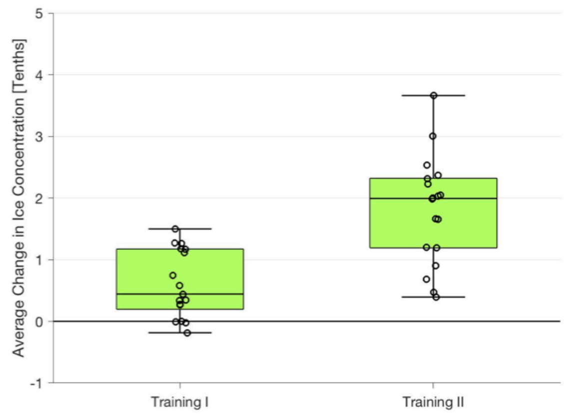



**Figure 31: Prop Wash Scenario Average Change in Ice Concentration Box Plot**

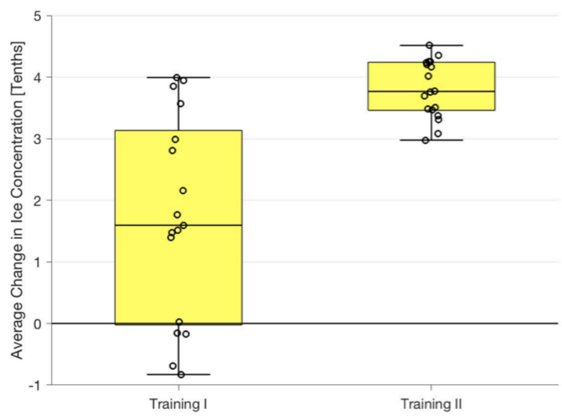



**Figure 32: Leeway Scenario Average Change in Ice Concentration Box Plot**

For the average change in ice concentration performance metric in all three training scenarios, the mean performance of the Training II group in their second attempt of the scenario was higher than the mean performance of the Training I group in their first attempt of the scenario (+0.46 tenths pushing, +1.20 tenths prop wash, +2.08 tenths leeway). This indicates a combination of two things:

(1) additional training had a positive impact on the ice management performance of the inexperienced cadets and

(2) the cadets performed better when repeating the scenarios than in their first attempt of the scenarios.

In addition to the improvement in the mean results, the median, maximum, and minimum results of each training group was better in the second attempt of the scenario by the Training II group than the first attempt of the scenario by the Training I group. The results for the between subject effect size and statistical significance for the pushing, prop wash, and leeway scenarios in the average change in ice concentration performance metric are listed in tables Table 10, Table 11, and Table 12, respectively. There was a large positive effect of training on the ice management performance of the cadets in all the training scenarios (Cohen's d > 0.8 pushing and prop wash, effect size > 0.5 leeway). For all the training scenarios, the results were also statistically significant ($p < 0.05$).

**Table 10: Average Change in Ice Concentration ANOVA and Effect Size Results for the Pushing Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 1.83 | 1.83 | 14.81 | <0.001 | 1.34 |

**Table 11: Average Change in Ice Concentration ANOVA and Effect Size Results for the Prop Wash Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 12.44 | 12.44 | 23.17 | <0.001 | 1.68 |

**Table 12: Average Change in Ice Concentration Mann Whitney U-Test Results for the Leeway Scenario**

| | $n_1$ | $n_2$ | $R_1$ | $R_2$ | $U_1$ | $U_2$ | p Value | Effect Size |
|---|---|---|---|---|---|---|---|---|
| **Training** | 17 | 18 | 191 | 439 | 268 | 38 | <0.05 | 0.64 |

The within subject results of the average change in ice concentration performance metric for the pushing, prop wash, and leeway scenarios are shown in Figure 33, Figure 34, and Figure 35, respectively.

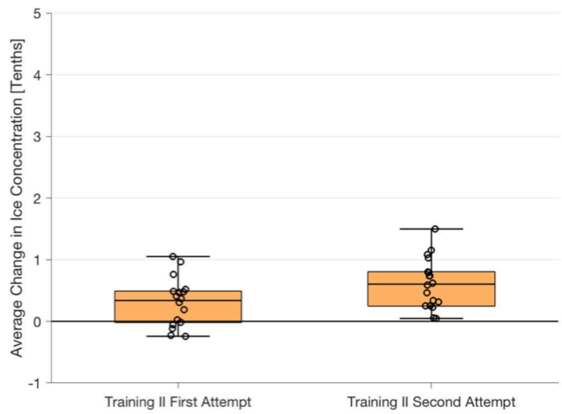



**Figure 33: Pushing Scenario Average Change in Ice Concentration Box Plot (Within Subjects)**

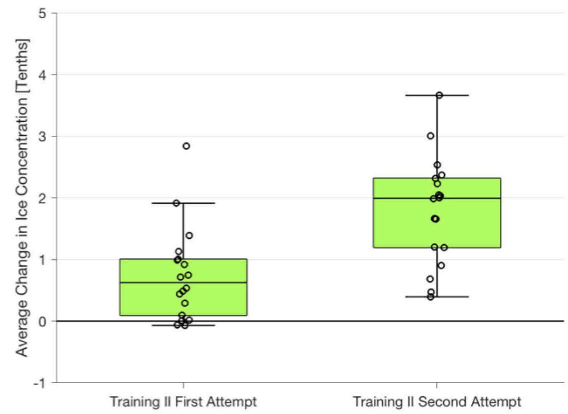



**Figure 34: Prop Wash Scenario Average Change in ice Concentration Box Plot (Within Subjects)**

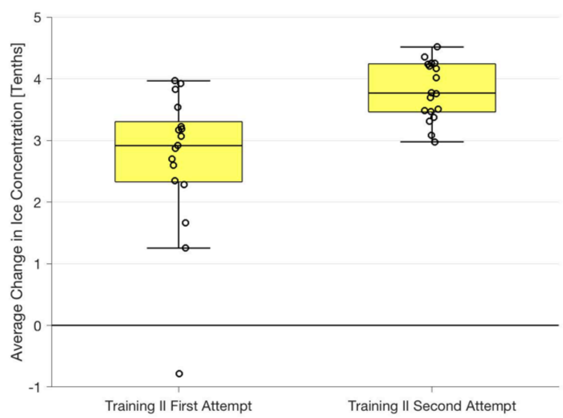



**Figure 35: Leeway Scenario Average Change in Ice Concentration Box Plot (Within Subjects)**

The mean performance in the second attempt of the scenarios by the Training II group was higher than the mean performance in the first attempt of the scenarios by the Training II group (+0.31 tenths pushing, +1.06 tenths prop wash, and

+1.11 tenths leeway). Additionally, 15/18, 17/18, and 16/17 of the cadets in the Training II group performed better in their second attempt of the pushing, prop wash, and leeway scenarios, respectively. These results indicate that training had a positive impact on performance and performance on an individual basis improved for most cadets on their second attempt of the scenarios.

The results for effect size and statistical significance for the within subject results of the training scenarios in the average change in ice concentration performance metric are listed in Table 13, Table 14, and Table 15 for the pushing, prop wash, and leeway scenarios, respectively. Similarly to the between subject results, there was a large effect of training on performance in all of the training scenarios (Cohen's $d > 0.8$ pushing and prop wash, effect size $> 0.5$ leeway) and the results were statistically significant ($p < 0.05$). It should be noted that the results for one Training II participant in their first attempt of the leeway scenario are not available because the scenario was not recorded. Therefore, the leeway results for this participant were not included in the Wilcoxon Signed Rank test, which requires paired results.

**Table 13: Average Change in Ice Concentration Within Subjects ANOVA and Effect Size Results for the Pushing Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 0.88 | 0.88 | 6.89 | 0.018 | 0.81 |

**Table 14: Average Change in Ice Concentration Within Subjects ANOVA and Effect Size Results for the Prop Wash Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 9.98 | 9.98 | 29.23 | <0.001 | 1.33 |

**Table 15: Average Change in Ice Concentration Wilcoxon Signed Rank Test Results for the Leeway Scenario**

| | n | R+ | R- | p Value | Effect Size |
|---|---|---|---|---|---|
| **Training** | 17 | 147 | 6 | <0.05 | 0.81 |

In all of the training scenarios, the mean performance of the Training II group in their first attempt of the scenarios was higher than the mean performance of the Training I group in their first attempt of the scenarios in the average change in ice concentration performance metric (+0.15 tenths pushing, +0.14 tenths prop wash, and +0.97 tenths leeway).

### 4.1.1.2 End Change in Ice Concentration

The results for the training scenarios for the end change in ice concentration performance metric are listed in Table 16 and shown in the form of box plots in Figure 36, Figure 37, and Figure 38 for the between subject results of the pushing, prop wash, and leeway scenarios, respectively.

**Table 16: Training Scenarios End Change in Ice Concentration Results**

| | | | Mean (tenths) | Median (tenths) | Max (tenths) | Min (tenths) | Standard Deviation (tenths) |
|---|---|---|---|---|---|---|---|
| **Pushing Scenario** | 1st Attempt | **Training I** | 0.67 | 0.42 | 2.49 | -0.73 | 0.86 |
| | | **Training II** | 0.95 | 0.58 | 2.96 | -0.58 | 1.05 |
| | 2nd Attempt | **Training II** | 1.75 | 1.64 | 2.95 | 0.50 | 0.75 |
| **Prop Wash Scenario** | 1st Attempt | **Training I** | 2.57 | 1.97 | 6.32 | -0.34 | 1.73 |
| | | **Training II** | 2.90 | 3.02 | 6.81 | 0.20 | 1.70 |
| | 2nd Attempt | **Training II** | 5.18 | 5.60 | 7.22 | 2.50 | 1.42 |
| **Leeway Scenario** | 1st Attempt | **Training I** | 2.99 | 3.69 | 6.48 | -1.74 | 3.40 |
| | | **Training II** | 5.62 | 6.48 | 6.48 | -0.16 | 1.93 |
| | 2nd Attempt | **Training II** | 6.33 | 6.48 | 6.48 | 5.44 | 0.29 |

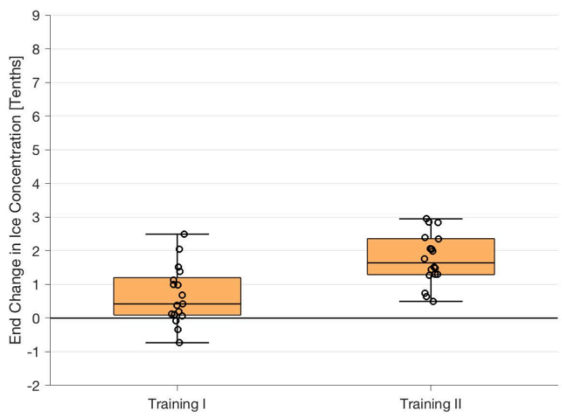



**Figure 36: Pushing Scenario End Change in Ice Concentration Box Plot**

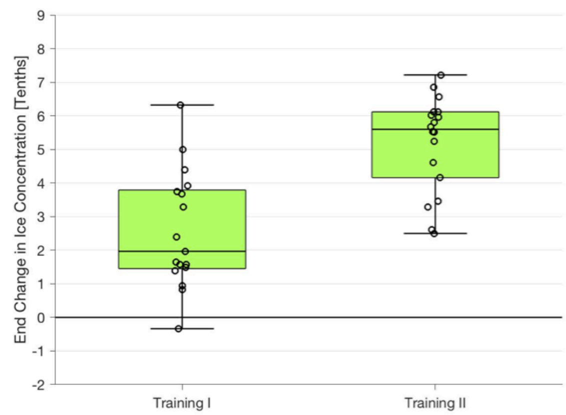



**Figure 37: Prop Wash Scenario End Change in ice Concentration Box Plot**

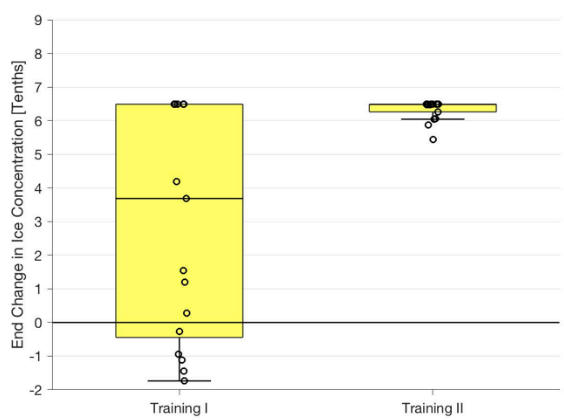



**Figure 38: Leeway Scenario End Change in Ice Concentration Box Plot**

For the end change in ice concentration performance metric, the mean performance of the Training II group in their second attempt of the training scenarios was higher than the mean performance of the first attempt of the scenarios by the Training I group (+1.08 tenths pushing, +2.61 tenths prop wash, +3.34 tenths leeway). Once again in this performance metric, the results indicate that training had a positive impact on the ice management performance of the inexperienced cadets and that the cadets performed better when repeating the scenarios. In addition to the means, the median and minimum performances of the Training II group in their second attempt of the scenarios was higher than the Training I group in their first attempt of the scenarios. The maximum results were higher for the Training II group in their second attempt of the scenarios for the pushing and prop wash scenarios, and equal for the leeway scenario as there were participants in both training groups who had no ice remaining in the zone at the end of the scenario.

Table 17, Table 18, and Table 19 list the results for effect size and statistical significance for the pushing, prop wash, and leeway scenario between subject results respectively in the end change in ice concentration performance metric. There was a large effect of training on ice management performance in the pushing and prop wash scenarios (Cohen's $d > 0.8$). In the leeway scenario there was only a medium effect of training on ice management performance ($0.2 <$ effect size $< 0.5$) because many of the cadets in the Training I group already had the zone completely or mostly cleared at the end of their first attempt of the scenario. Training also had a statically significant effect ($p < 0.05$) on performance in all three training scenarios.

**Table 17: End Change in Ice Concentration ANOVA and Effect Size Results for the Pushing Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 10.16 | 10.16 | 15.72 | <0.001 | 1.38 |

**Table 18: End Change in Ice Concentration ANOVA and Effect Size Results for the Prop Wash Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 59.22 | 59.22 | 23.68 | <0.001 | 1.69 |

**Table 19: End Change in Ice Concentration Mann Whitney U-Test Results for the Leeway Scenario**

| | $n_1$ | $n_2$ | $R_1$ | $R_2$ | $U_1$ | $U_2$ | p Value | Effect Size |
|---|---|---|---|---|---|---|---|---|
| **Training** | 17 | 18 | 244 | 368 | 215 | 91 | <0.05 | 0.35 |

The within subject results of the training scenarios for the end change in ice concentration performance metric are shown in Figure 39, Figure 40, and Figure 41. The mean performance of the Training II group in their second attempt of the scenarios was higher in all three scenarios than the mean performance of the Training II group in their first attempt of the scenarios (+0.80 tenths pushing, +0.33 tenths prop wash, +0.71 tenths leeway). 13/18 cadets in the pushing scenario and 17/18 cadets in the prop wash scenario performed better in their second attempt of the scenarios than in their first attempt of the scenarios. In the leeway scenario, 7/17 performed better in their second attempt of the scenario and 7/17 performed the same in their second attempt of the scenario having no ice remaining in the zone.

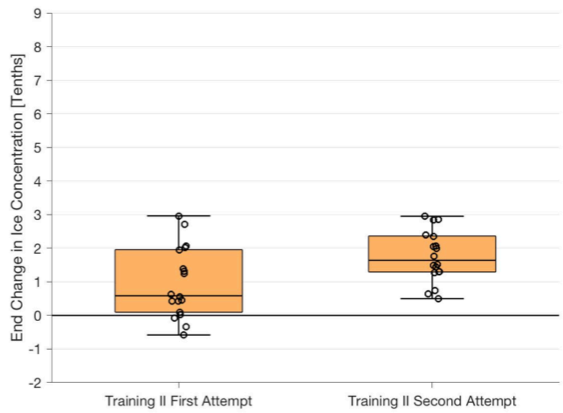



**Figure 39: Pushing Scenario End Change in Ice Concentration Box Plot (Within Subjects)**

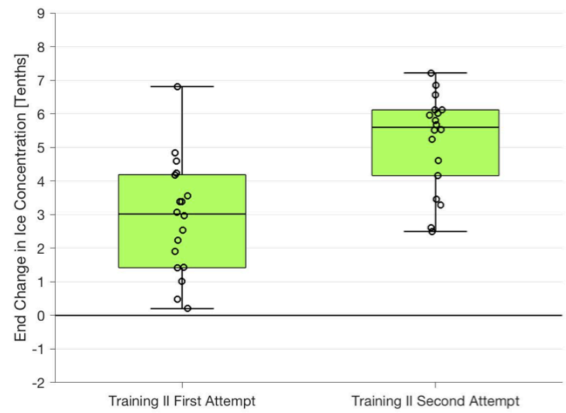



**Figure 40: Prop Wash Scenario End Change in ice Concentration Box Plot (Within Subjects)**

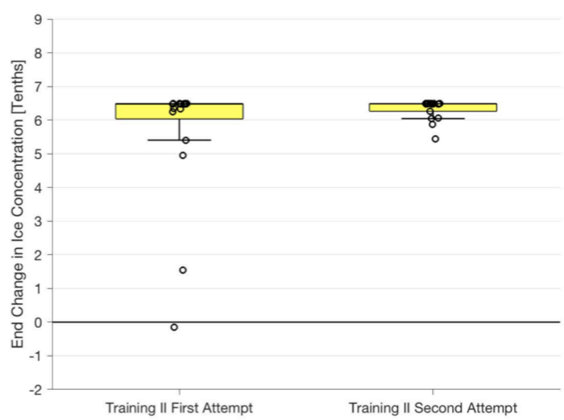



**Figure 41: Leeway Scenario End Change in Ice Concentration Box Plot (Within Subjects)**

The results for effect size and statistical significance for the within subject results of the training scenarios for the end change in ice concentration performance metric are listed in Table 20, Table 21, and Table 22. For all three training scenarios, there was a large effect on performance due to training (Cohen's $d > 0.8$ pushing and prop wash, effect size $> 0.5$ leeway). These results indicate that training had a positive effect on the performance of the cadets in this metric. The results were also statically significant ($p < 0.05$), in all three scenarios.

**Table 20: End Change in Ice Concentration Within Subjects ANOVA and Effect Size Results for the Pushing Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 5.65 | 5.65 | 9.57 | 0.007 | 0.9 |

**Table 21: End Change in Ice Concentration Within Subjects ANOVA and Effect Size Results for the Prop Wash Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 46.55 | 46.55 | 45.33 | <0.001 | 1.5 |

**Table 22: End Change in Ice Concentration Wilcoxon Signed Rank Test Results for the Leeway Scenario**

| | n | R+ | R- | p Value | Effect Size |
|---|---|---|---|---|---|
| **Training** | 17 | 56 | 22 | <0.01 | 0.63 |

Once again in the end change in ice concentration performance metric, the mean performance of the Training II group in their first attempt of the training scenarios was higher than the mean performance of the Training I group in their first attempt of the training scenarios (+0.28 tenths pushing, +0.33 tenths prop wash, +2.61 tenths leeway).

### 4.1.1.3 Clearing to Distance Ratio

The average clearing results for the training scenarios are listed in Table 23. The clearing to distance ratio performance metric results are listed in Table 24 and shown in Figure 42, Figure 43, and Figure 44 for the between subject results of the pushing, prop wash, and leeway scenarios, respectively.

**Table 23: Training Scenarios Average Clearing Results**

| | | | Mean ($km^2$) | Median ($km^2$) | Max ($km^2$) | Min ($km^2$) | Standard Deviation ($km^2$) |
|---|---|---|---|---|---|---|---|
| Pushing Scenario | 1st Attempt | Training I | 0.17 | 0.06 | 0.95 | -0.19 | 0.32 |
| | | Training II | 0.34 | 0.39 | 1.20 | -0.28 | 0.44 |
| | 2nd Attempt | Training II | 0.69 | 0.69 | 1.73 | 0.03 | 0.47 |
| Prop Wash Scenario | 1st Attempt | Training I | 0.34 | 0.26 | 0.87 | -0.11 | 0.32 |
| | | Training II | 0.42 | 0.35 | 1.66 | -0.05 | 0.44 |
| | 2nd Attempt | Training II | 1.04 | 1.15 | 2.16 | 0.21 | 0.52 |
| Leeway Scenario | 1st Attempt | Training I | 0.23 | 0.22 | 0.54 | -0.11 | 0.22 |
| | | Training II | 0.36 | 0.39 | 0.53 | -0.11 | 0.16 |
| | 2nd Attempt | Training II | 0.51 | 0.51 | 0.61 | 0.40 | 0.06 |

**Table 24: Training Scenarios Clearing to Distance Ratio Results**

| | | | Mean (km) | Median (km) | Max (km) | Min (km) | Standard Deviation (km) |
|---|---|---|---|---|---|---|---|
| Pushing Scenario | 1st Attempt | Training I | 0.19 | 0.02 | 1.03 | -0.38 | 0.38 |
| | | Training II | 0.37 | 0.42 | 1.38 | -0.38 | 0.51 |
| | 2nd Attempt | Training II | 0.70 | 0.69 | 1.52 | 0.03 | 0.45 |
| Prop Wash Scenario | 1st Attempt | Training I | 0.45 | 0.28 | 1.11 | -0.11 | 0.43 |
| | | Training II | 0.53 | 0.42 | 2.05 | -0.07 | 0.56 |
| | 2nd Attempt | Training II | 1.27 | 1.36 | 2.35 | 0.26 | 0.55 |
| Leeway Scenario | 1st Attempt | Training I | 0.49 | 0.51 | 1.24 | -0.27 | 0.50 |
| | | Training II | 0.84 | 0.90 | 1.41 | -0.27 | 0.45 |
| | 2nd Attempt | Training II | 1.37 | 1.36 | 1.68 | 1.00 | 0.19 |

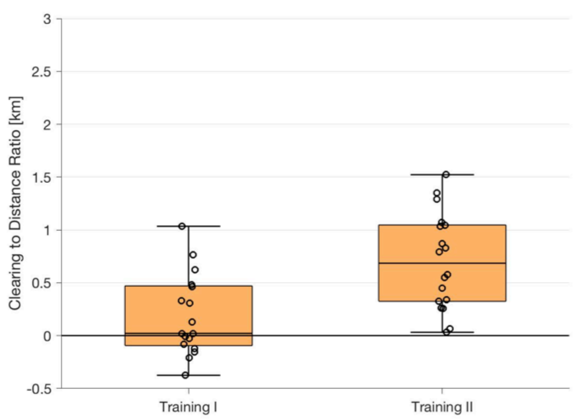



**Figure 42: Pushing Scenario Clearing to Distance Ratio Box Plot**

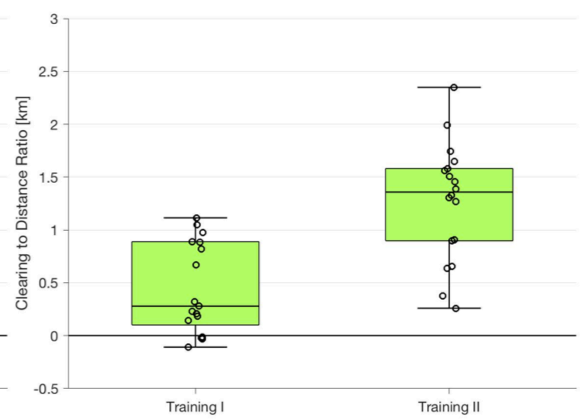



**Figure 43: Prop Wash Scenario Clearing to Distance Ratio Box Plot**

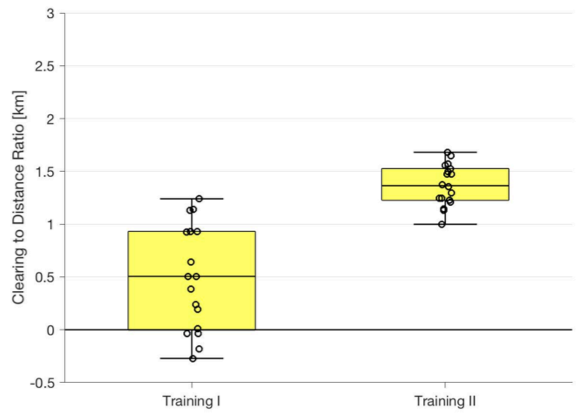



**Figure 44: Leeway Scenario Clearing to Distance Ratio Box Plot**

Similarly to the other performance metrics, the mean performance of the Training II group in their second attempt of all three training scenarios was higher than the mean performance of the Training I group in their first attempt of the training scenarios in the clearing to distance ratio performance metric (+0.51 km pushing, +0.82 km prop wash, +0.88 km leeway). Once again in this metric, the results indicate that training had a positive impact on performance and that the cadets performed better in a second attempt of the scenarios. The median, minimum and maximum performance was also better for the Training II group in their second attempt of the training scenarios than for the Training I group in first attempt of the scenarios.

The between subject results for effect size and statistical significance for the training scenarios in the clearing to distance ratio performance metric are listed in Table 25, Table 26, and Table 27. There was a large effect of training on ice management performance in all of the training scenarios (Cohen's d > 0.8 pushing and prop wash, effect size > 0.5 leeway), indicating training had a large positive impact on performance. The results for all three training scenarios were also statistically significant ($p < 0.05$).

**Table 25: Clearing to Distance Ratio ANOVA and Effect Size Results for the Pushing Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 2.33 | 2.33 | 13.19 | <0.001 | 1.26 |

**Table 26: Clearing to Distance Ratio ANOVA and Effect Size Results for the Prop Wash Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 5.93 | 5.93 | 5.93 | 24.02 | <0.001 | 1.71 |

**Table 27: Clearing to Distance Ratio Mann Whitney U-Test Results for the Leeway Scenario**

| | $n_1$ | $n_2$ | $R_1$ | $R_2$ | $U_1$ | $U_2$ | p Value | Effect Size |
|---|---|---|---|---|---|---|---|---|
| **Training** | 17 | 18 | 162 | 468 | 297 | 9 | <0.05 | 0.8 |

The within subject results for the clearing to distance ratio performance metric for the pushing, prop wash, and leeway training scenarios are shown in Figure 45, Figure 46, and Figure 47, respectively. In all the training scenarios, the mean performance of the Training II group in their second attempt of the scenario was higher than the mean performance of the Training II group in their first attempt of the scenario (+0.33 km pushing, +0.74 km prop wash, +0.53 km leeway). 14/18, 18/18, and 15/17 cadets performed better in their second attempt of the pushing, prop wash and leeway scenarios, respectively. These results indicate that training had a positive impact on performance and that the cadets performed better in their second attempt of the scenarios.

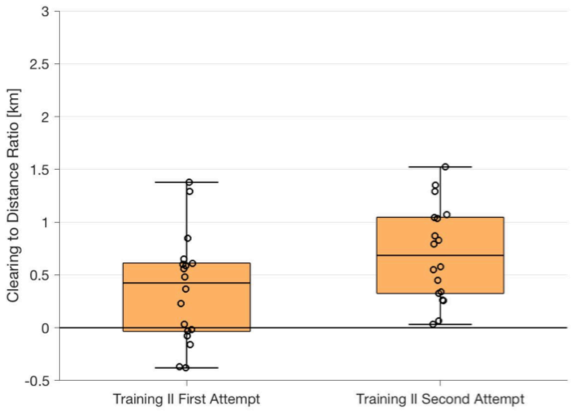



**Figure 45: Pushing Scenario Clearing to Distance Ratio Box Plot (Within Subjects)**

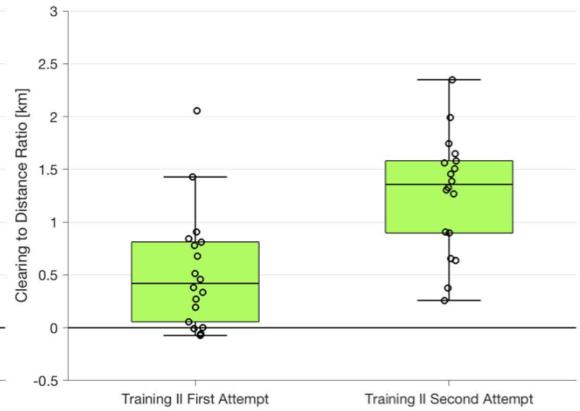



**Figure 46: Prop Wash Scenario Clearing to Distance Ratio Box Plot (Within Subjects)**

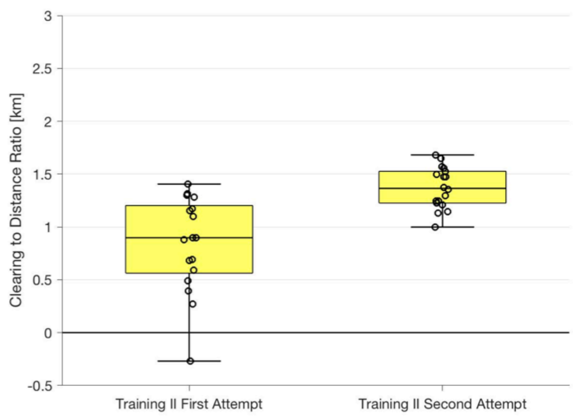



**Figure 47: Leeway Scenario Clearing to Distance Ratio Box Plot (Within Subjects)**

The results for effect size and statistical significance for the within subject results of the clearing to distance ratio performance metric are listed in Table 28, Table 29, and Table 30. For the pushing scenario, there was a medium effect on performance due to training (0.5 < Cohen's d < 0.8). For the prop wash and leeway scenarios, there was a large effect on performance due to training (Cohen's d > 0.8 prop wash, effect size > 0.5 leeway). The results were also statically significant ($p < 0.05$) for all of the within subject results of the training scenarios in the clearing to distance ratio performance metric.

**Table 28: Clearing to Distance Ratio Within Subjects ANOVA and Effect Size Results for the Pushing Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 1.02 | 1.02 | 6.36 | 0.022 | 0.72 |

**Table 29: Clearing to Distance Ratio Within Subjects ANOVA and Effect Size Results for the Prop Wash Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value | Cohen's d |
|---|---|---|---|---|---|---|
| **Training** | 1 | 4.91 | 4.91 | 40.09 | <0.001 | 1.37 |

**Table 30: Clearing to Distance Ratio Wilcoxon Signed Rank Test Results for the Leeway Scenario**

| | n | R+ | R- | p Value | Effect Size |
|---|---|---|---|---|---|
| **Training** | 17 | 148 | 5 | <0.01 | 0.82 |

Similarly to the other performance metrics, the mean performance of the Training II group in their first attempt of the scenarios was higher than the mean performance of the Training I group in their first attempt of the scenarios in the clearing to distance ratio performance metric (+0.18 km pushing, +0.0.8 km, prop wash, +0.35 km, leeway).

## 4.1.2 Precautionary Ice Management Scenario

### 4.1.2.1 Average Change in Ice Concentration

The results for the average change in ice concentration performance metric for the precautionary ice management scenario are listed in Table 31 and shown in Figure 48 and Figure 49 for mild and severe ice conditions, respectively.

**Table 31: Precautionary Ice Management Scenario Average Change in Ice Concentration Results**

| | | Mean (tenths) | Median (tenths) | Max (tenths) | Min (tenths) | Standard Deviation (tenths) |
|---|---|---|---|---|---|---|
| Mild Ice Conditions | Training I | 1.67 | 1.67 | 2.18 | 1.01 | 0.34 |
| | Training II | 1.60 | 1.56 | 2.68 | 0.88 | 0.50 |
| Severe Ice Conditions | Training I | 2.50 | 2.71 | 3.12 | 1.83 | 0.49 |
| | Training II | 3.01 | 3.18 | 3.54 | 1.69 | 0.58 |

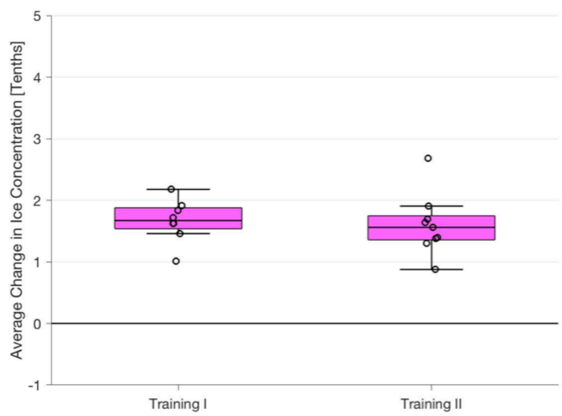



**Figure 48: Mild Ice Conditions Precautionary Ice Management Scenario Average Change in Ice Concentration Box Plot**

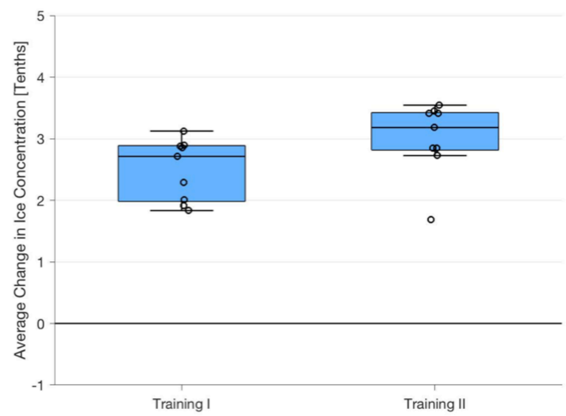



**Figure 49: Severe Ice Conditions Precautionary Ice Management Scenario Average Change in Ice Concentration Box Plot**

For both mild and severe ice conditions, there was little difference between the mean performance (-0.07 tenths mild, +0.51 tenths severe) and the standard deviation (+0.16 tenths mild, +0.09 tenths severe) of the Training II group compared to the Training I group in the average change in ice concentration performance metric for the precautionary ice management scenario. These results indicate that additional training had minimal impact on the ice management performance of the cadets in this scenario.

The effect size and statistical significance for both mild and severe ice conditions for the precautionary ice management scenario in the average change in ice concentration performance metric are listed in Table 32. For mild ice conditions, there was only a small effect (0.1 < effect size < 0.3) on ice management performance due to training. For severe ice conditions, there was a medium effect (0.3 < effect size < 0.5) on ice management performance due to training. These results indicate that in mild conditions additional training did not have a significant impact on training and there was some improvement with additional training in severe ice conditions. For both mild and severe ice conditions, there were no statistically significant effects (p > 0.025) on ice management performance due to training for this scenario and ice conditions.

**Table 32: Average Change in Ice Concentration Mann Whitney U-Test Results for the Precautionary Ice Management Scenario**

| | $n_1$ | $n_2$ | $R_1$ | $R_2$ | $U_1$ | $U_2$ | p Value | Effect Size |
|---|---|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | 8 | 9 | 81 | 72 | 27 | 45 | >0.025 | 0.21 |
| **Severe Ice Conditions** | 9 | 9 | 66 | 105 | 60 | 21 | >0.025 | 0.41 |

### 4.1.2.2 End Change In Ice Concentration

The results for the end change in ice concentration performance metric for the precautionary ice management scenario are listed in Table 33 and shown in Figure 50 and Figure 51 for mild and severe ice conditions, respectively.

**Table 33: Precautionary Ice Management Scenario End Change in Ice Concentration Results**

| | | Mean (tenths) | Median (tenths) | Max (tenths) | Min (tenths) | Standard Deviation (tenths) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Training I** | 4.12 | 4.22 | 5.37 | 2.52 | 0.98 |
| | **Training II** | 3.96 | 4.13 | 5.06 | 2.46 | 0.90 |
| **Severe Ice Conditions** | **Training I** | 6.08 | 6.44 | 6.96 | 4.65 | 0.81 |
| | **Training II** | 5.27 | 5.90 | 6.93 | 2.49 | 1.62 |

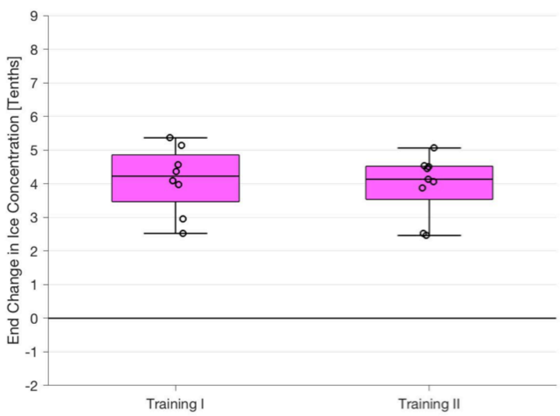



**Figure 50: Mild Ice Conditions Precautionary Ice Management Scenario End Change in Ice Concentration Box Plot**

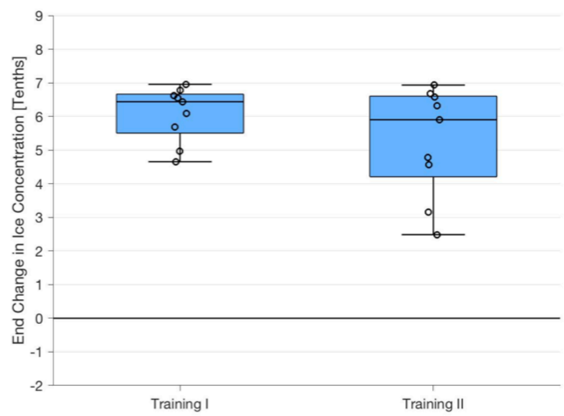



**Figure 51: Severe Ice Conditions Precautionary Ice Management Scenario End Change in Ice Concentration Box Plot**

For mild ice conditions, there was little difference between the mean results (-0.16 tenths) and the standard deviation (-0.08 tenths) of the Training II group compared to the Training I group for the precautionary ice management scenario in the end change in ice concentration performance metric. These results indicate that training had little effect on the ice management performance of the inexperienced cadets in these ice conditions.

For severe ice conditions, the Training II group had a lower mean ice management performance than the Training II group (-0.81 tenths) for the precautionary ice management scenario in the end change in ice concentration performance metric. The standard deviation of the Training II group was higher for the Training II group than the Training I group (+0.81 tenths). These results indicate that for this scenario and ice conditions training had a negative impact on the ability of the cadets to manage ice.

The results for effect size and statistical significance for the precautionary ice management scenario in the end change in ice concentration performance metric are listed in Table 34 and Table 35, respectively. In mild ice conditions, there was no effect (Cohen’s d < 0.02) on ice management performance due to training. In severe ice conditions, there was a medium negative effect (0.5 < Cohen’s d < 0.8) on ice management performance due to training. The effects of training on ice management performance in the end change in ice concentration performance metric for the precautionary ice management scenario were not statically significant (p > 0.05).

**Table 34: End Change in Ice Concentration Effect Size Results for the Precautionary Ice Management Scenario**

| | Cohen's d |
|---|---|
| **Mild Ice Conditions** | 0.19 |
| **Severe Ice Conditions** | 0.68 |

**Table 35: End Change in Ice Concentration ANOVA Results for the Precautionary Ice Management Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value |
|---|---|---|---|---|---|
| **Training** | 1 | 2.11 | 2.11 | 1.66 | 0.207 |
| **Ice Conditions** | 1 | 23.33 | 23.33 | 18.33 | <0.001 |
| **Interaction** | 1 | 0.93 | 0.93 | 0.73 | 0.399 |
| **Total** | 34 | 66.1 | | | |

### 4.1.2.3 Clearing to Distance Ratio

The results for the average clearing performance metric for the precautionary ice management scenario are listed in Table 36. The results for the clearing to distance ratio performance metric for the precautionary ice management scenario are listed in Table 37 and shown in Figure 52 and Figure 53 for mild and severe ice conditions, respectively.

**Table 36: Precautionary Ice Management Scenario Area Cleared Results**

| | | Mean ($km^2$) | Median ($km^2$) | Max ($km^2$) | Min ($km^2$) | Standard Deviation ($km^2$) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Training I** | 1.41 | 1.42 | 1.85 | 0.85 | 0.29 |
| | **Training II** | 1.36 | 1.32 | 2.29 | 0.74 | 0.43 |
| **Severe Ice Conditions** | **Training I** | 2.12 | 2.29 | 2.65 | 1.54 | 0.42 |
| | **Training II** | 2.56 | 2.70 | 3.03 | 1.44 | 0.49 |

**Table 37: Precautionary Ice Management Clearing to Distance Ratio Results**

| | | Mean (km) | Median (km) | Max (km) | Min (km) | Standard Deviation (km) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Training I** | 1.02 | 1.06 | 1.56 | 0.45 | 0.37 |
| | **Training II** | 1.18 | 0.96 | 2.70 | 0.48 | 0.69 |
| **Severe Ice Conditions** | **Training I** | 1.75 | 1.62 | 2.61 | 1.23 | 0.50 |
| | **Training II** | 2.02 | 2.08 | 2.73 | 0.70 | 0.65 |

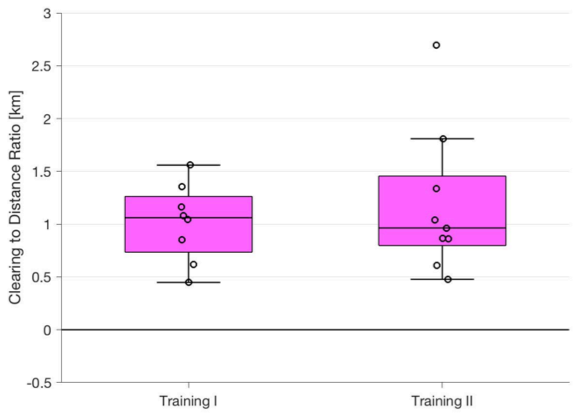



Figure 52: Mild Ice Conditions Precautionary Ice Management Scenario Clearing to Distance Ratio Box Plot

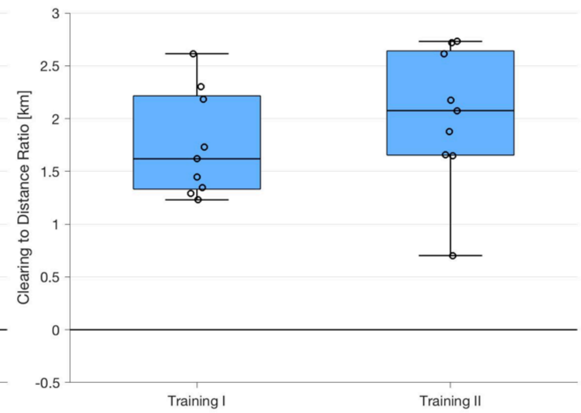



Figure 53: Severe Ice Conditions Precautionary Ice Management Scenario Clearing to Distance Ratio Box Plot

For the precautionary ice management scenario in the clearing to distance ratio performance metric for both mild and severe ice conditions, the mean performance of the Training II group was only marginally better than the mean performance of the Training I group (+0.16 km mild, +0.27 km severe). The standard deviation of the Training II group was higher than the Training I group (+0.32 km mild, +0.15 km severe). These results indicate that training had little impact on the ice management performance of the cadets in this scenario and performance metric.

Table 38 lists the effect sizes for both mild and severe ice conditions for the precautionary ice management scenario in the clearing to distance ratio performance metric, which were small (0.2 < Cohen's d < 0.5). This indicates that training had little effect on ice management performance. Training was also not found to have a statistically significant effect on ice management performance ($p > 0.05$) for this scenario and performance metric, as listed in Table 39.

**Table 38: Clearing to Distance Ratio Effect Size Results for the Precautionary Ice Management Scenario**

| | Cohen's d |
|---|---|
| **Mild Ice Conditions** | 0.31 |
| **Severe Ice Conditions** | 0.49 |

**Table 39: Clearing to Distance Ratio ANOVA Results for the Precautionary Ice Management Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value |
|---|---|---|---|---|---|
| **Training** | 1 | 0.42 | 0.42 | 1.29 | 0.265 |
| **Ice Conditions** | 1 | 5.41 | 5.41 | 16.54 | <0.001 |
| **Interaction** | 1 | 0.02 | 0.02 | 0.07 | 0.795 |
| **Total** | 34 | 15.94 | | | |

## 4.1.3 Emergency Ice Management Scenario

### 4.1.3.1 Average Change in Ice Concentration

The results for both mild and severe ice conditions in the average change in ice concentration performance metric for the emergency ice management scenario are listed in Table 40 and shown in Figure 54 and Figure 55.

**Table 40: Emergency Ice Management Scenarios Average Change in Ice Concentration Results**

| | | Mean (tenths) | Median (tenths) | Max (tenths) | Min (tenths) | Standard Deviation (tenths) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Seafarers** | 1.76 | 2.01 | 2.20 | 1.11 | 0.45 |
| | **Training 0** | 1.10 | 1.02 | 2.17 | 0.09 | 0.65 |
| | **Training I** | 2.23 | 2.18 | 3.86 | 0.94 | 1.02 |
| | **Training II** | 2.10 | 2.00 | 2.78 | 1.23 | 0.48 |
| **Severe Ice Conditions** | **Seafarers** | 2.78 | 3.12 | 3.64 | 0.98 | 0.80 |
| | **Training 0** | 1.87 | 1.94 | 3.05 | 0.35 | 0.83 |
| | **Training I** | 2.48 | 2.24 | 4.08 | 1.47 | 0.83 |
| | **Training II** | 2.95 | 2.89 | 4.07 | 2.06 | 0.71 |

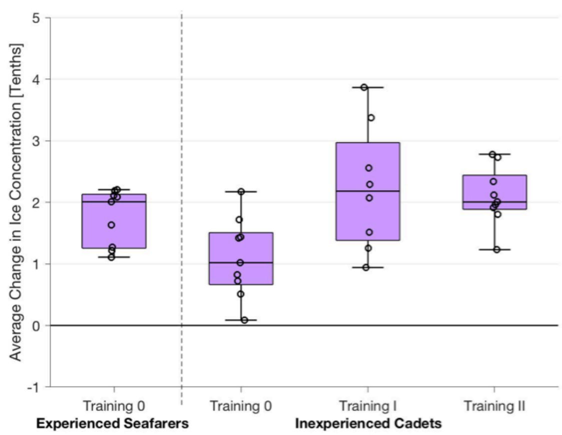



**Figure 54: Mild Ice Conditions Emergency Ice Management Scenario Average Change in Ice Concentration Box Plot**

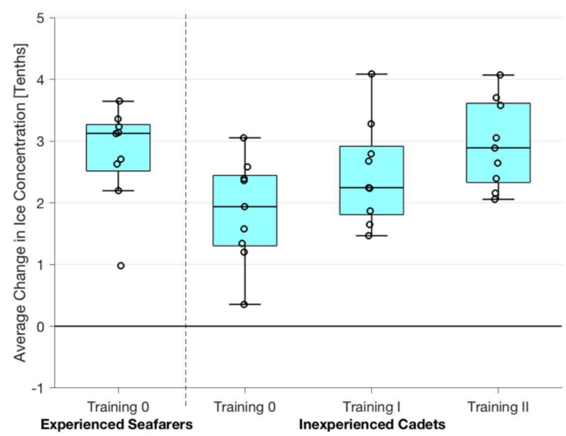



**Figure 55: Severe Ice Conditions Emergency Ice Management Scenario Average Change in Ice Concentration Box Plot**

For mild ice conditions, the mean performance for the emergency ice management scenario in the average change in ice concentration performance metric for both the Training I and Training II groups was higher than the mean performance of both the Training 0 group (+1.13 tenths Training I, +1.00 tenths Training II) and the experienced seafarers (+0.47 tenths Training I, +0.34 tenths Training II). This indicates that training had a large positive impact on ice management performance and that most cadets could perform better than the mean level of the experienced seafarer after training. However, there was little difference in the mean performance between the Training I and Training II groups (-0.13 tenths), indicating that additional training after the first session did not have much effect on the ability of the average inexperienced cadet to manage ice. The effect sizes between each level of training, listed in Table 41, support the results observed from the means because there was a large effect (Cohen's d > 0.8) of training on ice management performance between Training 0 and Training I but no significant effects (Cohen's d < 0.2) between Training I and Training II.

For severe ice conditions, the mean performance for the emergency ice management scenario in the average change in ice concentration performance metric of the Training I group was higher than the mean performance of the Training 0 group (+0.61 tenths) and the mean performance of the Training II group was higher than both the Training I group (+0.47 tenths) and the experienced seafarers (+0.17 tenths). These results indicate that, for the assumed more difficult severe ice conditions, training once again had a large positive impact on performance. In severe ice conditions it took two training sessions for the mean performance level of inexperienced cadets to be higher than the mean performance level of the experienced seafarers and a second training session did have a positive impact on the ability of the average inexperienced cadet to manage ice. The effect sizes, listed in Table 41, once again give similar results as observed from the means as there was a medium effect (0.5 < Cohen's d < 0.8) on ice management performance because of training from both Training 0 to Training I and Training I to Training II with a large overall effect (Cohen's d > 0.8) from Training 0 to Training II.

**Table 41: Average Change in Ice Concentration Effect Size Results for the Emergency Ice Management Scenario**

| | | Cohen's d |
|---|---|---|
| **Mild Ice Conditions** | Training 0 + Training II | 1.87 |
| | Training 0 + Training I | 1.44 |
| | Training I +Training II | 0.18 |
| **Severe Ice Conditions** | Training 0 + Training II | 1.48 |
| | Training 0 + Training I | 0.78 |
| | Training I +Training II | 0.65 |

For the average change in ice concentration performance metric in the emergency ice management scenario, the standard deviation amongst each group's performance in mild ice conditions increased from Training 0 to Training I (+0.37 tenths) but went down again from Training I to Training II (-0.54 tenths). The standard deviation of the Training II group was approximately equal to the experienced seafarers (+0.03 tenths). In severe ice conditions, the standard deviation did not change from Training 0 to Training I (+/- 0 tenths) and decreased only marginally from Training I to Training II (-0.12 tenths). The standard deviation of the Training II group compared to the experienced seafarers was also approximately equal (-0.9 tenths). These results indicate no clear relationship between variance in performance and amount of training for the average change in ice concentration performance metric for the emergency ice management scenario.

While no statistical conclusions can be made from the emergency ice management scenario results because of the violation of the independence assumption, the ANOVA results, listed in Table 42, indicated a statistically significant effect ($p < 0.05$) on the mean ice management performance of the cadets due to training in the average change in ice concentration performance metric. There is also a statistically significant effect ($p < 0.05$) on ice management performance due to ice conditions, but this is not of interest as there is more ice in the severe ice condition scenario and therefore more of an opportunity to have a higher average change in ice concentration than in the mild ice conditions scenario.

**Table 42: Average Change in Ice Concentration ANOVA Results for the Emergency Ice Management Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value |
|---|---|---|---|---|---|
| **Training** | 2 | 11.18 | 5.59 | 9.53 | <0.001 |
| **Ice Conditions** | 1 | 5.07 | 5.07 | 8.65 | 0.005 |
| **Interaction** | 2 | 0.94 | 0.47 | 0.8 | |
| **Total** | 52 | 44.94 | | | |

### 4.1.3.2 End Change In Ice Concentration

The results for mild and severe ice conditions for the end change in ice concentration performance metric for the emergency ice management scenario are listed in Table 43 and shown in Figure 56 and Figure 57, respectively.

**Table 43: Emergency Ice Management Scenario End Change in Ice Concentration Results**

| | | Mean (tenths) | Median (tenths) | Max (tenths) | Min (tenths) | Standard Deviation (tenths) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Seafarers** | 2.76 | 3.29 | 5.93 | -1.24 | 2.03 |
| | **Training 0** | 2.69 | 2.87 | 4.74 | -0.22 | 1.60 |
| | **Training I** | 3.05 | 2.70 | 7.25 | 0.19 | 2.36 |
| | **Training II** | 4.40 | 4.78 | 5.86 | 2.17 | 1.26 |
| **Severe Ice Conditions** | **Seafarers** | 3.06 | 3.94 | 6.16 | 0.19 | 2.08 |
| | **Training 0** | 3.23 | 4.63 | 5.26 | -0.71 | 2.22 |
| | **Training I** | 4.78 | 5.83 | 7.65 | -0.12 | 2.98 |
| | **Training II** | 5.14 | 4.84 | 8.89 | 1.26 | 2.73 |

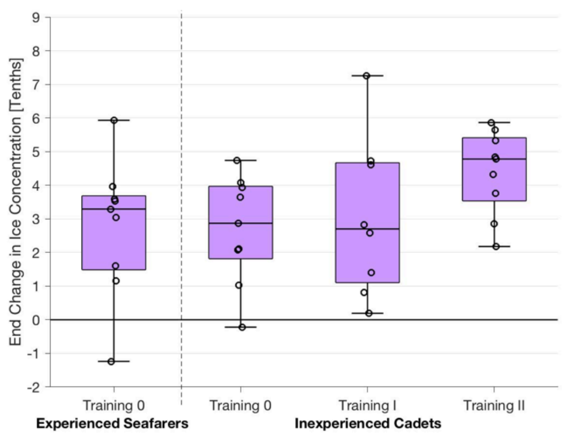



**Figure 56: Mild Ice Conditions Emergency Ice Management Scenario End Change in Ice Concentration Box Plot**

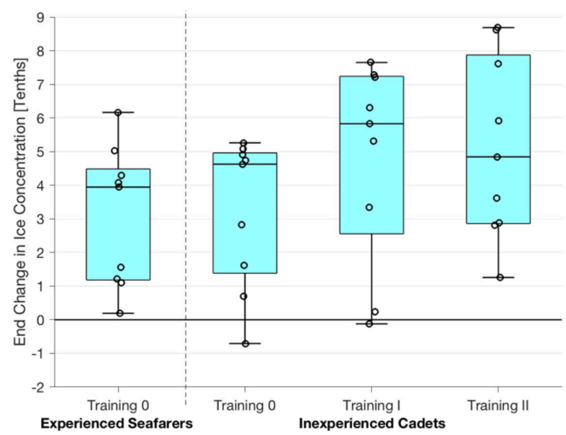



**Figure 57: Severe Ice Conditions Emergency Ice Management Scenario End Change in Ice Concentration Box Plot**

For both mild and severe ice conditions, the mean performance for the emergency ice management scenario in the end change in ice concentration performance metric of the Training I and Training II groups was higher than both the Training 0 group (+0.36 tenths Training I mild, +1.71 tenths Training II mild, +1.55 tenths Training I severe, +1.91 tenths Training II severe) and the experienced seafarers (+0.29 tenths Training I mild, +1.64 tenths Training II mild, +1.72 tenths Training I severe, +2.08 tenths Training II severe). These results indicate that training had a positive impact on ice management performance and that most cadets could perform better than the mean level of the experienced seafarers in the emergency ice management scenario after training. In both ice conditions, the mean end change in ice concentration of the Training II group was also higher than the mean end change in ice concentration of the Training I group (+1.35 tenths mild, +0.36 tenths severe). This indicates that for this performance metric, additional training sessions had a positive impact on the ice management performance of the inexperienced cadets. Table 44 lists the results for effect size. In both ice conditions, there was a large overall positive effect from Training 0 to Training II on performance due to training (Cohen's $d > 0.8$). For mild ice conditions, there was no effect on performance due to training from Training 0 to Training I (Cohen's $d < 0.2$) and a medium effect from Training I to Training II ($0.5 <$ Cohen's $d < 0.8$), indicating the largest effects on performance were after the second training session. For severe ice conditions, there was a medium effect of training on ice management performance from Training 0 to Training I ($0.5 <$ Cohen's $d < 0.8$) and no significant effects of training on ice management performance from Training I to Training II (Cohen's $d < 0.2$), indicating that in severe ice conditions the largest effects on performance were after the first training session.

**Table 44: End Change in Ice Concentration Effect Size Results for the Emergency Ice Management Scenario**

| | | Cohen's d |
|---|---|---|
| **Mild Ice Conditions** | Training 0 + Training II | 1.26 |
| | Training 0 + Training I | 0.19 |
| | Training I +Training II | 0.77 |
| **Severe Ice Conditions** | Training 0 + Training II | 0.82 |
| | Training 0 + Training I | 0.63 |
| | Training I +Training II | 0.13 |

The standard deviation in both mild and severe ice conditions for the emergency ice management scenario in the end change in ice concentration performance metric increased from Training 0 to Training I (+0.76 tenths mild, +0.76 tenths severe) but went down again from Training I to Training II (-1.10 tenths mild, -0.25 tenths severe). In mild ice conditions, the standard deviation of the Training II group was less than the standard deviation of the experienced seafarers (-0.77 tenths). In severe ice conditions, the standard deviation of the Training II group was greater than the standard deviation of the experienced seafarers (+0.65 tenths). These results do not indicate a clear relationship between variance in performance and amount of training for the end change in ice concentration performance metric.

The ANOVA results for the end change in ice concentration performance metric for the emergency ice management scenario are listed in Table 45. Training did not have a statistically significant effect ($p > 0.05$) on performance.

**Table 45: End Change in Ice Concentration ANOVA Results for the Emergency Ice Management Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value |
|---|---|---|---|---|---|
| **Training** | 2 | 29.39 | 14.69 | 2.86 | 0.068 |
| **Ice Conditions** | 1 | 12.33 | 13.33 | 2.59 | 0.114 |
| **Interaction** | 2 | 3.55 | 1.78 | 0.35 | 0.71 |
| **Total** | 52 | 287.84 | | | |

### 4.1.3.3 Clearing to Distance Ratio

Results for the area cleared performance metric for the emergency ice management scenario are listed in Table 46. Results for the clearing to distance ratio performance metric are given in Table 47 and shown in Figure 58 and Figure 59. Five data points are missing from this metric because of log files that did not record in the simulator. The sample size is reduced to five for Training I in mild ice conditions and eight for Training II in both mild and severe ice conditions.

**Table 46: Emergency Ice Management Scenario Area Cleared Results**

| | | Mean ($km^2$) | Median ($km^2$) | Max ($km^2$) | Min ($km^2$) | Standard Deviation ($km^2$) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Seafarers** | 0.81 | 0.92 | 1.00 | 0.51 | 0.21 |
| | **Training 0** | 0.50 | 0.47 | 1.00 | 0.02 | 0.30 |
| | **Training I** | 1.03 | 1.01 | 1.77 | 0.43 | 0.47 |
| | **Training II** | 0.96 | 0.91 | 1.28 | 0.56 | 0.22 |
| **Severe Ice Conditions** | **Seafarers** | 1.28 | 1.43 | 1.67 | 0.45 | 0.37 |
| | **Training 0** | 0.86 | 0.88 | 1.40 | 0.17 | 0.38 |
| | **Training I** | 1.13 | 1.02 | 1.87 | 0.67 | 0.38 |
| | **Training II** | 1.35 | 1.32 | 1.86 | 0.94 | 0.28 |

**Table 47: Emergency Ice Management Scenario Clearing to Distance Ratio Results**

| | | Mean (km) | Median (km) | Max (km) | Min (km) | Standard Deviation (km) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Seafarers** | 0.52 | 0.61 | 0.64 | 0.26 | 0.17 |
| | **Training 0** | 0.25 | 0.21 | 0.58 | 0.01 | 0.16 |
| | **Training I** | 0.61 | 0.72 | 1.02 | 0.12 | 0.34 |
| | **Training II** | 0.70 | 0.67 | 1.27 | 0.36 | 0.29 |
| **Severe Ice Conditions** | **Seafarers** | 0.86 | 0.86 | 1.74 | 0.28 | 0.43 |
| | **Training 0** | 0.48 | 0.53 | 0.79 | 0.13 | 0.19 |
| | **Training I** | 0.95 | 0.85 | 1.74 | 0.51 | 0.45 |
| | **Training II** | 1.13 | 1.10 | 1.66 | 0.71 | 0.42 |

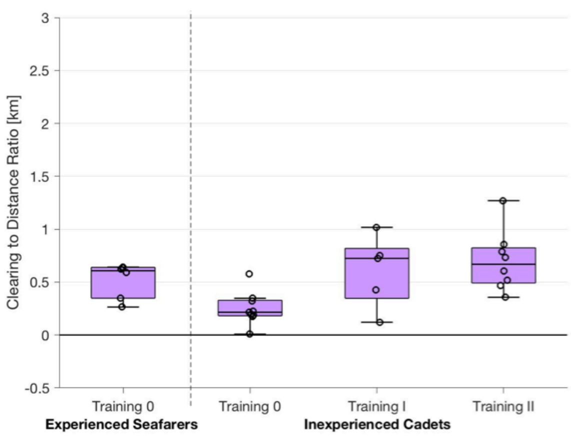



**Figure 58: Mild Ice Conditions Emergency Ice Management Scenario Clearing to Distance Ratio Box Plot**

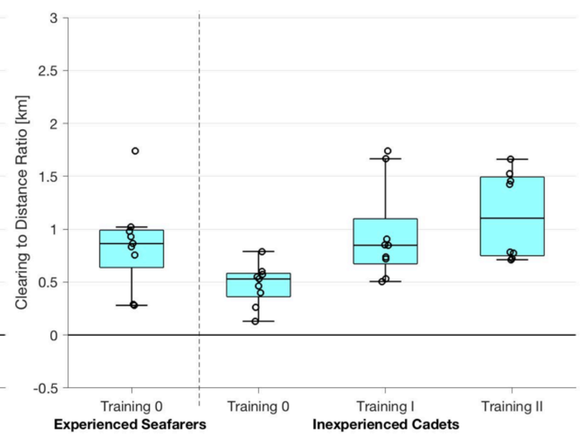



**Figure 59: Severe Ice Conditions Emergency Ice Management Scenario Clearing to Distance Ratio Box Plot**

For the emergency ice management scenario in the clearing to distance ratio performance metric, the mean results for mild and severe ice conditions show similar trends. The mean performance of the Training I group was higher than the Training 0 group (+0.36 km mild, +0.47 km severe) and the mean performance of the Training II group was marginally higher then the mean performance of the Training I group (+0.09 km mild, +0.18 km severe). The mean performance of both the Training I and Training II groups was also higher than the mean performance of the experienced seafarers (+0.09 km Training I mild, +0.18 km Training II mild, +0.09 km Training I severe, +0.27 km Training II severe). These results indicate that training once again for this metric had a positive impact on the average performance of the inexperienced cadets and that most cadets could perform better than the average experienced seafarers after just one training session. The largest impacts are seen from Training 0 to Training I. The rate of improvement in performance began to plateau from Training I to Training II. For this metric, as listed in Table 48, Training I had a medium effect on performance in mild ice conditions compared to Training 0 (0.3 < effect size < 0.5) and a large effect (effect size > 0.5) in severe ice conditions. In both ice conditions, Training II had only a small effect (0.1 < effect size < 0.3) on ice management performance compared to Training I, and training over all had a large effect (effect size > 0.5) on ice management performance.

**Table 48: Clearing to Distance Ratio Effect Size Results for the Emergency Ice Management Scenario**

| | | $n_1$ | $n_2$ | $R_1$ | $R_2$ | Effect Size |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | Training 0 + Training II | 9 | 8 | 48 | 105 | 0.77 |
| | Training 0 + Training I | 9 | 5 | 54 | 51 | 0.48 |
| | Training I + Training II | 5 | 8 | 32 | 59 | 0.12 |
| **Severe Ice Conditions** | Training 0 + Training II | 9 | 8 | 49 | 104 | 0.75 |
| | Training 0 + Training I | 9 | 9 | 56 | 115 | 0.61 |
| | Training I + Training II | 9 | 8 | 76 | 77 | 0.12 |

It should be noted that while the mean performance in mild ice conditions was higher for the Training II group than the Training I group, the median performance was not. Therefore, in Figure 59 the average performance appears higher in Training I than in Training II. As listed in Table 48, the mean rank (R) of the Training II group is higher than the mean rank of the Training I group (+2.4), indicating the Training II group had a better average performance.

For the emergency ice management scenario in the clearing to distance ratio performance metric, the standard deviation for the Training I and Training II groups in both ice conditions was higher than the standard deviation in the Training 0 group (+0.18 km Training I mild, +0.13 km Training II mild, +0.26 km Training I severe, +0.23 km Training II severe). This indicates greater variance in ice management performance after training. The standard deviation of the cadets after training was higher than the experienced seafarers (+0.17 km Training I, +0.12 km Training II) in mild ice conditions and approximately equal (+0.02 km Training I, -0.01 km Training II) in severe ice conditions.

The Kruskal-Wallis Test results for the emergency ice management scenario in the clearing to distance ratio performance metric, listed in Table 49 and Table 50, indicate a statically significant ($p < 0.025$) effect on the ice management performance because of training in both mild and severe ice conditions.

**Table 49: Clearing to Distance Ratio Kruskal-Wallis Test Results in Mild Ice Conditions for the Emergency Ice Management Scenario**

| | n | Mean Rank |
|---|---|---|
| Training 0 | 9 | 6.3 |
| Training I | 5 | 13.6 |
| Training II | 8 | 16.0 |

| Source | Degrees of Freedom | Sum of Squares | Mean Square | $\chi^2$ value | p value |
|---|---|---|---|---|---|
| **Training** | 2 | 424.3 | 212.15 | 10.06 | 0.007 |
| **Total** | 21 | 885.5 | | | |

**Table 50: Clearing to Distance Ratio Kruskal-Wallis Test Results in Severe Ice Conditions for the Emergency Ice Management Scenario**

| | n | Mean Rank |
|---|---|---|
| Training 0 | 9 | 6.7 |
| Training I | 9 | 16.2 |
| Training II | 8 | 18.1 |

| Source | Degrees of Freedom | Sum of Squares | Mean Square | $\chi^2$ value | p value |
|---|---|---|---|---|---|
| **Training** | 2 | 658.07 | 329.04 | 11.25 | 0.004 |
| **Total** | 25 | 1462.5 | | | |

### 4.1.3.4 Longest Time the Lifeboat Launch Zone is Clear

The results for the longest time the lifeboat launch zone is clear performance metric for the emergency ice management scenario are listed in Table 51 and shown in Figure 60 and Figure 61 for mild and severe ice conditions, respectively.

**Table 51: Emergency Ice Management Scenario Longest Time Lifeboat Launch Zone Clear Results**

| | | Mean (sec.) | Median (sec.) | Max (sec.) | Min (sec.) | Standard Deviation (sec.) |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | **Seafarers** | 580.00 | 580.00 | 970.00 | 210.00 | 285.35 |
| | **Training 0** | 396.67 | 230.00 | 1320.00 | 20.00 | 418.33 |
| | **Training I** | 387.67 | 315.00 | 790.00 | 210.00 | 221.28 |
| | **Training II** | 420.00 | 400.00 | 780.00 | 30.00 | 228.36 |
| **Severe Ice Conditions** | **Seafarers** | 545.56 | 490.00 | 1080.00 | 20.00 | 393.32 |
| | **Training 0** | 294.44 | 260.00 | 890.00 | 0.00 | 263.44 |
| | **Training I** | 400.00 | 390.00 | 730.00 | 60.00 | 196.79 |
| | **Training II** | 618.00 | 540.00 | 900.00 | 240.00 | 235.55 |

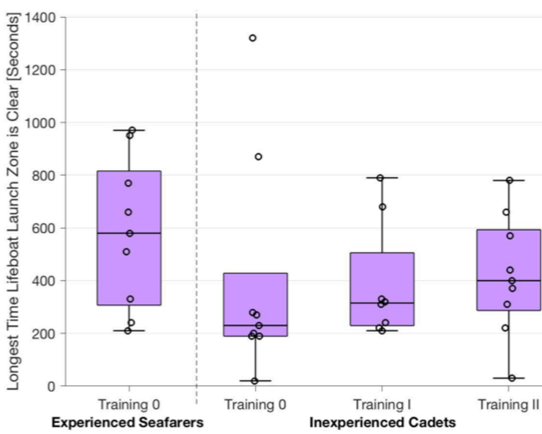



**Figure 60: Mild Ice Conditions Emergency Ice Management Scenario Longest Time Lifeboat Launch Zone Clear Box Plot**

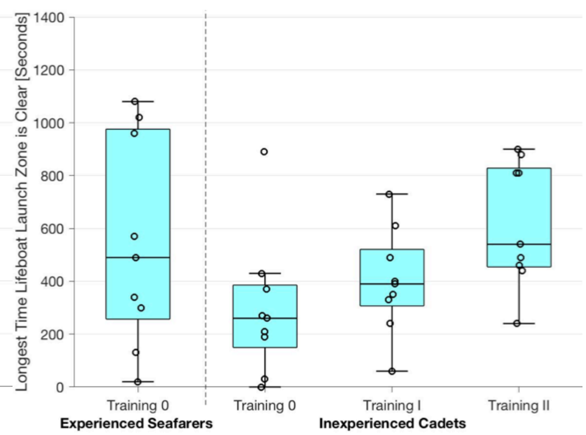



**Figure 61: Severe Ice Conditions Emergency Ice Management Scenario Longest Time Lifeboat Launch Zone Clear Box Plot**

In mild ice conditions, the mean performance of the Training I group for the emergency ice management scenario in the longest time the lifeboat launch zone is clear performance metric was approximately equal to the Training 0 group (-9 seconds) and the mean performance of the Training II group was only marginally higher than the Training I group (+32 seconds). Both training groups had a lower mean performance than the experienced seafarers (-192 seconds Training I, -160 seconds Triaging II). This indicates that there were no significant impacts from training on ice management performance in this metric for mild ice conditions. The effect sizes, listed in Table 52, confirm this, as there was a small effect (0.1 < effect size < 0.3) of training on ice management performance from Training 0 to Training II in mild ice conditions.

In severe ice conditions, the mean performance of the Training I group for the emergency ice management scenario in the longest time the lifeboat launch zone is clear performance metric was higher than the Training 0 group (+106 seconds). The mean performance of the Training II group was also higher than that of the Training I group (+219 seconds) and the experienced seafarers (+73 seconds). Similarly to the results for the average change in ice concentration performance metric for this scenario, in the more difficult severe ice conditions, training had a large positive impact on performance and it took two training sessions for the average inexperienced cadet to perform better than average experienced seafarer. The effect size for severe ice conditions, as listed in Table 52, was medium (0.3 < effect size < 0.5) from Training 0 to Training I and from Training I to Training II, but large (effect size > 0.5) overall from Training 0 to Training II.

**Table 52: Longest Time Lifeboat Launch Zone Clear Effect Size Results for the Emergency Ice Management Scenario**

| | | $n_1$ | $n_2$ | $R_1$ | $R_2$ | Effect Size |
|---|---|---|---|---|---|---|
| **Mild Ice Conditions** | Training 0 + Training II | 9 | 9 | 72 | 99 | 0.28 |
| | Training 0 + Training I | 9 | 8 | 69 | 84 | 0.28 |
| | Training I + Training II | 8 | 9 | 66 | 87 | 0.14 |
| **Severe Ice Conditions** | Training 0 + Training II | 9 | 9 | 57 | 114 | 0.59 |
| | Training 0 + Training I | 9 | 9 | 70 | 101 | 0.32 |
| | Training I + Training II | 9 | 9 | 63 | 108 | 0.47 |

The standard deviation in mild ice conditions for the emergency ice management scenario in the longest time the lifeboat launch zone is clear performance metric was lower with training compared to Training 0 (-97 seconds Training I, -190 seconds Training II). This indicates that while the mean ice management performance is not affected by training, there is a less variance in performance amongst the inexperienced cadets after training. In severe ice conditions the standard deviation decreased from Training 0 to Training I (-66 seconds) but increased from Training I to Training II (+39 seconds). This indicates no obvious relationship between variance in performance and amount of training. In both ice conditions, the standard deviation after training was less than the standard deviation of the experienced seafarers (-64 seconds Training I mild, -57 seconds Training II mild, -196 seconds Training I severe, -157 seconds Training II severe).

The results for statistical significance in the longest time the lifeboat launch zone is clear performance metric for the emergency ice management scenario, obtained from the Kruskal-Wallis Test, are shown in Table 53 and Table 54. The results indicate no statistical significance ($p > 0.025$) for this metric in mild ice conditions and statistical significance ($p < 0.025$) in severe ice conditions.

**Table 53: Longest Time Lifeboat Launch Zone Clear Kruskal-Wallis Test Results in Mild Ice Conditions for the Emergency Ice Management Scenario**

| | **n** | **Mean Rank** |
|---|---|---|
| Training 0 | 9 | 10.7 |
| Training I | 8 | 14.3 |
| Training II | 9 | 15.7 |

| **Source** | **Degrees of Freedom** | **Sum of Squares** | **Mean Square** | $\chi^2$ **value** | **p value** |
|---|---|---|---|---|---|
| **Training** | 2 | 119.00 | 59.50 | 2.04 | 0.361 |
| **Total** | 25 | 1461.00 | | | |

**Table 54: Longest Time Lifeboat Launch Zone Clear Kruskal-Wallis Test Results in Severe Ice Conditions for the Emergency Ice Management Scenario**

| | **n** | **Mean Rank** |
|---|---|---|
| Training 0 | 9 | 9.1 |
| Training I | 9 | 13.2 |
| Training II | 9 | 19.7 |

| **Source** | **Degrees of Freedom** | **Sum of Squares** | **Mean Square** | $\chi^2$ **value** | **p value** |
|---|---|---|---|---|---|
| **Training** | 2 | 509.56 | 254.78 | 8.10 | 0.018 |
| **Total** | 26 | 1636.50 | | | |

### 4.1.3.5 Total Time The Lifeboat Launch Zone is Clear

The results in both mild and severe ice conditions for the total time the lifeboat launch zone is clear performance metric for the emergency ice management scenario are listed in Table 55 and shown in Figure 62 and Figure 63.

**Table 55: Emergency Ice Management Scenario Total Time Lifeboat Launch Zone Clear Results**

| | | Mean (sec.) | Median (sec.) | Max (sec.) | Min (sec.) | Standard Deviation (sec.) |
|---|---|---|---|---|---|---|
| Mild Ice Conditions | Seafarers | 686.67 | 680.00 | 990.00 | 400.00 | 209.64 |
| | Training 0 | 585.56 | 460.00 | 1350.00 | 20.00 | 405.53 |
| | Training I | 735.00 | 710.00 | 1230.00 | 550.00 | 223.93 |
| | Training II | 546.67 | 610.00 | 840.00 | 80.00 | 218.63 |
| Severe Ice Conditions | Seafarers | 710.00 | 910.00 | 1150.00 | 20.00 | 418.27 |
| | Training 0 | 407.78 | 430.00 | 940.00 | 0.00 | 304.38 |
| | Training I | 567.78 | 550.00 | 1010.00 | 150.00 | 273.12 |
| | Training II | 743.33 | 730.00 | 1140.00 | 340.00 | 281.74 |

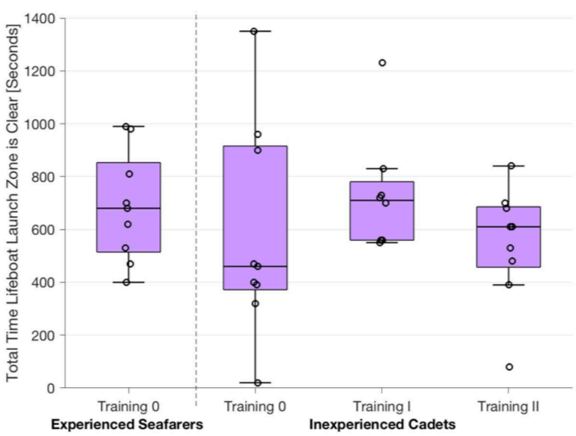



**Figure 62: Mild Ice Conditions Emergency Ice Management Scenario Total Time Lifeboat Launch Zone Clear Box Plot**

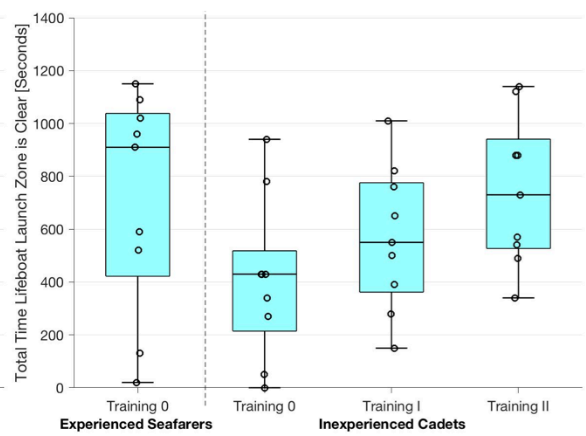



**Figure 63: Severe Ice Conditions Emergency Ice Management Scenario Total Time Lifeboat Launch Zone Clear Box Plot**

In mild ice conditions, the mean performance of the Training II group for the emergency ice management scenario in the total time the lifeboat launch zone is clear performance metric was worse than the mean performance of the Training I group (-188 seconds). The mean performance of the Training I group was better than the mean performance of the Training 0 group (+149 seconds). The mean performance of the experienced seafarers was greater than the mean performance of the Training II group (+140 seconds) and less than the mean performance of the Training I group (-48 seconds). These results indicate that, in mild ice conditions performance improved after just one training session and the average performance of the cadets after training was better than the average performance of the experienced seafarers. However, after the second training session the performance of the inexperienced cadets worsened and performance was no longer better than the experienced seafarers. The results for effect size in mild ice conditions are listed in Table 56. Training overall had no significant effects on performance (Cohen's d < 0.2) but there was a small positive effect from Training 0 to Training I (0.2 < Cohen's d < 0.5) and a large negative effect from Training I to Training II (Cohen's d > 0.8).

For severe ice conditions, the mean performance of the Training II group in the total time the lifeboat launch zone is clear performance metric for the emergency ice management scenario was better than the mean performance of the Training I group (+176 seconds) and the mean performance of the Training I group was better than the mean performance of the Training 0 group (+160 seconds). The mean performance of the Training II group was marginally better than the mean performance of the experienced seafarers (+33 seconds) and the mean performance of the Training I group was worse than the mean performance of the experienced seafarers (-142 seconds). These results indicate that, in severe ice conditions in this metric, performance improved with increasing amounts of training and after two training sessions the average inexperienced cadet could perform to the level of the average experienced seafarer. The results for effect size in severe ice conditions are listed in Table 56. There was a large overall effect (Cohen's d > 0.8) on performance due to training from Training 0 to Training II with medium effects (0.5 < Cohen's d < 0.8) from both Training 0 to Training I and Training I to Training II.

**Table 56: Total Time Lifeboat Launch Zone Clear Effect Size Results for the Emergency Ice Management Scenario**

| | | Cohen's d |
|---|---|---|
| **Mild Ice Conditions** | Training 0 + Training II | 0.13 |
| | Training 0 + Training I | 0.48 |
| | Training I +Training II | 0.91 |
| **Severe Ice Conditions** | Training 0 + Training II | 1.21 |
| | Training 0 + Training I | 0.59 |
| | Training I +Training II | 0.67 |

The standard deviation in both mild and severe ice conditions for the emergency ice management scenario in the total time the lifeboat launch zone is clear performance metric was approximately equal for the Training I and Training II groups (-5 seconds mild, +9 seconds severe). The standard deviation of the Training 0 group was higher than the Training I and Training II groups in both mild and severe ice conditions (+182 seconds Training I mild, +187 seconds Training II mild, +31 seconds Training I severe, +23 seconds Training II severe).

This indicates less variance in ice management performance after training. The standard deviation of the experienced seafarers was the lower than all of the training groups in mild ice conditions and higher than all of the training groups in severe ice conditions.

The ANOVA results for the total time lifeboat launch zone is clear performance metric for the emergency ice management scenario are listed in Table 57. The results indicate no significantly significant effects ($p > 0.05$) of training on ice management performance in this performance metric.

**Table 57: Total Time Lifeboat Launch Zone Clear ANOVA Results for the Emergency Ice Management Scenario**

| | Degrees of Freedom | Sum of Squares | Mean Square | F Value | p Value |
|---|---|---|---|---|---|
| **Training** | 2 | 272780.56 | 136390.28 | 1.59 | 0.214 |
| **Ice Conditions** | 1 | 32330.61 | 32330.61 | 0.38 | 0.542 |
| **Interaction** | 2 | 405357.44 | 202678.72 | 2.37 | 0.105 |
| **Total** | 52 | 4720724.53 | | | |

# 4.2 Ice Management Technique Analysis Results

## 4.2.1 Ice Management Methods Breakdown

### 4.2.1.1 Pushing Scenario

Table 58 lists the number of cadets in each training group who implemented each of the identified methods in the pushing scenario and the mean performance score of those who implemented each method.

**Table 58: Pushing Scenario Method Results**

| Technique | n | Average Change in Ice Concentration | | End Change in Ice Concentration | | Clearing to Distance Ratio | |
|---|---|---|---|---|---|---|---|
| | | Mean (tenths) | Standard Deviation (tenths) | Mean (tenths) | Standard Deviation (tenths) | Mean (km) | Standard Deviation (km) |
| | **Training I** | | | | | | |
| **Port Side** | 8 | 0.01 | 0.11 | 0.54 | 0.59 | 0.01 | 0.16 |
| **Top Bow** | 4 | 0.43 | 0.28 | 0.79 | 0.53 | 0.50 | 0.19 |
| **Top Side** | 2 | 0.51 | 0.21 | 2.27 | 0.31 | 0.83 | 0.29 |
| **Circle** | 1 | 0.06 | - | 0.38 | - | 0.02 | - |
| **None** | 2 | -0.16 | 0.02 | -0.54 | 0.28 | -0.29 | 0.12 |
| | **Training II First Attempt** | | | | | | |
| **Port Side** | 5 | -0.12 | 0.12 | 0.00 | 0.45 | -0.18 | 0.19 |
| **Top Bow** | 3 | 0.33 | 0.17 | 1.10 | 0.42 | 0.36 | 0.13 |
| **Top Side** | 6 | 0.63 | 0.30 | 2.03 | 0.84 | 0.89 | 0.36 |
| **Circle** | 2 | 0.61 | 0.21 | 0.85 | 0.56 | 0.59 | 0.04 |
| **None** | 2 | -0.04 | 0.03 | -0.03 | 0.08 | -0.05 | 0.04 |
| | **Training II Second Attempt** | | | | | | |
| **Port Side** | 6 | 0.33 | 0.25 | 1.38 | 0.40 | 0.41 | 0.34 |
| **Top Bow** | 6 | 0.52 | 0.35 | 1.55 | 0.89 | 0.65 | 0.46 |
| **Top Side** | 2 | 0.94 | 0.21 | 2.67 | 0.39 | 1.41 | 0.16 |
| **Circle** | 4 | 1.00 | 0.40 | 2.13 | 0.66 | 0.87 | 0.24 |
| **None** | 0 | - | - | - | - | - | - |

Clearing ice on the port side of the platform using the broadside of the ice management vessel was a commonly used technique but resulted in low mean performance scores in every metric. The cadets in the Training II group on their second attempt of the scenario implement this method more effectively than those on their first attempt of the scenario. In all the training groups in most performance metrics, the cadets who started by going across the top of the platform with the broadside of the ice management vessel had the best mean performance, but less cadets on their second attempt of the scenario used this technique than on their first attempt of the scenario. In the first and second attempt of the scenario by the Training II group, the circling method provided either the best or second best mean performance scores in most metrics and more cadets implemented this technique in their second attempt of the scenario. The cadets who used none of the identified methods did poorly in every performance metric. There were no cadets in their second attempt of the scenario that did not implement one of the identified methods.

#### 4.2.1.2 Prop Wash Scenario

The number of cadets in each training group who implemented each of the identified methods in the prop wash scenario and their mean performance in each performance metric are listed in Table 59.

For the Training II group, those who started prop washing above the zone and prop washed either straight or at an angle did poorly in every performance metric, but only one cadet used either of these techniques in their second attempt of the scenario. Only one of the cadets started at the side of the zone and prop washed straight in their first attempt of the scenario while eight cadets implemented this method in their second attempt of the scenario. This method resulted in the best mean performance in all metrics. Starting above the zone and prop washing on an angle was the most commonly used method in both training groups in the first attempt of the scenario, but this technique resulted in poor mean performance in every metric. None of the cadets chose to use this technique in their second attempt of the scenario.

**Table 59: Prop Wash Scenario Method Results**

| Technique | n | Average Change in Ice Concentration | | End Change in Ice Concentration | | Clearing to Distance Ratio | |
|---|---|---|---|---|---|---|---|
| | | Mean (tenths) | Standard Deviation (tenths) | Mean (tenths) | Standard Deviation (tenths) | Mean (km) | Standard Deviation (km) |
| | **Training I** | | | | | | |
| **Above Angle** | 6 | 0.38 | 0.27 | 2.04 | 0.96 | 0.25 | 0.23 |
| **Side Angle** | 5 | 0.75 | 0.71 | 2.86 | 1.59 | 0.56 | 0.53 |
| **Above Straight** | 5 | 0.88 | 0.49 | 3.51 | 2.15 | 0.68 | 0.41 |
| **Side Straight** | 0 | - | - | - | - | - | - |
| **None** | 1 | -0.18 | - | -0.34 | - | -0.11 | - |
| | **Training II First Attempt** | | | | | | |
| **Above Angle** | 9 | 0.48 | 0.37 | 2.68 | 1.36 | 0.36 | 0.30 |
| **Side Angle** | 6 | 0.91 | 0.76 | 2.94 | 1.77 | 0.65 | 0.56 |
| **Above Straight** | 1 | 0.01 | - | 1.42 | - | -0.01 | - |
| **Side Straight** | 1 | 2.84 | - | 6.81 | - | 2.05 | - |
| **None** | 1 | 0.75 | - | 2.24 | - | 0.34 | - |
| | **Training II Second Attempt** | | | | | | |
| **Above Angle** | 0 | - | - | - | - | - | - |
| **Side Angle** | 9 | 1.45 | 0.73 | 4.69 | 1.41 | 1.04 | 0.49 |
| **Above Straight** | 1 | 0.47 | - | 2.61 | - | 0.38 | - |
| **Side Straight** | 8 | 2.35 | 0.69 | 6.04 | 0.73 | 1.64 | 0.37 |
| **None** | 0 | - | - | - | - | - | - |

### 4.2.1.3 Leeway Scenario

Table 60 lists the number of cadets in each training group who either did not implement the leeway technique or implemented the leeway technique with either the bow or stern of the ice management vessel facing the FPSO in the leeway scenario. The mean performance in each metric is also listed.

**Table 60: Leeway Scenario Method Results**

| Technique | n | Average Change in Ice Concentration | | End Change in Ice Concentration | | Clearing to Distance Ratio | |
|---|---|---|---|---|---|---|---|
| | | Mean (tenths) | Standard Deviation (tenths) | Mean (tenths) | Standard Deviation (tenths) | Mean (km) | Standard Deviation (km) |
| | **Training I** | | | | | | |
| **Stern in** | 9 | 2.36 | 1.33 | 4.15 | 3.10 | 0.66 | 0.40 |
| **Bow in** | 3 | 2.77 | 1.20 | 5.55 | 1.62 | 0.89 | 0.37 |
| **None** | 5 | -0.07 | 0.93 | -0.64 | 1.17 | -0.07 | 0.18 |
| | **Training II First Attempt** | | | | | | |
| **Stern in** | 13 | 2.90 | 0.71 | 6.36 | 0.30 | 0.88 | 0.32 |
| **Bow in** | 3 | 2.12 | 2.54 | 3.76 | 3.48 | 0.81 | 0.94 |
| **None** | 1 | 1.66 | - | 1.54 | - | 0.40 | - |
| | **Training II Second Attempt** | | | | | | |
| **Stern in** | 11 | 3.91 | 0.46 | 6.42 | 0.14 | 1.32 | 0.20 |
| **Bow in** | 7 | 3.64 | 0.46 | 6.18 | 0.41 | 1.45 | 0.17 |
| **None** | 0 | - | - | - | - | - | - |

The cadets who did not implement the leeway technique had the worst mean performance in every metric. All of the cadets were able to implement the leeway technique in their second attempt of the scenario. In most performance metrics, there was not a large difference in mean performance between those who had their bow or stern facing the FPSO. More cadets implemented the leeway technique with the bow facing the FPSO in their second attempt of the scenario than in their first attempt of the scenario.

## 4.2.2 Ice Management Techniques

### 4.2.2.1 Precautionary Ice Management Scenario

Table 61 lists the number of cadets in each training group that used primarily either the pushing technique, leeway technique, or no distinct technique in the precautionary ice management scenario. The mean performance of the cadets who used the techniques in each performance metric is also listed.

**Table 61: Precautionary Ice Management Technique Results**

| | | Average Change in Ice Concentration | | End Change in Ice Concentration | | Clearing to Distance Ratio | |
|---|---|---|---|---|---|---|---|
| | **n** | Mean (tenths) | Stan. Dev. (tenths) | Mean (tenths) | Stan. Dev. (tenths) | Mean (km) | Stan. Dev. (km) |
| | **Mild Ice Conditions - Training I** | | | | | | |
| **Pushing** | 5 | 1.71 | 0.44 | 4.39 | 1.12 | 0.95 | 0.22 |
| **Leeway** | 2 | 1.59 | 0.18 | 4.04 | 0.08 | 1.46 | 0.14 |
| **None** | 1 | 1.62 | - | 2.96 | - | 0.45 | - |
| | **Mild Ice Conditions - Training II** | | | | | | |
| **Pushing** | 5 | 1.43 | 0.33 | 4.00 | 0.97 | 0.94 | 0.31 |
| **Leeway** | 3 | 2.00 | 0.65 | 4.37 | 0.27 | 1.79 | 0.92 |
| **None** | 1 | 1.30 | - | 2.52 | - | 0.61 | - |
| | **Severe Ice Conditions - Training I** | | | | | | |
| **Pushing** | 9 | 2.50 | 0.49 | 6.08 | 0.81 | 1.75 | 0.50 |
| **Leeway** | 0 | - | - | - | - | - | - |
| **None** | 0 | - | - | - | - | - | - |
| | **Severe Ice Conditions - Training II** | | | | | | |
| **Pushing** | 8 | 2.95 | 0.58 | 5.35 | 1.71 | 1.93 | 0.64 |
| **Leeway** | 1 | 3.54 | - | 4.56 | - | 2.73 | - |
| **None** | 0 | - | - | - | - | - | - |

In both mild and severe ice conditions for the Training I and Training II group pushing was the most commonly used technique in the precautionary ice management scenario. Twice as many cadets in the Training II group used the leeway technique, indicating that with more training the cadets were more likely to implement this technique in the precautionary ice management scenario. None of the cadets used prop wash as their primary method of ice management in this scenario. In severe ice conditions, all but one the cadets used pushing as their dominate technique and there is not enough data on the leeway technique to compare which technique is most effective in each performance metric.

In mild ice conditions, the cadets who used no distinct technique did the worst in most performance metrics, indicating that it is more effective to use a distinct technique in this scenario. In mild ice conditions, the average performance of the cadets in Training II who primarily used the leeway technique was better than average performance of the cadets who primarily used the pushing technique in every performance metric. In Training I, those who implemented the pushing technique had a better mean performance in two of the three metrics than those who implemented the leeway technique.

#### 4.2.2.2 Emergency Ice Management Scenario

Table 62 lists the number of cadets in each training group who primarily used the pushing, leeway, or no distinct technique in the emergency ice management scenario and the mean performance in every performance metric of the cadets who used each technique.

**Table 62: Emergency Ice Management Scenario Technique Results**

| | n | Average Change in Ice Concentration | | End Change in Ice Concentration | | Clearing to Distance Ratio | | Lifeboat Launch Zone | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean (tenths) | Stan. Dev. (tenths) | Mean (tenths) | Stan. Dev. (tenths) | Mean (km) | Stan. Dev. (km) | Mean (sec.) | Stan. Dev. (sec.) |
| | **Mild Ice Conditions - Training I** | | | | | | | | |
| **Pushing** | 5 | 2.35 | 1.24 | 3.14 | 2.88 | 0.61 | 0.34 | 472.00 | 245.70 |
| **Leeway** | 0 | - | - | - | - | - | - | - | - |
| **None** | 0 | - | - | - | - | - | - | - | - |
| | **Mild Ice Conditions - Training II** | | | | | | | | |
| **Pushing** | 5 | 1.96 | 0.54 | 4.00 | 1.48 | 0.56 | 0.19 | 280.00 | 163.55 |
| **Leeway** | 3 | 2.36 | 0.41 | 4.75 | 0.94 | 0.93 | 0.29 | 573.33 | 205.02 |
| **None** | 0 | - | - | - | - | - | - | - | - |
| | **Severe Ice Conditions - Training I** | | | | | | | | |
| **Pushing** | 5 | 2.73 | 0.84 | 5.19 | 3.13 | 0.95 | 0.46 | 464.00 | 200.45 |
| **Leeway** | 3 | 2.39 | 0.82 | 4.58 | 3.80 | 1.08 | 0.51 | 406.67 | 80.21 |
| **None** | 1 | 1.47 | - | 3.34 | - | 0.51 | - | 60.00 | - |
| | **Severe Ice Conditions - Training II** | | | | | | | | |
| **Pushing** | 5 | 3.17 | 0.71 | 6.12 | 3.02 | 1.03 | 0.37 | 488.00 | 205.11 |
| **Leeway** | 3 | 2.87 | 0.71 | 4.00 | 2.44 | 1.30 | 0.51 | 773.33 | 202.32 |
| **None** | 0 | - | - | - | - | - | - | - | - |

Only one cadet used no distinct technique in the emergency ice management scenario, and this provided the lowest performance score in all of the performance metrics. This indicates that using a technique resulted in a better ice management performance in all metrics. Once again for this scenario, the most commonly used technique in all training groups was the pushing technique and more cadets in the Training II group used the leeway technique than in the

Training I group. None of the cadets used prop wash as their primary method of ice management in this scenario.

In the Training I group in mild ice conditions in the emergency ice management scenario, all of the cadets used the pushing technique so it is not possible to compare which technique is most effective. For the other training groups, in the clearing to distance ratio performance metric, the leeway technique had a better mean performance than the pushing technique. For the average change in ice concentration and end change in ice concentration performance metrics, different techniques had better mean scores in different training groups. For the lifeboat launch zone performance metric, pushing had a better average performance for the Training I group but leeway had a much higher average performance in the Training II groups. For this scenario, the cadets did not do well in all performance metrics simultaneously. Overall, the leeway technique had the best performance in the most metrics, indicating it is the most effective technique in this scenario.

## 4.3 Speed Analysis

Table 63 lists the number of participants who went above both three and four knots in each scenario and the mean percent of time the participants spent above these speeds during the scenarios.

**Table 63: Speed Analysis Results**

| | | n | Number Above 3 kt | Percent of Time Above 3 kt | | Number Above 4 kt | Percent of Time Above 4 kt | |
|---|---|---|---|---|---|---|---|---|
| | | | | Mean | Stan. Dev. | | Mean | Stan. Dev. |
| Pushing Scenario | Training I | 17 | 15 | 0.10 | 0.22 | 9 | 0.07 | 0.22 |
| | Training II | 18 | 15 | 0.13 | 0.19 | 7 | 0.03 | 0.10 |
| Prop Wash Scenario | Training I | 17 | 16 | 0.09 | 0.09 | 9 | 0.02 | 0.03 |
| | Training II | 18 | 17 | 0.07 | 0.07 | 8 | 0.01 | 0.03 |
| Leeway Scenario | Training I | 17 | 14 | 0.05 | 0.08 | 6 | 0.01 | 0.02 |
| | Training II | 18 | 12 | 0.02 | 0.02 | 1 | 0.00 | 0.01 |
| Precautionary Ice Management Scenario - Mild Ice Conditions | Training I | 8 | 7 | 0.10 | 0.18 | 2 | 0.04 | 0.09 |
| | Training II | 9 | 7 | 0.04 | 0.04 | 4 | 0.01 | 0.02 |
| Precautionary Ice Management Scenario - Severe Ice Conditions | Training I | 9 | 4 | 0.02 | 0.05 | 1 | 0.00 | 0.01 |
| | Training II | 9 | 5 | 0.03 | 0.04 | 3 | 0.00 | 0.00 |
| Emergency Ice Management Scenario - Mild Ice Conditions | Training 0 | 9 | 9 | 0.23 | 0.24 | 6 | 0.07 | 0.09 |
| | Training I | 5 | 5 | 0.18 | 0.18 | 4 | 0.09 | 0.13 |
| | Training II | 8 | 5 | 0.08 | 0.10 | 3 | 0.03 | 0.06 |
| | Seafarers | 6 | 6 | 0.09 | 0.05 | 5 | 0.02 | 0.03 |
| Emergency Ice Management Scenario - Severe Ice Conditions | Training 0 | 9 | 9 | 0.10 | 0.06 | 7 | 0.02 | 0.03 |
| | Training I | 9 | 7 | 0.04 | 0.06 | 2 | 0.01 | 0.01 |
| | Training II | 8 | 7 | 0.03 | 0.04 | 3 | 0.00 | 0.01 |
| | Seafarers | 9 | 9 | 0.13 | 0.19 | 7 | 0.08 | 0.19 |

In most scenarios, the number of cadets in the Training I and Training II groups who exceeded three and four knots was within two of each other and the mean amount of time exceeding these speeds is within a few percent of each other. These results indicate that increasing amounts of training did not affect whether or not the cadets followed the POLARIS speed recommendations. In the leeway scenario, five more cadets exceeded three knots in the Training I group than the Training II group. Indicating that more cadets were able to stay relatively close to the three knot limit on their second attempt of this scenario. In mild ice conditions for both the precautionary and emergency ice management scenarios, the percent of time the Training II group spent above three and four knots was much lower than the percent of time the Training I group spent above three and four knots. This indicates that in mild ice conditions with more training the cadets were more likely to stay close to the three knot limit for more of the scenario.

In the emergency ice management scenario in severe ice conditions, fewer cadets in the Training I and Training II groups exceeded both three and four knots than in the Training 0 group and the experienced seafarers. This indicates that the cadets were more likely after training to follow the POLARIS recommendations. The cadets after training in severe ice conditions also spent a lower mean percent of time above three and four knots than the cadets without training and the experienced seafarers.

## 4.4 Rankings

The rankings of each participant for each scenario are listed in Appendix I: Ranking Tables. Table 64 lists the mean rankings for each training group in every scenario.

**Table 64: Mean Ranking Results**

| | | Average Change in Ice Concentration | End Change in Ice Concentration | Clearing to Distance Ratio | Lifeboat Launch Zone |
|---|---|---|---|---|---|
| Pushing Scenario | Training I | 12 | 12 | 12 | - |
| | Training II | 24 | 24 | 23 | |
| Prop Wash Scenario | Training I | 11 | 11 | 11 | |
| | Training II | 25 | 24 | 25 | |
| Leeway Scenario | Training I | 11 | 11 | 10 | |
| | Training II | 24 | 17 | 26 | |
| Precautionary Ice Management Scenario - Mild Ice Conditions | Training I | 10 | 10 | 9 | |
| | Training II | 8 | 8 | 9 | |
| Precautionary Ice Management Scenario - Severe Ice Conditions | Training I | 7 | 11 | 8 | |
| | Training II | 12 | 8 | 11 | |
| Emergency Ice Management Scenario - Mild Ice Conditions | Training 0 | 9 | 15 | 7 | 13 |
| | Training I | 23 | 16 | 18 | 17 |
| | Training II | 23 | 25 | 20 | 19 |
| | Seafarers | 18 | 16 | 16 | 23 |
| Emergency Ice Management Scenario - Severe Ice Conditions | Training 0 | 11 | 15 | 8 | 12 |
| | Training I | 17 | 22 | 20 | 17 |
| | Training II | 23 | 22 | 23 | 24 |
| | Seafarers | 23 | 14 | 20 | 21 |

For the training scenarios, the average ranking of the Training II group in their second attempt of the scenarios was higher than the average ranking of the Training I group in their first attempt of the scenarios in every performance metric. This indicates that training had a positive effect on the performance of the inexperienced cadets. In the pushing and prop wash scenarios for the both training groups and the leeway scenario for the Training I group, the ranking in each performance metric is within one ranking of each other. These results indicate that the cadets performed to a similar level in each performance metric.

For the Training II group in the leeway scenario, the mean ranking in the end change in ice concentration performance metric is lower because many cadets were able to clear all the ice by the end of the scenario and therefore many cadets were tied at the highest ranking.

In both mild and severe ice conditions for the precautionary ice management scenario, the rankings of the Training I and Training II groups were within five rankings of each other and relatively similar. This indicates that, as found in each performance metric, training did not have any significant effect on performance in this scenario. The average ranking in each performance metric was also approximately equal in the precautionary ice management scenario.

In the emergency ice management scenario in mild ice conditions, the average ranking of the Training I group was higher than the average ranking of the Training 0 group in every performance metric. However, in the end change in ice concentration metric it is only one ranking higher. The Training II group is zero to two rankings higher than the Training I group in three of the four performance metrics and nine rankings higher in the end change in ice concentration metric. These results indicate that in mild ice conditions in the end change in ice concentration metric training did not have a significant impact on performance until after the second training session while in every other performance metric training had a positive impact after one training session but did not improve significantly after the second training session. In the average change in ice concentration and clearing to distance ratio performance metrics, the experienced seafarers had a higher mean ranking than the Training 0 group but a lower mean ranking than the Training I and Training II groups, indicating that the average performance of the inexperienced cadets was better than the experienced seafarers after training. In the end change in ice concentration performance metric, the Training 0 group, Training I group, and experienced seafarers were within one ranking of each other and the Training II group had a much higher average ranking, indicating that after two training sessions the cadets could perform very well in this performance metric. In the lifeboat launch zone performance metric, the average ranking of the experienced seafarers was higher than each group of inexperienced cadets indicating that after training the inexperienced cadets could not perform as well as the experienced seafarers in this metric.

In the severe ice conditions version of the emergency ice management scenario, the Training I group had a significantly higher mean ranking than the Training 0 group in every performance metric. The Training II group had an equal average ranking in the end change in ice concentration performance metric and a higher average ranking in every other performance metric. These results indicate that in most performance metrics increasing amounts of training had a positive impact on performance in severe ice conditions. The Training II group had an equal or higher mean ranking than the experienced seafarers in every performance metric, indicating that in severe ice conditions the average inexperienced cadet could perform the same as the average experienced seafarer in every performance metric.

Unlike in the other scenarios, in the emergency ice management scenario the average ranking of each group in each performance metric is not the same or similar in each of the performance metrics. The individual results also show that each participant’s ranking in this scenario was not always similar in each of the performance metrics. These results indicate that in this scenario the participants did not perform to a similar level across all metrics.

# Chapter 5: Discussion

## 5.1 Training Scenarios

In all performance metrics, the cadets in the Training II group had a higher mean performance in their second attempt of the training scenarios than both the Training I and Training II groups in their first attempt of the training scenarios. For every training scenario in all performance metrics, training was found to have a statistically significant effect on ice management performance and, in most cases, the effects of training on ice management performance were large in both between and within subject comparisons. Based on these results, the hypothesis that the Training II group in their second attempt of the training scenarios would perform better in both between and within subject comparisons is found to be true.

It was not only performance at the average level of the training scenarios that improved with training. In every scenario and performance metric, the performance at the worst and third quartile levels of the Training II group on their second attempt of the scenario was better than both the Training I and Training II groups on their first attempt of the scenario. This shows that even the cadets at below average performance levels had improved performance after more training. With enough training it is likely possible to train almost all cadets to a specified target performance level.

In Experiment 1, many of the participants felt that they could perform better if they were given another opportunity to attempt the testing scenarios (Veitch, 2018b). In Experiment 2, the cadets in the Training II group were given another opportunity to attempt the training scenarios and most of them performed better in their second attempt in all performance metrics. The few cadets who did not perform better in their second attempt of the scenarios either performed only slightly worse or attempted a different method that was not as successful. The cadets who attempted an unsuccessful method in their second attempt of the training scenarios vocalized after viewing the feedback that if they were to do the scenario a third time they would not use the same method. After being given the opportunity to practice the same scenarios twice, the cadets were able to see what worked and what did not work. If they were to approach similar situations in the real world they would have a better idea of what course of action to take.

In every training scenario and performance metric, the mean performance of the Training II group in their first attempt of the scenario was better than the mean performance of the Training I group in their first attempt of the scenario. Sometimes this difference was quite significant. For example, in the leeway scenario in the end change in ice concentration performance metric, the mean performance of the Training II group in their first attempt of the scenario was 2.61 tenths higher than the mean performance of the Training I group in their first attempt of the scenario while the mean performance of the Training II group in their second attempt of the scenario was only 0.71 tenths higher than the mean performance of the Training II group in their first attempt of the scenario. The only difference between the first training session of the Training II group and the only training session of the Training I group was that the Training II group knew they would be returning for another training session and would get a second attempt of the training scenarios. Since the cadets were randomly assigned to each training group, the better performance of the Training II group in their first attempt of the training scenarios is either a coincidence, and the differences in performances between training groups would disappear if a much larger sample size was possible, or knowing that they would get a second attempt of the training scenarios lead the cadets to perform better on their first attempt of the scenarios.

In the feedback to the training scenarios, the cadets watched a sped up replay video of an experienced seafarer completing the same scenario. In the pushing scenario, the experienced seafarer used the circling method. In the prop wash scenario, the experienced seafarer started at the side of the zone and prop washed on an angle. In the leeway scenario, the experienced seafarer created a lee with the bow of the ice management vessel facing the tanker. In each of the training scenarios, more cadets in the Training II group used the same method as the experienced seafarer in their second attempt of the scenarios than their first attempt of the scenarios. This indicates that more of the cadets tried to follow the experienced seafarer patterns when approaching the scenario a second time.

For the leeway scenario, there were no examples from Experiment 1 where a seafarer created a lee with the bow of the ice management vessel facing the FPSO. Therefore, the cadets did not see an example of creating a lee in this direction until after their first attempt of the scenario and it was recommended in the training that the cadets lee with the stern of the ice management vessel facing the target vessel. After seeing an example of an experienced seafarer creating a lee with the bow of the ice management vessel facing the tanker, many of the cadets decided to switch to this method in their second attempt of the scenario.

Other than the average change in ice concentration performance metric for the pushing scenario and the clearing to distance ratio performance metric for the leeway scenario, the cadets who used the same method as the experienced seafarer did not have the highest mean performance in the training scenarios. This could be because the cadets were not able to implement the techniques as well as the experienced seafarer, or because through training the cadets were able to identify better methods for approaching the scenarios than the experienced seafarers who were not necessarily familiar with the specific scenarios used and may not have known the best approach to use.

In the pushing scenario, most cadets in the Training II group did not use the methods that resulted in the best mean performance in any metric on their second attempt of the scenario. This indicates that with more training the cadets did not make better decisions on how to approach the pushing scenario. In the prop wash scenario, all but one of the cadets in the Training II group used one of the two best methods in their second attempt of the scenario, indicating that with more training the cadets did make better decisions on how to approach the prop wash scenario. In the leeway scenario, it is not evident which of the two methods was most effective based on performance scores, but all of the cadets were able to implement one of the methods in their second attempt of the scenario.

The first learning objective of the training used in this experiment was that the cadets be able to implement the three applicable ice management techniques. All of the cadets in the Training II group implemented the three techniques in their second attempt of the training scenarios, indicating this learning objective was met. For the Training I group, most cadets met this learning objective in their first attempt of the scenarios, but there were some cadets who did not implement all of the techniques, indicating additional training was required for them to met this learning objective.

The second learning objective of the training used in this experiment was that the cadets follow the POLARIS three knot max speed recommendation. Most of the cadets went over three knots in every training scenario. The second learning objective was not met by many of the cadets after training. Many of the cadets expressed during training that it was not necessary to stay under three knots after noting in the example and feedback replay videos that the experienced seafarers went over three knots. Fewer cadets in the Training II group went over four knots in their second attempt of the scenarios indicating that the cadets were trying to stay relatively close to this recommended speed after more training. Most of the cadets did make an attempt to stay at a relatively slow speed in ice, with very few going over five knots. Some cadets expressed that they did not feel three knots was enough speed to mange the ice effectively. This was not found to be true, as the average ice management performance of the cadets who stayed below three knots was not lower than the average performance of the cadets who went above three knots in any performance metrics.

The third learning objective of the training curriculum used in Experiment 2 was to be able to keep a lifeboat launch zone clear for evacuation. The results of the emergency ice management scenario indicate that most cadets were able to meet this learning objective after training.

Most of the cadets ranked similarly in all of the performance metrics in each of the training scenarios. There was only one cadet in the pushing and prop wash scenarios who moved up or down more than one quartile amongst the different performance metrics (e.g. ranking in the first quartile in the average change in ice concentration performance metric and ranking in the third quartile in the end change in ice concentration performance metric). In the leeway scenario, rankings fluctuated more with seven cadets moving up or down more than one quartile amongst the different performance metrics. This is likely because many of the cadets performed similarly in the leeway scenario, meaning it required less difference in performance to change rankings. These results indicate that most of the time the cadets could perform to similar levels in all performance metrics in the training scenarios.

There were cadets who performed either well in every training scenario or poorly in every training scenario. However, many of the cadets ranked in different quartiles in the different scenarios. This indicates that being able to perform one of the techniques effectively is not necessarily an indicator of being able to perform another technique effectively. Some of the cadets were above average performers in one of the techniques and below average performers in others. These cadets would benefit from a training program with more time spent on the techniques they are not as good at, rather than spending the same amount of training time on each technique.

## 5.2 Precautionary Ice Management Scenario

The results of the precautionary ice management scenario did not have statistically significant effects in any of the performance metrics. Based on these findings, training was not found to have an effect on ice management performance in this scenario. The hypothesis that the cadets with more training would perform better in this scenario than the cadets with less training is not found to be true.

The effect of training on ice management performance was small or not significant in every performance metric in mild ice conditions in the precautionary ice management scenario. This could be because the cadets were already performing to a high performance level after one training session or because the scenario was too difficult for the cadets to complete even after two training sessions. With no benchmark of comparison from Experiment 1, no conclusions can be made about how going from no training to some training affected performance, or how the performance of the cadets with training compares to the experienced seafarers in this scenario. Over all, all of the cadets in both training groups felt the training adequately prepared them for the precautionary ice management scenario in mild ice conditions.

Several of the cadets who completed the precautionary ice management scenario in mild ice conditions said that one of the most challenging parts of the scenario was small floes that were either missed by ice management because of obstructed views or would drift around the ice management vessel. The researchers observed that this issue was less common in the severe ice conditions because the larger quantities of ice were more likely to clump together and could more easily be blocked by the ice management vessel or pushed out of the zone. This is one aspect of the scenario that was more difficult in mild ice conditions than in severe ice conditions.

In severe ice conditions, training had a medium positive effect on performance in the average change in ice concentration and clearing to distance ratio performance metrics, and a medium negative effect on performance in the end change in ice concentration performance metric in the precautionary ice management scenario. Figure 64 shows the mean change in ice concentration over time for the Training I and Training II groups in severe ice conditions. The Training II group was able to clear more of the ice earlier in the scenario than the Training I group, but the change in concentration came to a plateau around the twenty minute mark for the Training II group. This resulted in a greater end change in ice concentration for the Training I group compared to the Training II group. This could be because it was difficult to clear a large quantity of ice for the full thirty-minute scenario. The Training II group was able to start clearing the ice sooner but was not able to keep up with that level of ice management for the full thirty-minutes. While there was little difference in performance between training groups, all but one of the cadets felt that the training adequately prepared them for the precautionary ice management scenario in severe ice conditions.

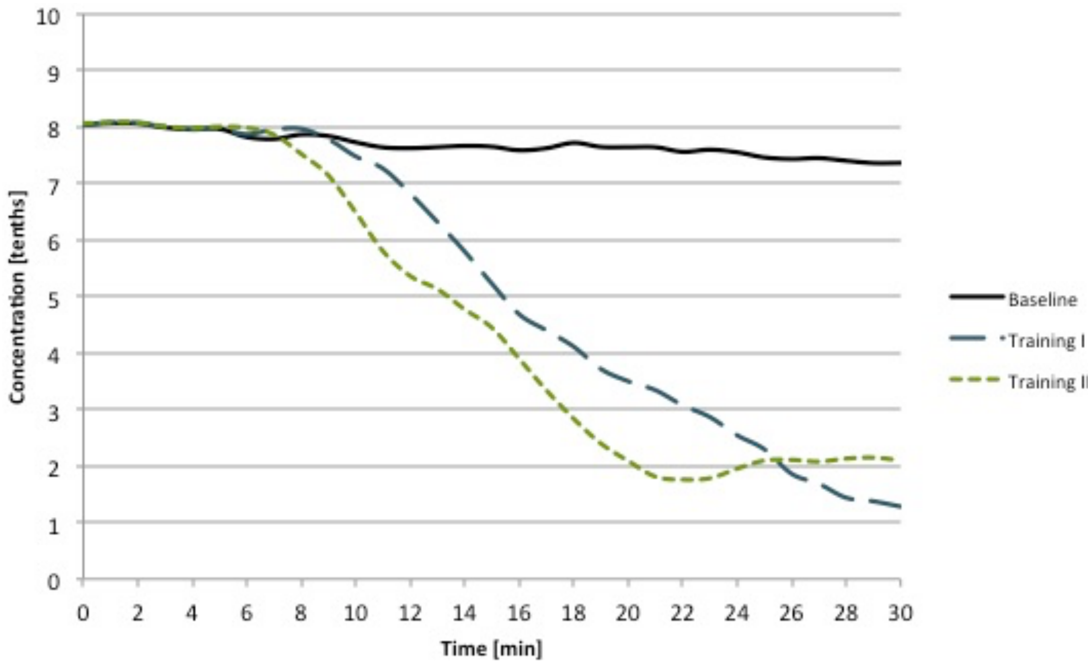



**Figure 64: Concentration Over Time Plot – Precautionary Ice Management Scenario – Severe Ice Conditions**

In every performance metric, except the end change in ice concentration metric in mild ice conditions, the standard deviation of the Training II group was higher than the standard deviation of the Training I group in the precautionary ice management scenario. This is the opposite of what was hypothesized, as the Training II group had a more variable performance than the Training I group. In most cases this variable performance was because more cadets performed better in the scenario and this is not necessarily an indication that with more training the cadets are less likely to successfully complete an ice management operation.

The mean performance of the cadets who used the leeway technique in the precautionary ice management scenario was lower than the mean performance of the cadets who used the pushing technique in Training I, but higher than the mean performance of the cadets who used the pushing technique in the Training II. These results could indicate that the leeway technique is the most effective technique for this scenario, but that the cadets needed two training sessions before they could effectively implement the leeway technique.

In mild ice conditions, the cadets in the Training II group spent a lower mean percentage of time above the three knot POLARIS speed recommendation than the Training I group. This indicates that the cadets were more likely to follow the regulation after more training in these ice conditions. In severe ice conditions, the Training II group spent a higher mean percentage of time above the three knot POLARIS speed recommendation compared to the Training I group. This indicates that the cadets were less likely to follow the regulation after more training in these ice conditions.

Overall, the precautionary ice management scenario did not provide much insight into the effects of training on ice management performance. Based on the results of the scenario no significant conclusions can be made.

## 5.3 Emergency Ice Management Scenario

The results in all performance metrics for the emergency ice management scenario indicate that training had a positive impact on the ice management performance of the inexperienced cadets. There was a large effect of training on ice management performance in all performance metrics except the lifeboat launch zone performance metric in mild ice conditions where there was only a medium effect of training on ice management performance. The positive effects of training on ice management performance were found to be statistically significant in all performance metrics except the end change in ice concentration metric. In the end change in ice concentration performance metric, the p-value was less than 10% and it is likely that the results would have been statistically significant if a larger sample size were possible. The cadets also felt the training was effective with 32/35 of them saying that the training adequately prepared them for the emergency ice management scenario.

The results of the emergency ice management scenario did not show any definitive relationship between successive training sessions and variance in the ice management performance of the inexperienced cadets. The hypothesis that the variability in performance within a group of inexperienced cadets would consistently decrease with increasing amounts of training is not found to be true. However, while the standard deviation in performance did not decrease with increasing amounts of training, the performance at the first quartile level was higher from Training 0 to Training I and from Training I to Training II in every performance metric, except the end change in ice concentration metric in mild ice conditions where the first quartile performance of the Training I group was lower than the first quartile performance of the Training 0 group. This is also true of the worst performers in each group, except for the lifeboat launch zone performance metric in mild ice conditions where the worst performance of the Training II group was lower than the worst performance of the Training I group. This shows that in almost all cases, the below average performances of the cadets consistently improved with increasing amounts of training. This indicates that while the variability amongst performance did not consistently decrease after increasing amounts of training, the uncertainty related to each cadet’s ability to successfully complete the ice management task is still reduced because the worst of this variable performance is improved.

Figure 65 and Figure 66 show the mean change in ice concentration over time for each group in the emergency ice management scenario in mild and severe ice conditions, respectively. Each group (except the Training 0 group in mild ice conditions) was able to clear the ice effectively for approximately eighteen minutes and then the change in ice concentration began to plateau and even increased in some cases. Due to the lack of effective ice management in the last twelve minutes of the scenario, the resulting end change in ice concentration was not significantly different between each training group. Neither the cadets nor the experienced seafarers were able to mange the ice effectively for the full thirty-minute scenario. This could be because they were not able to effectively implement the task for a full thirty minutes or because the amount of ice that accumulated due to the angle of the FPSO was more difficult to manage after the eighteen-minute mark.

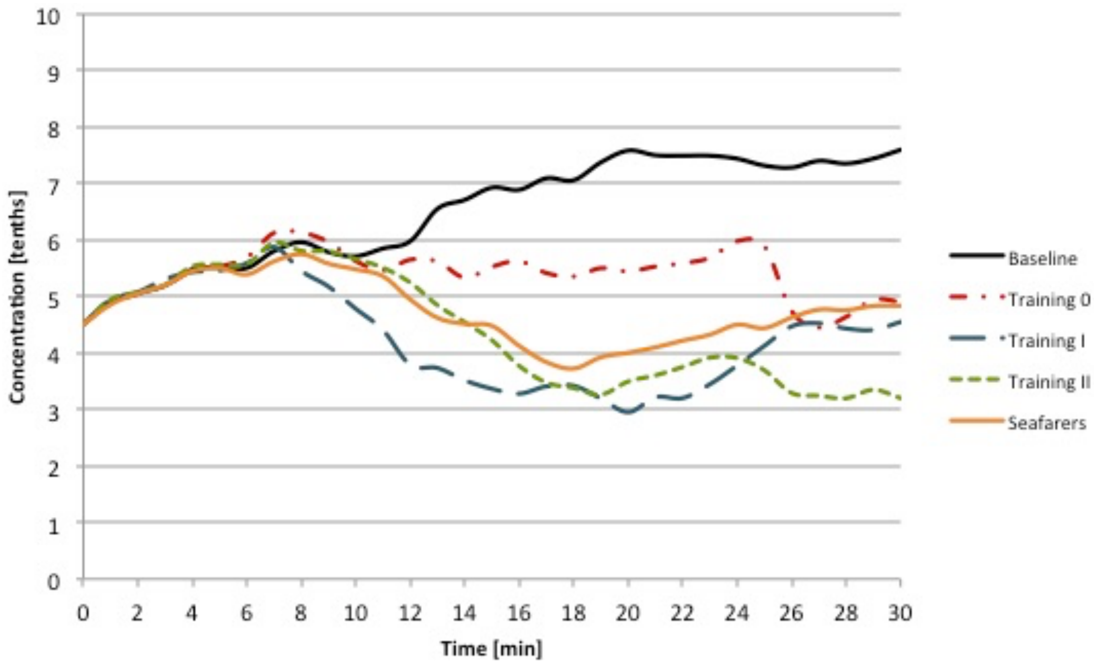



**Figure 65: Concentration Over Time Plot – Emergency Ice Management Scenario – Mild Ice Conditions**

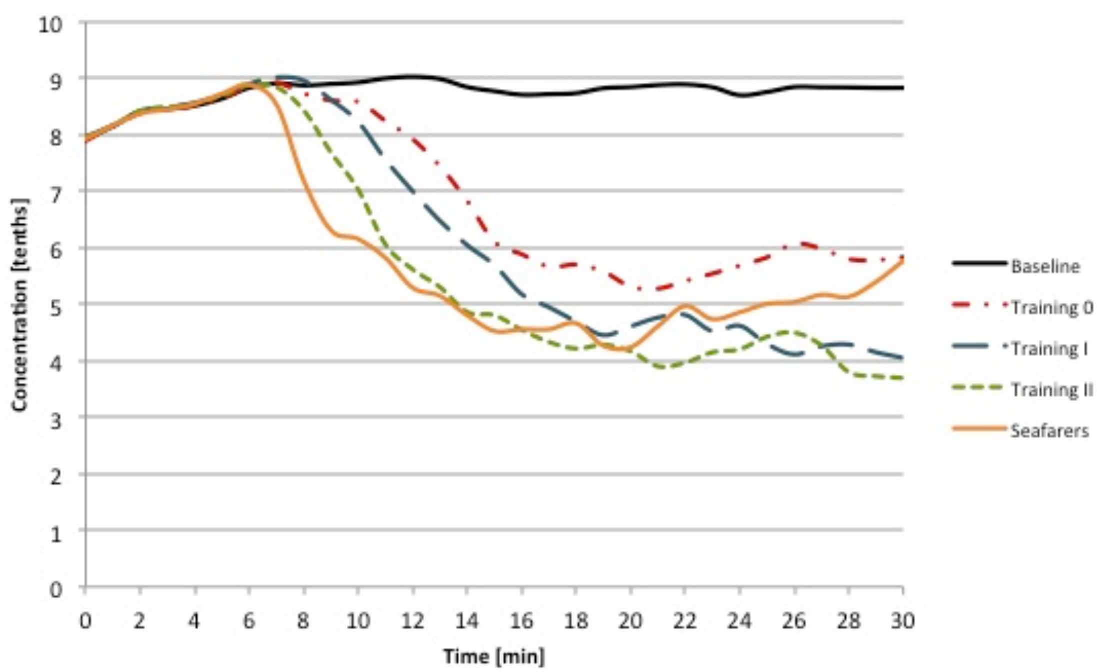



**Figure 66: Concentration Over Time Plot – Emergency Ice Management Scenario – Severe Ice Conditions**

The target performance level for the cadets after training in the emergency ice management scenario was set at the median performance of the experienced seafarers from Experiment 1. In the average change in ice concentration and clearing to distance ratio performance metrics in mild ice conditions and end change in ice concentration performance metric in severe ice conditions the median performance of the cadets in the Training I group exceeded the target performance level. The median performance of the cadets in the Training II group exceed the target performance level in these metrics as well as the end change in ice concentration performance metric in mild ice conditions and clearing to distance ratio and lifeboat launch zone performance metrics in severe ice conditions. After three hours of training, the median performance of the Training II group was below the median performance of the experienced seafarers in only the lifeboat launch zone performance metric in mild ice conditions and average change in ice concentration performance metric in severe ice conditions. In both of these performance metrics, the median performance of the cadets increased with successive amounts of training and likely would exceed the target performance level after additional training.

The mean results in severe ice conditions improved with successive amounts of training in all performance metrics in the emergency ice management scenario. These results support the hypothesis that increasing amounts of training would lead to improved ice management performance amongst the inexperienced cadets. These results can also be used to illustrate a proposed method for estimating the amount of training needed to reach a specified performance target. Figure 67 illustrates this proposed method using the average change in ice concentration performance metric. Average, above average, and below average performance is assumed to be the median, third quartile, and first quartile performance, respectively, at each amount of training. An exponential trend is created from each set of three points. These trends are used to represent the relationship between amount of training and ice management performance. As shown in Figure 67, the average performance trend is used to predict that it would take approximately 3.6 hours of training for the average inexperienced cadet to reach the target performance level in the average change in ice concentration performance metric. Furthermore, the above and below average trends are used to predict that it took about 1.9 hours of training for above average inexperienced cadets to reach the target performance level and that it would take approximately 4.5 hours of training for below average cadets to reach the target performance level.

In Figure 67, exponential curves are used to represent the relationship between amount of training and ice management performance because this type of curve fits the data better than other types of curves. It is possible that other curves could also be a reasonable representation of the data. The use of exponential curves is in line with the shape of the learning curves identified in the literature (Champney et al., 2006; Kim et al., 2013; Lee et al., 2017; Malysuz and Pem, 2014; Pusic et al., 2011). It is not expected that this exponential relationship would continue indefinitely. The three-phase curve of learning development suggests that the rate of learning would slow as the cadet's knowledge of ice management transitions from declarative to procedural. More experiments would be necessary to identify at which point this slowed rate of learning begins.

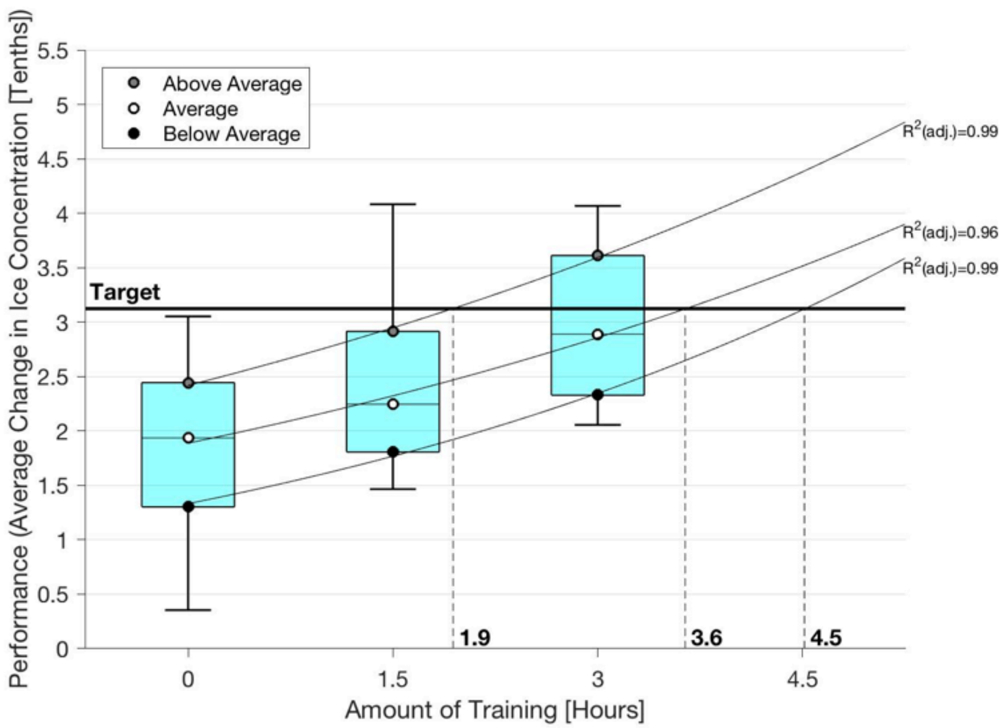



**Figure 67: Trend Plot – Average Change In Ice Concentration – Severe Ice Conditions**

This proposed method for estimating the amount of training needed to reach a target performance level in the emergency ice management scenario is repeatable in the clearing to distance ratio and lifeboat launch zone performance metrics in severe ice conditions. As shown in Figure 68, the method can be used to predict that it would approximately 1.0 hour, 1.9 hours, and 3.5 hours respectively for above average, average, and below average inexperienced cadets to reach the target performance level in the clearing to distance ratio performance metric. In the lifeboat launch zone performance metric, as shown in Figure 69, reaching the target performance level would take approximately 1.1 hours, 2.6 hours, and 3.2 hours for each performance level.

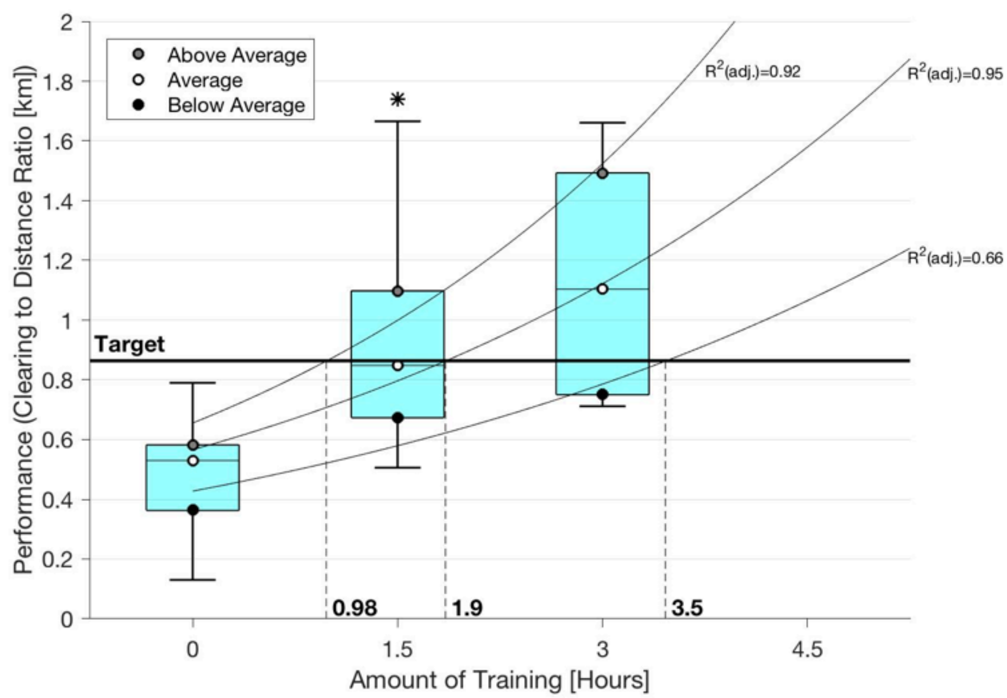



**Figure 68: Trend Plot – Clearing to Distance Ratio – Severe Ice Conditions**

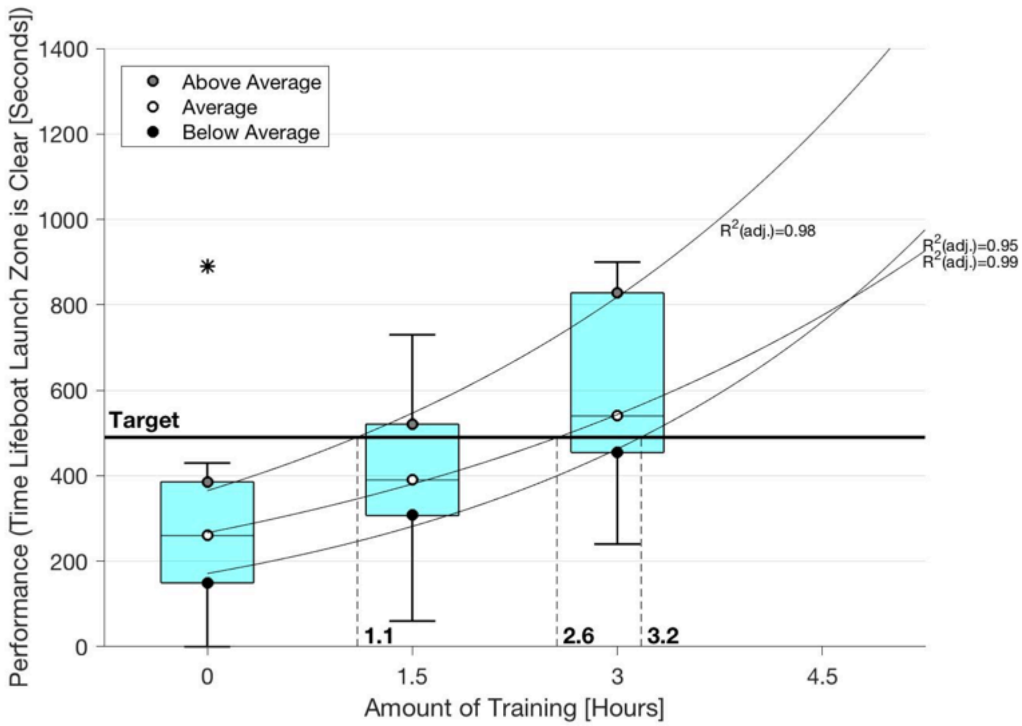



**Figure 69: Trend Plot – Lifeboat Launch Zone – Severe Ice Conditions**

As performance did not consistently increase at the average level for the emergency ice management scenario in mild ice conditions, the method of estimating the amount of training needed to reach a target performance level cannot be repeated for the average change in ice concentration or clearing to distance ratio performance metrics. However, as shown in Figure 70 and Figure 71, the exponential trend is followed at the below average level for these metrics. It is predicted to take approximately 3.1 hours and 3.6 hours of training for below average inexperienced cadets to reach the performance target in the average change in ice concentration and clearing to distance ratio performance metrics, respectively.

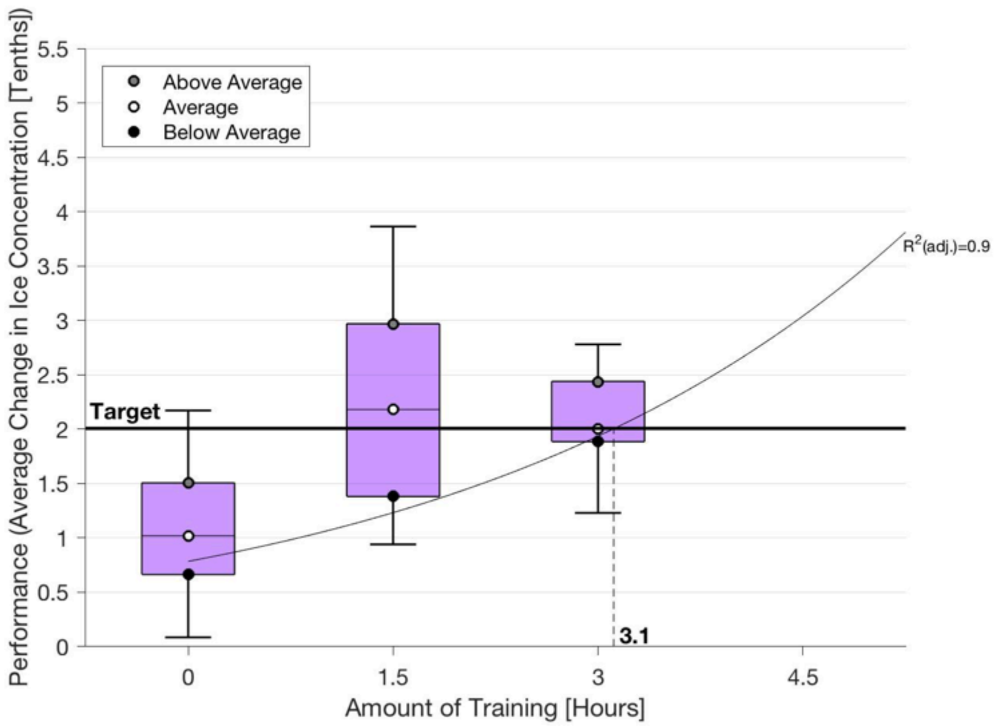



**Figure 70: Trend Plot – Average Change In Ice Concentration – Mild Ice Conditions**

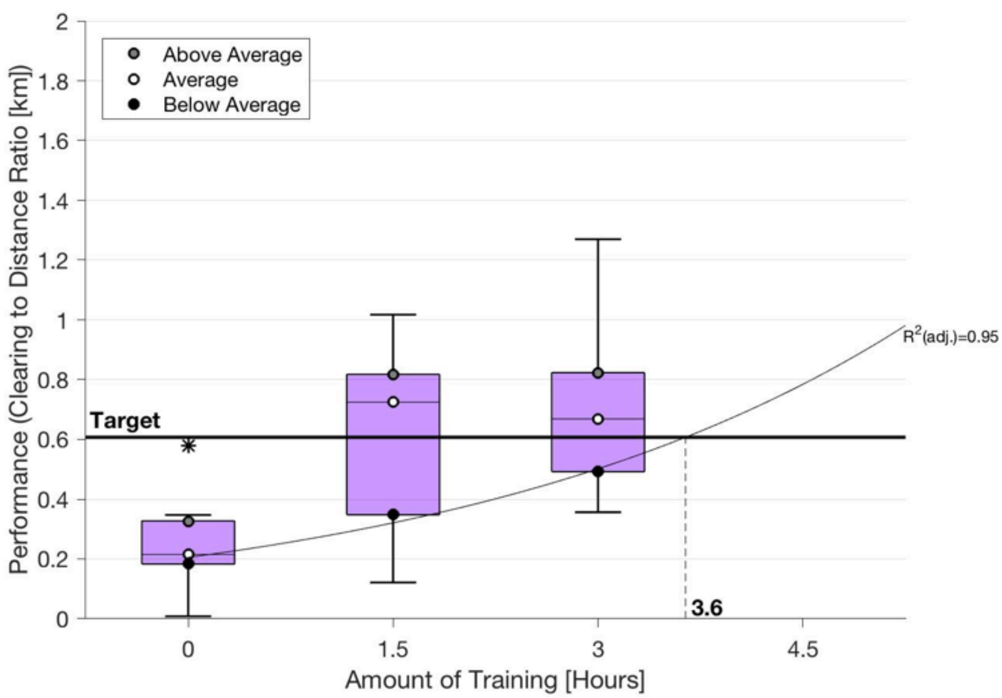



**Figure 71: Trend Plot – Clearing to Distance Ratio – Mild Ice Conditions**

In the emergency ice management scenario for the lifeboat launch zone performance metric in mild ice conditions, the method for estimating how much training is needed to reach a target performance level can be repeated. As shown in Figure 72, it is predicted to take approximately 2.8 hours, 5 hours, and 8.1 hours for the above average, average, and below average inexperienced cadet to reach the target performance level, respectively. These times are longer than those estimated in the other performance metrics. This could be a result of the training curriculum used. Feedback was given for how well the inexperienced cadets cleared a target area throughout training, but not for how long they were able to keep an area clear for lifeboat launch. After training, the cadets may have placed more of an emphasis on keeping the entire area clear rather than the specific lifeboat launch zone. This may also explain why there are outliers in the Training 0 group of the lifeboat launch zone performance metric. The two outliers in mild ice conditions who ranked 1/35 and 4/35 in the lifeboat launch zone performance metric ranked 32/35 and 34/35 in the average change in ice concentration performance metric. An updated training curriculum with more of an emphasis on keeping the lifeboat launch zone clear may result in a faster rate of performance improvement in the lifeboat launch zone performance metric.

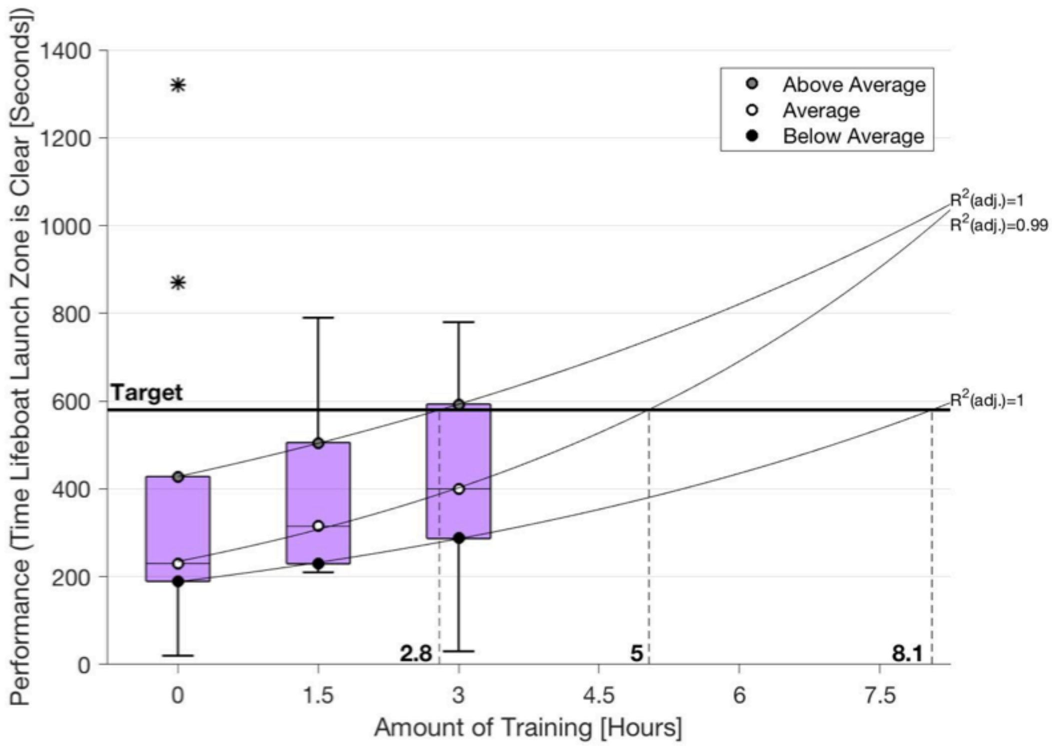



**Figure 72: Trend Plot – Lifeboat Launch Zone – Mild Ice Conditions**

The exponential curves in Figure 67 to Figure 72 are in line with what is expected in the first phase of the three-phase curve of learning development. An exponential curve is expected in the first phase of learning as trainees rapidly develop declarative knowledge on the skill. The small relative change seen between Training I and Training II for the average change in ice concentration and clearing to distance ratio performance metrics in mild ice conditions could be indicative of a slowed rate of improvement as the skill moves into the second procedural phase of the learning curve, or could be a temporary plateau in the learning curve as the cadets learn new ways to approach the complex skill.

From the results in severe ice conditions, it is predicted to take approximately 4.5 hours, equivalent to a half day of training, for 75% of inexperienced cadets to reach the same ice management performance level as the average experienced seafarer in the emergency ice management scenario in all performance metrics. In both the average change in ice concentration and clearing to distance ratio performance metrics in mild ice conditions, the average ice management performance amongst the groups of inexperienced cadets increased from Training 0 to Training I, but stayed relatively consistent from Training I to Training II. However, the mean performance of both the Training I and Training II groups in mild ice conditions was above the performance target. This indicates that after only one training session (1.5 hours of training) the average inexperienced cadet was able to perform to the target performance level in these metrics. In the end change in ice concentration performance metric in mild ice conditions, the average inexperienced cadet passed the performance target after only three hours of training. These results are clear evidence in support of the use of simulator training as a method of rapidly improving the ice management performance of inexperienced cadets.

In the mean ranking of all of the performance metrics of the emergency ice management scenario in mild ice conditions only one cadets from the Training II group is in the bottom fiftieth percentile and only one cadet from the Training 0 group is in the top fiftieth percentile. In severe ice conditions, only one cadet from the Training 0 group is in the top fiftieth percentile and only three cadets from the

Training II group are in the bottom fiftieth percentile. This indicates a positive relationship between training and ice management performance based on a combination of all performance metrics.

In the emergency ice management scenario, most of the participants did not perform to an equal ranking in all performance metrics. There was only one participant in mild ice conditions and two participants in severe ice conditions who performed in the bottom quartile in all performance metrics and only one participant in mild ice conditions and no participants in severe ice conditions who performed in the top quartile in all performance metrics. These results indicate that is difficult to perform well in all performance metrics simultaneously in this scenario. A judgment would likely need to be made on what metrics are most important when approaching similar situations in the real world. Some performance metrics are more useful than others, especially across different scenarios. In the emergency ice management scenario, the lifeboat launch zone performance metric is useful because the goal of the scenario is to allow the lifeboats to evacuate in ice-free waters. The end change in ice concentration performance metric may not be as useful in the emergency ice management scenario because the lifeboats could have evacuated before the end of the thirty-minute scenario. In the precautionary ice management scenario, the end change in ice concentration performance metric could be more useful because ice management would theoretically continue beyond the thirty-minute scenario.

The discussion of the emergency ice management scenario up until this point has focused on quantitative measurements of performance and how they are affected by training, but it is also interesting to look more specifically at how training affected *what* the inexperienced cadets did to manage the ice. Figure 73, Figure 74, Figure 75 and Figure 76 show heatmaps of the ice management vessel's position during the scenario for the Training 0 group, Training I group, Training II group, and seafarers in the emergency ice management scenario in severe ice conditions, respectively. The lighter the colour in these heatmaps, the more time the ice management vessel was at a position during the scenario. The position of the Training 0 group was spread out along the length of the FPSO with no pockets of light colour. The position of the experienced seafarers was most often on the forward half of the FPSO with a distinct concentrated area of light colour just above midships at the top of the zone that was to be kept clear in the scenario. The position of the Training I group was more concentrated around midships than the Training 0 group, but was still relatively spread out along the length of the FPSO. The position of the Training II group was even more concentrated at the area just above midships than the experienced seafarers. This is an indication that with more training, the position where the cadets chose to move the ice management vessel was focused on the target area and became increasingly similar to the position of the experienced seafarers. This indicates not only did the performance of the inexperienced cadets move towards the performance of the experienced seafarers based on the performance metrics, but the tactical choices the cadets made after training were also similar to those of the experienced seafarers. The heatmaps are not shown for mild ice conditions because the log files are not available for many of the participants and the numbers in the heatmaps would not be comparable across groups.

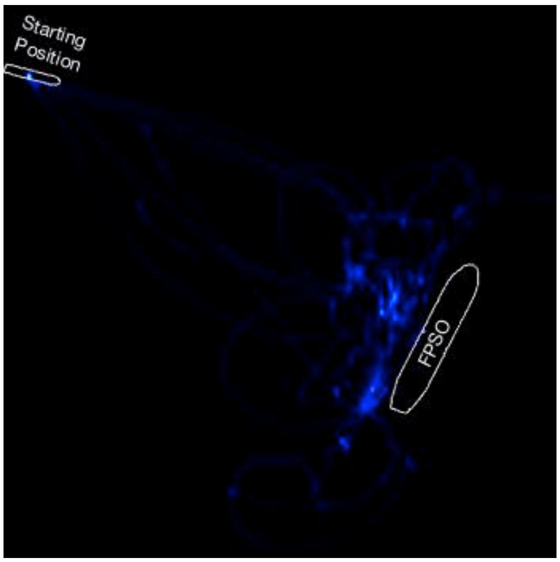



**Figure 73: Position Heatmap – Emergency Ice Management Scenario - Training 0 – Severe Ice Conditions**

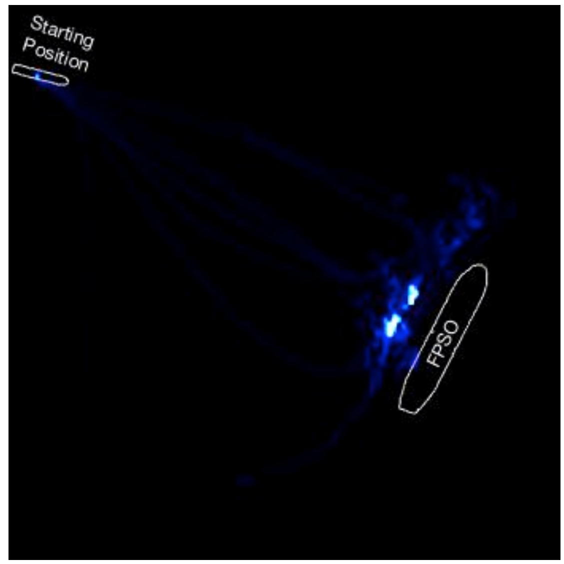



**Figure 75: Position Heatmap – Emergency Ice Management Scenario - Training II – Severe Ice Conditions**

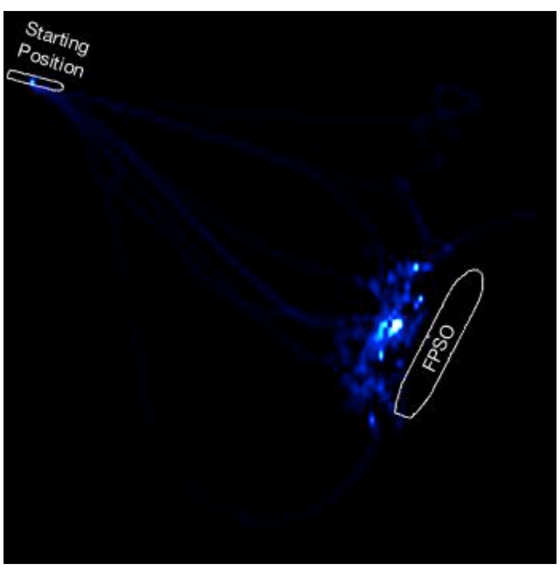



**Figure 74: Position Heatmap – Emergency Ice Management Scenario - Training I – Severe Ice Conditions**

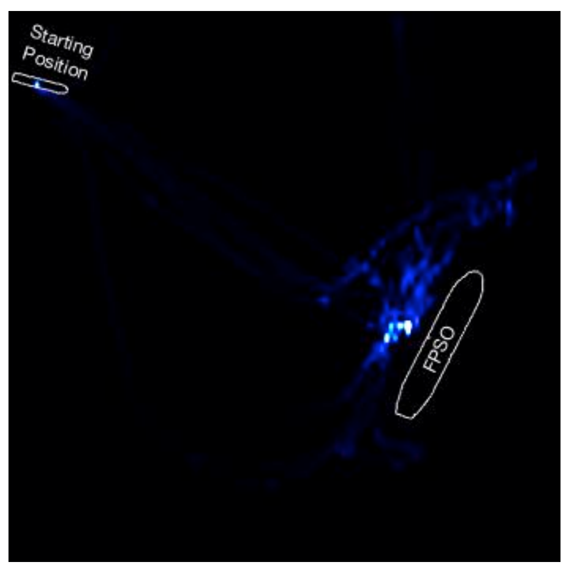



**Figure 76: Position Heatmap – Emergency Ice Management Scenario - Seafarers – Severe Ice Conditions**

The ice management techniques used by the cadets after training in the emergency ice management scenario were also similar to the techniques used by the experienced seafarers. This can be illustrated through the example of the best performers in severe ice conditions (based on an average ranking of the average change in ice concentration, clearing to distance ratio, and lifeboat launch zone performance metrics) in the seafarers, Training II, and Training 0 groups, shown in Figure 77, Figure 78, and Figure 79, respectively. The best experienced seafarer performance, which ranked 2/36, used the leeway technique with the stern of the ice management vessel facing the FPSO. This seafarer was able to keep the lifeboat launch zone and much of the target area clear while using minimal maneuvering. The best cadet in the Training II group ranked 1/36 in this scenario. This cadet also used the leeway technique with the stern of the ice management vessel facing the FPSO and the position of the vessel throughout the scenario is similar to that of the best experienced seafarer. The cadet with training was able to keep more of the target area clear than the experienced seafarer and was therefore higher in the average ranking. The best performance of a cadet with no training ranked 15/36. This cadet was able to do better than average in this scenario by primarily implementing the prop wash technique. However, the cadet with no training was not able to keep the lifeboat launch zone clear as effectively as the experienced seafarer or trained cadet. The cadet with no training also used more maneuvering using the prop wash technique than is required for the leeway technique. As shown in Figure 77 and

Figure 79, the position of the cadet with no training was not similar to that of the position of the best experienced seafarer.

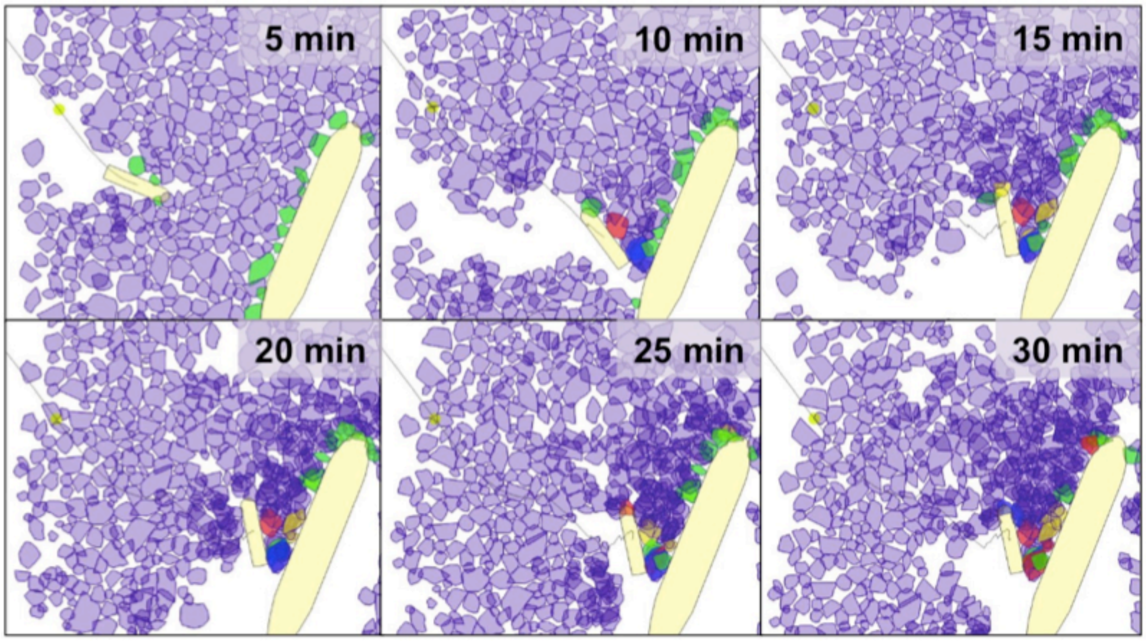



**Figure 77: Best Seafarer Performance in Severe Ice Conditions**

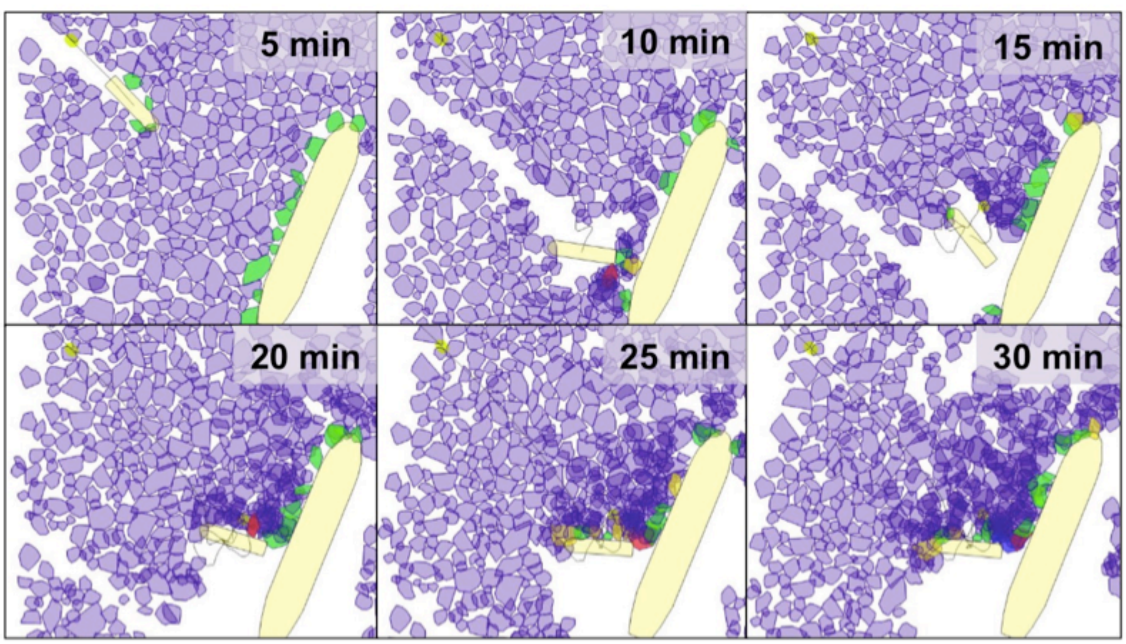



**Figure 78: Best Training II Performance in Severe Ice Conditions**

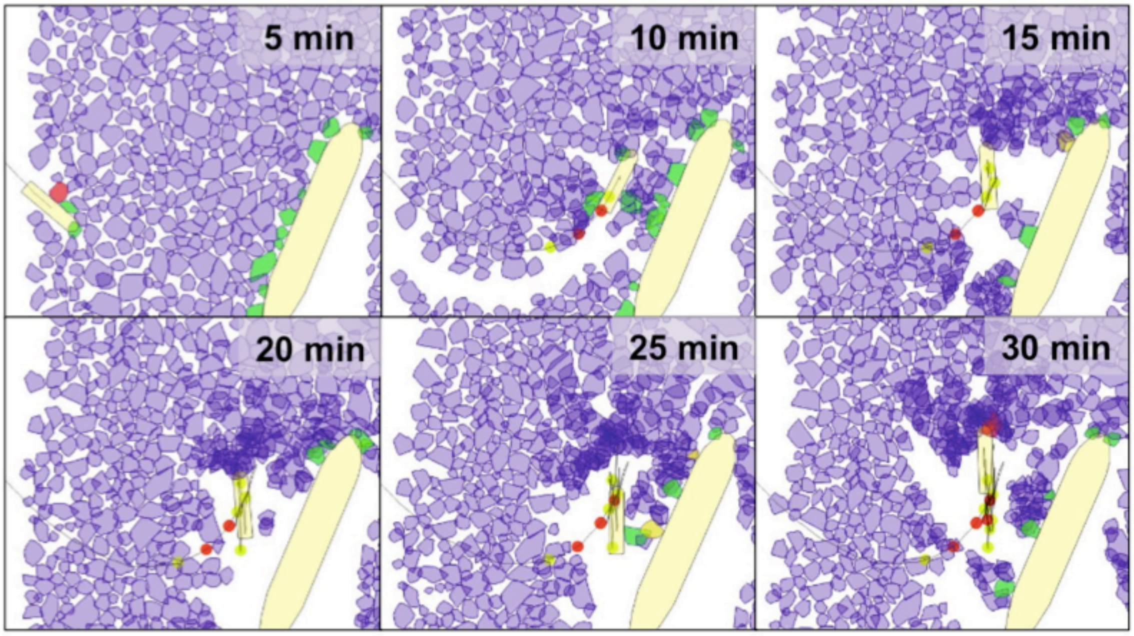



**Figure 79: Best Training 0 Performance in Severe Ice Conditions**

Examining the ice management techniques used during the emergency ice management scenario, the leeway technique was found to be the most effective technique for managing ice in this scenario and the cadets with more training were more likely to use the leeway technique. This is an indicator of improved decision making when managing ice after more training. The cadets were also more likely to effectively implement an ice management technique after training, with all of the cadets in the Training II group and all but one of the cadets in the Training I group implementing a distinct technique in this scenario. Using an ice management technique resulted in better ice management performance in all metrics.

In the emergency ice management scenario in severe ice conditions, the cadets with training spent a lower mean percentage of the time during the scenario above the three knot POLARIS recommended speed than both the seafarers and the cadets with no training. Additionally, a lower percentage of the cadets after training exceeded four knots than the seafarers or cadets with no training. In mild ice conditions the cadets with training spent a lower mean percentage of the time during the scenario above three knots than the cadets with no training and the Training II group spent a lower mean percentage of the time during the scenario above three knots than the seafarers. Furthermore, a lower percentage of the cadets after training exceeded four knots in mild ice conditions than the seafarers or cadets with no training. This is an indicator that after training the cadets were able to follow the regulations and reduce the risk of high ice loads more effectively than both the cadets with no training and the experience seafarers in the emergency ice management scenario.

# Chapter 6: Conclusions

## 6.1 Conclusions

This research provides practical insights into the relationship between training and the ice management performance of inexperienced cadets. For the emergency ice management scenario in most performance metrics, the results support the hypothesis that increasing amounts of training improved the average ice management performance of inexperienced cadets in a bridge simulator. Based on the results in all performance metrics, it is concluded that training overall had a positive effect on the ice management performance of the inexperienced cadets.

It was hypothesized that in the emergency ice management scenario, increasing amounts of training would reduce the variability in performance amongst the inexperienced cadets. Since the results demonstrated no definitive relationship between increasing amounts of training and variability in ice management performance, this hypothesis is rejected. However, as in most cases the below average and worst performance did improve with successive training sessions, the results indicate that the uncertainty associated with a cadet's ability to successfully complete an ice management operation is reduced after training.

As hypothesized, the relationship between amount of training and ice management performance in the emergency ice management scenario provided a method of estimating the amount of training an inexperienced cadet may need to reach a specified performance target. This method could be a valuable tool for estimating the amount of training needed to reach competency not only in ice management, but also for other skills in the marine industry and elsewhere.

For the precautionary ice management scenario, the results did not show any significant differences between the average performances or the variability in performances of the inexperienced cadets in each training group. Based on this it is concluded that increasing amounts of training had no effect on ice management performance of the cadets in this scenario. Since there is no baseline of inexperienced cadets with no training for the precautionary ice management scenario, no conclusions can be made about whether or not training overall had an effect on ice management performance of the inexperienced cadets in this scenario.

As hypothesized, it is concluded that having more training and repeating the simulator scenarios had a positive effect on the performance of the cadets in the training scenarios comparing the results both within and between subjects.

## 6.2 Possible Future Work and Applications

This research offers valuable insights into the relationship between amount of training and ice management performance. This could be used to inform future ice management training requirements in accordance with the IMO Polar Code.

The proposed method of estimating the amount of training needed to reach a specified performance target could also be applied to other areas of maritime training, or elsewhere, to ensure all trainees can perform to an expected performance level. This would help to estimate the effectiveness of a particular training curriculum, increase the likelihood of a successful operation after training, and reduce the amount of time that those who can already successfully complete a task need to spend in training. This method also offers a way to capture expertise and teach it to novices in a relatively short time frame.

Future research that could build on these results and provide further insights into the relationship between training and ice management performance could include: studying the effects of time on performance loss after training (i.e. skill retention), studying the effects of training on the performance of non-novice seafarers in an ice management bridge simulator, and comparing the effects of different ice management vessels or propulsion systems to the effects of training on ice management performance.

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# Appendices

## Appendix A: Informed Consent Form

**Informed Consent Form**

Title: Evaluation of the effects of simulator training on ice management performance

**Researcher:**
Rebecca Thistle
Principal Investigator
Faculty of Engineering and Applied Science
Memorial University of Newfoundland
[redacted]

**Supervisor:**
Brian Veitch
Supervisor
Faculty of Engineering and Applied Science
Memorial University of Newfoundland
[redacted]

You are invited to take part in a research project entitled *"Evaluation of the effects of simulator training on ice management."*

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. In order to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, *Rebecca Thistle*, if you have any questions about the study or would like more information before you consent.

It is entirely up to you to decide whether to take part in this research. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

**Introduction:**
I am Rebecca Thistle, a Masters Student in the Faculty of Engineering and Applied Science's Department of Ocean and Naval Architectural Engineering at Memorial University of Newfoundland in St. John's. As part of my Masters thesis I am conducting research under the supervision of Dr. Brian Veitch. The research is being conducted as a part of the Safety at Sea project, funded by Husky Energy, Natural Sciences and Engineering Research Council (NSERC), and Virtual Marine.

**Purpose of Study:**
In a previous study we tested experienced seafarers and cadets in the ice management simulator and found that on average the experienced seafarers performed better than the cadets. Now, in this study, we are trying to see if simulator training can be used to improve the average performance of cadets so that their performance level is closer to that of experienced seafarers. We are also trying to estimate how much simulator training would be needed for cadets to reach a particular level of performance. This research may be used to inform future training requirements for ice management. It is also intended to help confirm the use of ice management simulators as an affective method for training.

1

### What You Will Do in this Study:

If you volunteer for this study you will be randomly assigned one of two groups. Group one will be asked to attend one session while group two will be asked to attend two sessions. All sessions will take place at the Ice Management Simulator on the MUN campus. This simulator consists of a simple ship's bridge console surrounded by a 360-degree panoramic projection screen.

If you are assigned to group one you will be asked to complete the *Pre-read* before attending your session. Then, during the session you will complete the *Starting Interview, Habituation, Training A,* and *Testing.*

If you are assigned to group two you will be asked to complete the *Pre-read* before attending your first session. During your first session you will complete the *Starting Interview*, *Habituation*, and *Training A*. During your second session you will complete *Training B* and *Testing*.

*Pre-read:*

This material is designed to be brief and is meant to give you some background information on the topics that will be covered in the training.

*Starting Interview:*

You will be given an explanation of the experimental design and given an opportunity to ask questions or express concerns. If satisfied, you will indicate your free and informed consent by completing this Informed Consent Form. You will then be asked to complete a questionnaire that collects some information about you and your experience at sea. You will also be asked to complete a simulator sickness questionnaire. The intention of this questionnaire is to monitor you during your time in the simulator of simulator-induced sickness and stop the trails if you begin to experience moderate to severe symptoms. This first filling out of the questionnaire will be used to get a base line of your symptoms in order to monitor how you are feeling change over your time in the simulator.

*Habituation:*

Your first three scenarios in the simulator will be "habituation" scenarios. These will give you an opportunity to familiarize yourself with the controls of the simulator. These three scenarios will take you about thirty minutes to complete in total. Data will not be recorded during the habituation scenarios. After completing all the habituation scenarios you will be asked to fill out another simulator sickness questionnaire.

*Training A:*

Training A will consist of two hours of ice management training. This training is separated into three forty-minute sections. In each of these sections you will get: fifteen minutes of introduction to an ice management technique followed by twenty minutes of simulator time to practice this technique and five minutes of feedback on your performance during this practice. Data will be recorded during the practice scenarios. After each of the three practice sections you will be asked to fill out another simulator sickness questionnaire.

*Training B:*
The second session will start with another two hours of training. This training will once again be separated into three forty minute sections. In each of these sections you will get: fifteen minutes of feedback on your performance of that technique from last session which will include opportunity to watch a top down view of your practice scenario from last session, twenty minutes to practice the technique in the simulator, and another five minutes of feedback. Once again data will be recorded during the practice scenarios and you will be asked to fill out another simulator sickness questionnaire after each practice scenario.

*Testing:*
This study involves two test scenarios. Before starting these scenarios you will be given detailed instructions about the scenario mission and will be able to ask questions. The tests will not begin until you are ready. Data will be recorded during the testing scenarios. After each of the test scenarios you will be asked to complete another simulator sickness questionnaire. In total the testing should take about seventy minutes. After each test scenario you will be given a short exit interview. The intention of this interview is to ask you about your experience in the simulator and about the way you operated the virtual ship.

**Length of Time:**
You will be asked to attend one or two sessions. This will be coordinated beforehand so that you will know before you come in for your first session if your will be expected to come in for a second session. If you are only asked to come in for one session the total time of the session is expected to be approximately four hours. This time may vary from person to person. If you are asked to come in for two sessions, the first session is expected to be approximately three hours and the second session is expected to be approximately three and a half hours. Again, the times for these session may vary from person to person. These sessions will be scheduled so that you come in for your second session within three days of your first session.

**Withdrawal from the Study:**
You can withdraw from this study at any point during your participation without giving any reason, and all data collected up until that point will be destroyed. There are no consequences for withdrawal from the study. If you choose to withdraw from the study after your participation, your data can be removed from the study up to two weeks after the completion of your participation. To withdraw from the study just inform the principal investigator, *Rebecca Thistle*.

**Possible Benefits:**
Through participation in this study you will be receiving training using an ice management simulator. This training is not certified by any authority and is designed within the confines of an experiment. While this training may be perceived as a benefit it is important to remember the limitations of this training before applying the concepts learned outside of the study.

The outcomes of this research are intended to support safety through improvement of training of maritime and offshore industry personnel. The scientific community may also benefit through advancing knowledge in the areas of training and ice management performance.

**Possible Risks:**
Navigation through the virtual space, using the marine simulator may cause some individuals to experience symptoms of Visually Induced Motion Sickness (VIMS) or Simulator-Induced Sickness (SIS). Symptoms can include: fatigue, headache, eye strain, difficulty focusing, increased salivation, sweating, nausea, stomach awareness, blurred vision, dizziness, vertigo and burping. The symptoms can sometimes occur during, immediately after or several hours after exposure to the simulator.

To make sure you do not experience severe symptoms, your susceptibility to simulator sickness will be assessed before the study and you will be monitored throughout the study using a Simulator Sickness Questionnaire. You will also be provided with a habituation session to make sure that you are adjusted to using the simulator before starting the training and testing scenarios. To reduce the effects of simulator-induced sickness, your exposure time to the marine simulator will be limited to a maximum of 30 minutes per scenario with breaks and refreshments in between scenarios to allow you to rest. You will be requested to refrain from consuming alcohol or recreational drugs 24 hours prior to use of the marine simulator.

The researchers will monitor you during the trials for symptoms and stop the trials if you start to experience severe symptoms. The simulator sickness questionnaire allows you to rate the severity of your symptoms as no symptoms, minimal, moderate and severe. This questionnaire will be given to you after each scenario in the marine simulator. If you report a symptom as moderate, then the trials will be paused and you will be given an extended rest period to allow your symptoms to subside. You can decide whether or not you want to continue the trials after the rest period. If you report a symptom as severe, the trials will be stopped and you will be provided with a rest period until your symptoms have subsided. You will be informed that it may be unsafe to drive a vehicle if symptoms persist after the rest period. If your symptoms persist (beyond 20 minutes), you will be excluded from participating in the rest of the study and arrangements will be made to make sure you get home safely. Symptoms must subside before you are able to leave the experimental laboratory.

Your performance in the simulator will be assessed throughout the study. For some individuals, this may cause performance anxiety or stress. This anxiety or stress may be caused by poor performance in the scenarios, by the difficulty or novelty of the task, or by repeated testing and feedback. To reduce the likelihood of anxiety and stress, where possible, the research team will guide you through the testing scenarios of the study. You will receive a break between scenarios to rest and you will be instructed not to worry or dwell on the previous scenarios.

Some participants may experience embarrassment for any of the following reasons:

- if they do not perform to their expectations during the test scenarios;

- if they become sick (e.g. experience simulator sickness) and want to end their participation.

To reduce the likelihood of embarrassment, you will perform the task individually and you will be reminded that your performance in the simulator will be anonymous. You will also be reminded that if you are having difficulties during the scenarios that your performance information is very important because it will help improve the training effectiveness of the technology. If at any time you experience symptoms or discomfort which prevent you from continuing in this study you retain the right to withdraw from the study.

Because the researcher is recording information related to the performance of certain tasks, some participants may perceive that the researcher is in a position of power since they could conceivable report back to participants' instructors. To remove this position of power, as a participant you are reminded that your participation is voluntary and that data collected will remain confidential. Measures are taken to keep you information anonymous, meaning your name or any distinguishable identifiers will never be reported. Your instructors will not be informed of your participation or performance in this study.

**Confidentiality:**
The ethical duty of confidentiality includes safeguarding participants' identities, personal information, and data from unauthorized access, use, or disclosure. Protecting your privacy and maintaining confidentiality is an important to the research team. The information gathered will be seen solely by the researchers involved in this study and will be used solely for research purposes.

**Anonymity:**
Anonymity refers to protecting participants' identifying characteristics, such as name or description of physical appearance. Protecting your privacy is an important goal for the research team and this means ensuring all personal data recorded during participation remains anonymous. Every reasonable effort will be made to assure your anonymity. You will not be identified in publications. For example, this study will use a number to identify you, not your name. Only the principal investigator will be able to link this number to your name. Measures have been taken to remove any other possible identifiers other than your name, like number of years of experience onboard a specific type of vessel, for instance. You will not be video or audio recorded in this study.

**Recording of Data:**
As part of this study, we will be collecting various types of data. This data will include your: date of birth, gender, work and study experience, performance metrics in the simulator, and subjective assessments (questionnaire responses). Performance metrics will be recorded electronically during your simulation activities. This includes: route selection, extent of sea ice cleared from the defined area and replay of a top down view of the vessel and ice distribution during the scenarios. Afterwards, you will also be asked to fill out a questionnaire reporting symptoms of simulator sickness, followed by a brief interview about your experience in the simulator.

**Use, Access, Ownership, and Storage of Data:**
The research team will collect and use only the information they need for this research study. Your name and contact information will be kept in a locked office on a password protected PC by the research team at MUN. It will not be shared with others without your permission. You will receive an alphanumeric participant code. All information collected from you will be recorded with the participant code and you will not be identifiable in the documentation and data. Your name will not appear in any report or article published as a result of this study.

Information collected and used by the research team will be stored by the principal investigator, Rebecca Thistle, and she is the person responsible for keeping it secure. A hardcopy of your questionnaire responses will be kept in a filing cabinet in a locked office accessible by the research team. This data will have no identifiable information and will be kept separate from your signed consent form. Electronic data recorded in this study will be kept in a password-protected file on a hard drive accessible only by the research team. This data will not have any identifiable information. Data will be kept for a minimum of five years, as required by Memorial University's policy on Integrity in Scholarly Research. After five years, all electronic records of your participation will be permanently deleted and all paper files will be appropriately destroyed.

Data collected in this study will be documented in an Ocean Engineering Research Center (OERC) report. This will make the data accessible to other researchers but not the general public. This report will not include any of your identifiable information.

**Reporting of Results:**
The research team intends to publish the findings of this study in peer reviewed journals and academic conferences. Formal reports will be made available to the funding representatives (Husky Energy, NSERC, and Virtual Marine). Upon completion, my Master's thesis will be available at Memorial University's Queen Elizabeth II library, and can be accessed online at: http://collections.mun.ca/cdm/search/collection/theses. The data will be reported in a summarized statistical and descriptive form. Individual information or data will not be reported without your exclusive written consent.

**Sharing of Results with Participants:**
When data analysis is completed a report will be prepared and participants who wish to be informed of the results will have the opportunity to receive a copy of this report. The results will also be reported in my Master's thesis, which be available at Memorial University's Queen Elizabeth II library, and can be accessed online at: http://collections.mun.ca/cdm/search/collection/theses.

**Questions:**
You are welcome to ask questions before, during, or after your participation in this research. If you would like more information about this study, please contact: Rebecca Thistle [redacted] or Brian Veitch [redacted].

MEMORIAL UNIVERSITY

**ICEHR Approval Statement:**
The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at [redacted] or by telephone at [redacted].

**Consent:**
Your signature on this form means that:

- You have read the information about the research.
- You have been able to ask questions about this study.
- You are satisfied with the answers to all your questions.
- You understand what the study is about and what you will be doing.
- You understand that you are free to withdraw participation in the study without having to give a reason, and that doing so will not affect you now or in the future.
- You understand that if you choose to end participation during data collection, any data collected from you up to that point will be destroyed.
- You understand that if you choose to withdraw after data collection has ended, your data can be removed from the study up to two weeks after your participation.

By signing this form, you do not give up your legal rights and do not release the researchers from their professional responsibilities.

**Your Signature Confirms:**

☐ I have read what this study is about and understood the risks and benefits. I have had adequate time to think about this and had the opportunity to ask questions and my questions have been answered.

☐ I agree to participate in the research project understanding the risks and contributions of my participation, that my participation is voluntary, and that I may end my participation.

☐ A copy of this Informed Consent Form has been given to me for my records.

______________________________ ______________________________

Signature of Participant Date

**Researcher's Signature:**
I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

______________________________ ______________________________

Signature of Principal Investigator Date

# Appendix B: Simulator Sickness Questionnaire

## Simulator Sickness Questionnaire

Please indicate the severity of symptoms that apply to you right now. Also note that there is no obligation to answer any or all questions if you do not wish to do so, but you must answer all questions in order to continue the study. There are no consequences for withdrawal from the study.

| Symptom | 0<br>No symptom | 1<br>Minimal | 2<br>Moderate | 3<br>Severe |
|---|---|---|---|---|
| General Discomfort | | | | |
| Fatigue | | | | |
| Headache | | | | |
| Eyestrain | | | | |
| Difficulty Focusing | | | | |
| Increased Salivation | | | | |
| Sweating | | | | |
| Nausea | | | | |
| Difficulty Concentrating | | | | |
| Fullness of head | | | | |
| Blurred Vision | | | | |
| Dizzy (eyes open) | | | | |
| Dizzy (eyes closed) | | | | |
| Vertigo | | | | |
| Stomach Awareness | | | | |
| Burping | | | | |

Kennedy, R. S., Lane, N. E., Berebaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology*, 3(3), 203-220.

## Appendix C: Experience Questionnaire

# Experience Questionnaire

Please answer the following questions but feel free to omit any that you do not wish to answer. If something is unclear, ask the experiment coordinator. Your answers are confidential and anonymous.

| Question | Answer |
|---|---|
| 1. What is your year of birth? | ___________________________ |
| 2. What is your gender? | ☐ Male<br>☐ Female<br>☐ Non-binary<br>☐ Prefer not to say<br>Self-identify: ____________________ |
| 3. In what year of study to become a seafarer are you enrolled? | ☐ 1st year<br>☐ 2nd year<br>☐ 3rd year<br>☐ 4th year<br>☐ Over 4th year |
| 4. Approximately how many months experience do you have at sea? | ___________________________ |
| 5. On what types of vessels have you operated? (Select all that apply) | ☐ Offshore supply vessel (OSV) or Anchor handling tug supply (AHTS) vessel<br>☐ Icebreaker<br>☐ Tanker / Bulk / Cargo<br>☐ Ferry / Coastal<br>☐ I have not spent time at sea |
| 6. Have you ever operated in sea ice? | ☐ Yes<br>☐ No |
| 7. What types of operations did you perform while in ice? (Select all that apply) | ☐ Watchkeeping during transit<br>☐ Maneuvering ship while being escorted<br>☐ Maneuvering ship to escort another vessel<br>☐ Ice management (open water)<br>☐ Ice management (confined water)<br>☐ Towing or emergency response<br>☐ I have only observed operations in ice<br>☐ I have not operated in ice |

| | |
|---|---|
| 8. Where have you obtained your experience in operating in ice? (Select all that apply) | ☐ Great lakes<br>☐ Gulf of St. Lawrence<br>☐ Coastal Newfoundland and Labrador<br>☐ Arctic (north of 60)<br>☐ Baltic Sea<br>☐ Caspian Sea<br>☐ Sea of Okhotsk<br>☐ Antarctic<br>☐ I have not operated in ice |
| 9. Approximately how many months have you spent in the presence of ice? | ______________________ |
| 10. What types of shore based training have you taken for operating in ice? (Select all that apply) | ☐ Basic training in ice operations<br>☐ Advanced training in ice operations<br>☐ Attendance at professional seminars discussing techniques and procedures relevant to ice operations<br>☐ I have never received training related to ice operations |
| 11. Do you have any previous experience using a marine simulator? (Select all that apply) | ☐ Training for navigation in open water<br>☐ Training for navigation in ice<br>☐ Research study<br>☐ I have no experience using a marine simulator |

# Appendix D: Introduction to Controls Script

## Introduction

The bridge of the simulator is modeled after that of the Atlantic Hawk, a conventional diesel, twin screw, fixed pitch propeller Offshore Supply Vessel (OSV). The Atlantic Hawk is class 1C, meaning it is not an ice class vessel. Therefore, POLARIS guidelines for operations in icy water recommend a speed of no greater than 3kn when operating in ice. Exceeding this speed could damage the vessel.  Please consider that the Atlantic Hawk has unprotected rudders, so be cautious when reversing as ice can damage the steering gear. The design speed of the Atlantic Hawk is 13kn so its limits in ice can easily be exceeded.

## Control Consoles

The forward console display screen allows the operator visual feedback from the control gauges as well as the vessel speed, heading, and change of heading.

The steering wheel controls both the port and starboard rudders. The rudders may be locked by turning the steering wheel to lock and pressing the left-right slider button on the right hand of the steering wheel. To return controls of both rudders press the up-down slider button on the right hand of the steering wheel. The buttons on the left hand of the steering wheel do not control anything. Verify rudder position by checking the gages on the display screen. I suggest steering with the bottom of the wheel to avoid inadvertently locking a rudder.

The port and starboard throttles control the main engines and the fore and aft throttles control the fore and aft tunnel thrusters. For all controls operation is fairly intuitive, you push the controls in the direction you wish to go. Control inputs can be verified by checking the gages on the display screen. The black levers do not control anything.

### Switching Controls

To switch between forward and aft controls, at the forward controls press the 3 transfer buttons below the port and starboard main throttle of the active controls, then at the aft console press the 3 transfer buttons corresponding on the opposite console to take control of the opposite console. Control may be verified by checking the gages on the aft display screen. The same process is reversed to return to the forward console. Press the 3 transfer buttons at the aft console, then press the corresponding buttons on the forward console and verify control has been switched by checking the forward display screen. All ice management scenarios will begin with forward controls.

### Radio

The radio is used to communicate with me at the control center. To use it, depress and hold the large button and speak, then release the button and wait for a reply. You may use the radio for any questions you have while inside the simulator such as distance from your vessel to a target object, or heading of a target object, or time remaining in the simulation.

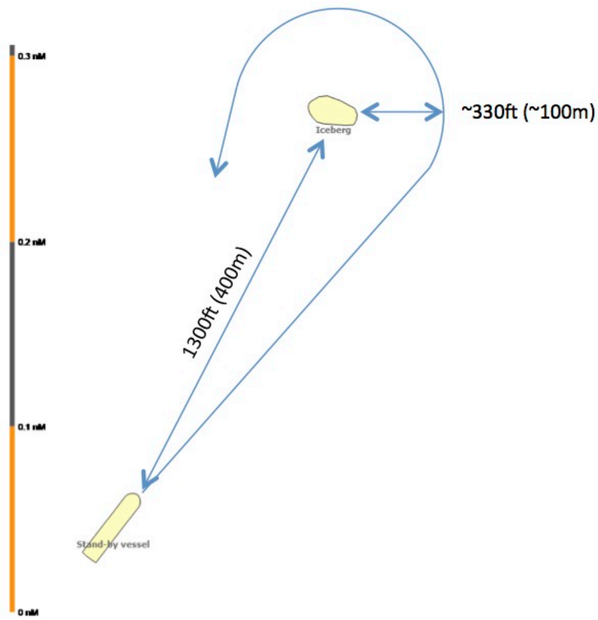
### Habituations

To begin we will have you complete 3 habituation scenarios to become familiar with the simulator controls. In the first habituation you will round a bergy bit and return towards your starting position. This habituation is to help you become familiar with reading your gauges and using landmarks to navigate. We ask that you use your radio to request distances between your ship and the bergy bit. In the second habituation you will park your vessel alongside an FPSO practicing maneuvering at slow speeds using your tunnel thrusters. In the third habituation you will practice switching between forward and aft consoles and use propeller wake wash to clear the ice aft of the vessel.

Please ask me if you have any questions.

# Appendix E: Scenario Instructions

## Habituation 1: Rounding the Iceberg

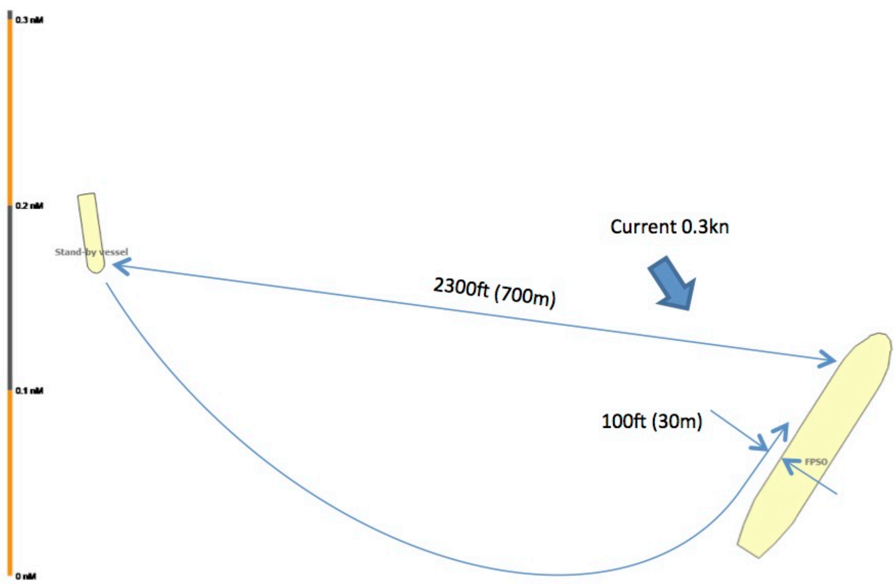



Objective: Round the iceberg, passing it to your port, and return
Time: ~10min (20min cut-off)

- This will give you the opportunity to:
  - Get used to the virtual environment
  - Get a feel for the controls and the bridge layout
  - Get used to calling the bridge officer in the wing console

- There is a bridge officer in your wing console. Radio them to ask for the distance between the iceberg and your vessel
  - Vessel heading: 33.5deg
  - Current: 0kn
  - Current direction: N/a
  - Wind: Light

# Habituation 2: Maneuver alongside FPSO



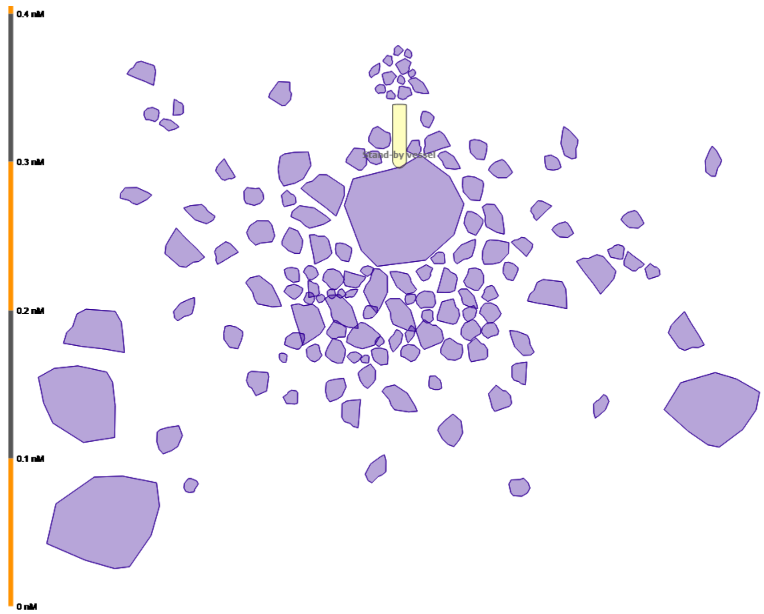

## Objective: Stop 30m (100ft) abeam of FPSO port side

## Time: ~10min (20min cut-off)

- This will give you the opportunity to:
    - Get used to slow maneuvers
    - Get used to radioing your wing console bridge officer for distance

- There is a bridge officer in your wing console. Radio them to ask for the distance between the iceberg and your vessel
    - Vessel heading: 172deg
    - Target heading: 32.5deg
    - Current: 0.3kn
    - Current direction: 327deg (NNW)
    - Wind: Light

## Habituation 3: Clear ice using propeller wake wash



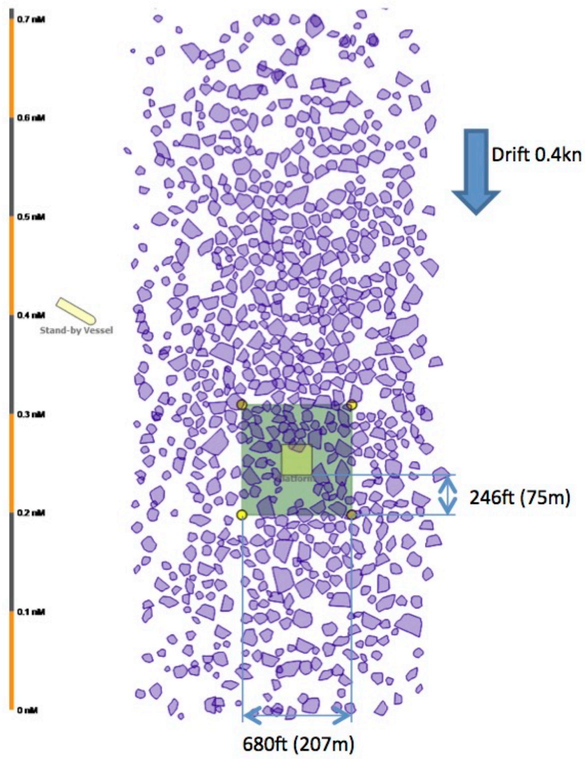

Objective: Use your propeller wash to push away the small floes directly aft of your vessel

Time: ~1min (or until complete)

- This will give you the opportunity to:
  - Get used to prop wash as a way to clear ice

  - Vessel heading: 180dg
  - Current : 0kn
  - Current direction: N/a
  - Wind: Light
  - Ice: 0.3-0.7m first year ice

# Training: Pushing




## Objective: Clear the encroaching pack ice from the indicated area using the pushing technique

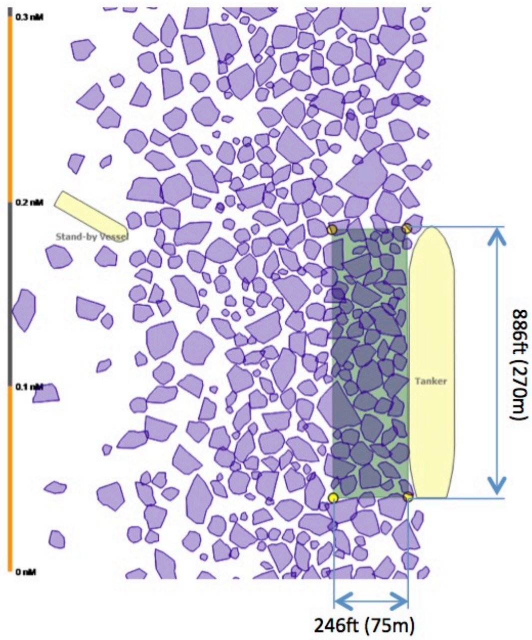
## Time: 15min

- Stand-by vessel support is required to clear the ice around the platform
- Ice clearing reduces the risks due to ice pressure on the platform and damage to the facility from ice

- Maintain a safe speed of 3kn
- The Atlantic Hawk has unprotected rudders while reversing; reverse in ice with caution

- Vessel heading: 120deg
- Current: 0.4kn
- Current direction: 180deg S
- Wind: Light
- Ice: 0.3-0.7m first year ice, 4-tenths concentration

## Training: Prop wash



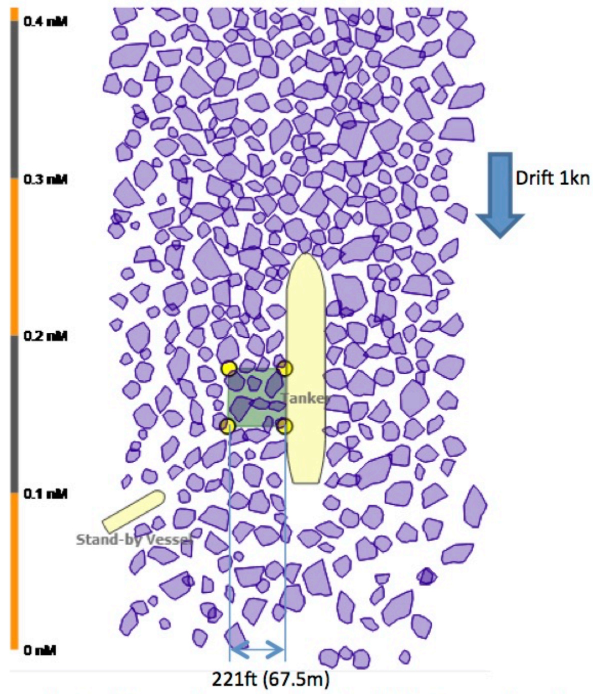

Objective: Clear pack ice on the port side of a tanker in the boxed area shown using the propeller wake wash technique

Time: 15min

- Stand-by vessel support is required to clear a ice free berth for a vessel to dock
- Ice clearing allows a vessel to dock and reduces the risk of damage due to ice

- Vessel heading: 120deg
- Target heading: 0deg
- Current: 0k
- Current direction: N/a
- Wind: Light
- Ice: 0.3-0.7m first year ice , 7-tenths concentration

## Training: Leeway




Objective: Clear the indicated area aft of midships using the leeway technique

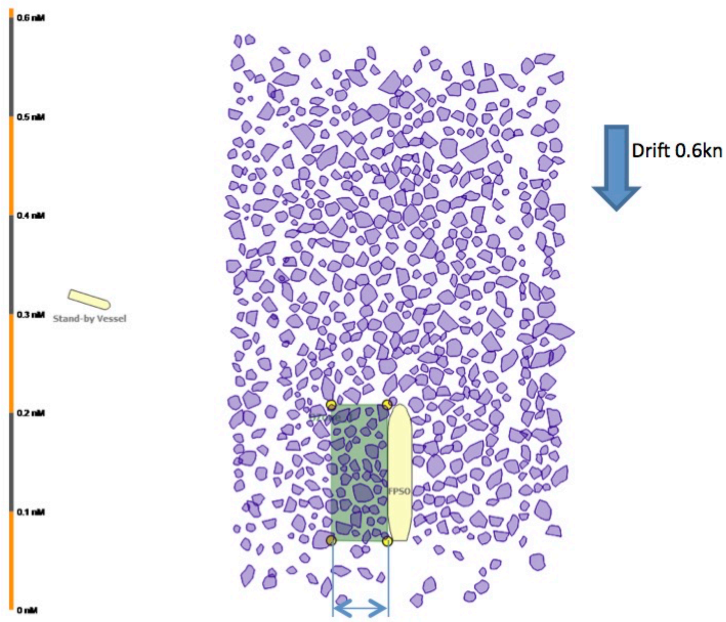
Time: 15min

- Stand-by vessel support is required to clear the indicated area so that research equipment can be launched
- Ice clearing reduces the risks of damage to the research equipment from ice

- Maintain a safe speed of 3kn
- The Atlantic Hawk has unprotected rudders while reversing; reverse in ice with caution

- Vessel heading: 60deg
- Target heading: 0deg
- Current: 1kn
- Current direction: 180deg S
- Wind: Light
- Ice: 0.3-0.7m first year ice, 5-tenths concentration

# Scenario A: Precautionary ice management (4tenths concentration)




## Objective: Clear encroaching pack ice from boxed area shown

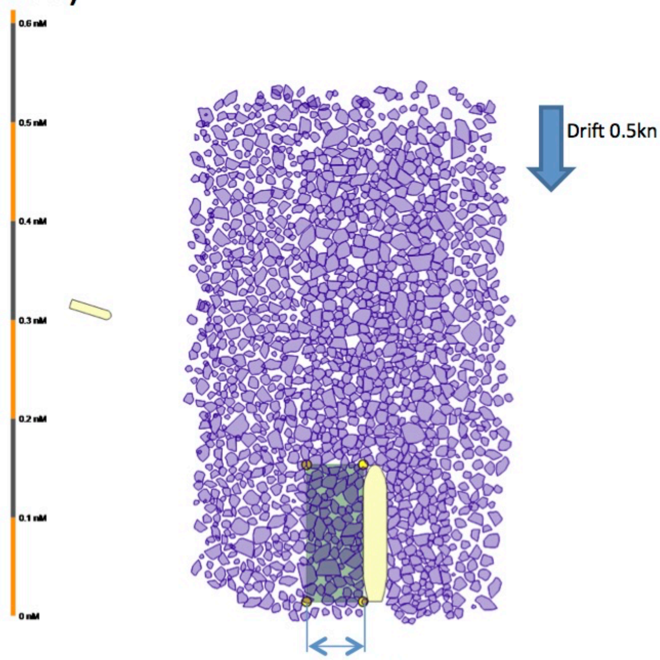
## Time: 30min

- Stand-by vessel support is required to clear ice to the port side of the FPSO and the port lifeboats
- Reduces risk of lifeboat evacuation in ice and the overall ability to evacuate (if a major event occurs while ice is present)
- Another support vessel is responsible for clearing the starboard side

- ➢ Maintain a safe speed of 3kn
- ➢ The Atlantic Hawk has unprotected rudders while reversing; reverse in ice with caution

- ➢ Current: 0.6kn
- ➢ Current direction: 180deg S
- ➢ Wind: Light
- ➢ Ice: 0.3-0.7m first year ice

## Scenario A: Precautionary ice management (7tenths concentration)




Objective: Clear encroaching pack ice from boxed area shown

Time: 30min

- Stand-by vessel support is required to clear ice to the port side of the FPSO and the port lifeboats
- Reduces risk of lifeboat evacuation in ice and the overall ability to evacuate (if a major event occurs while ice is present)
- Another support vessel is responsible for clearing the starboard side

➢ Maintain a safe speed of 3kn

➢ The Atlantic Hawk has unprotected rudders while reversing; reverse in ice with caution

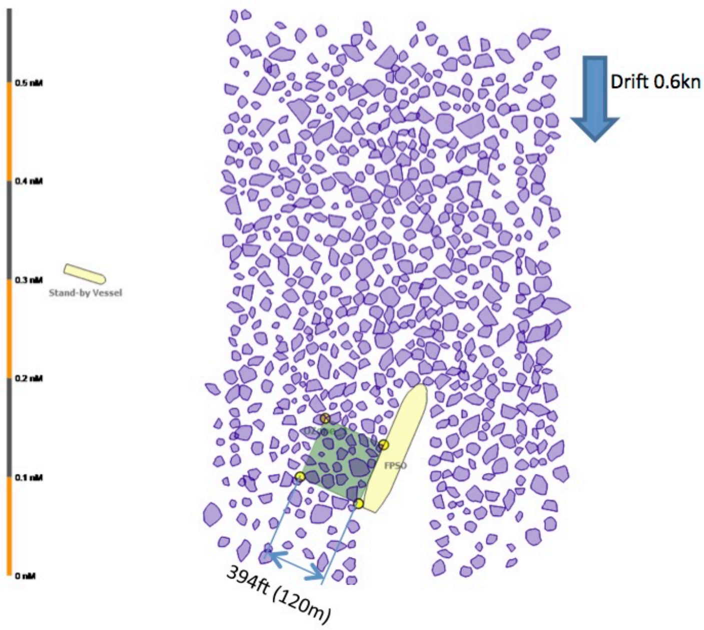
➢ Current: 0.5kn

➢ Current direction: 180deg S

➢ Wind: Light

➢ Ice: 0.3-0.7m first year ice

# Scenario B: Emergency ice management (4tenths concentration)




## Objective: Clear encroaching pack ice from the boxed area shown

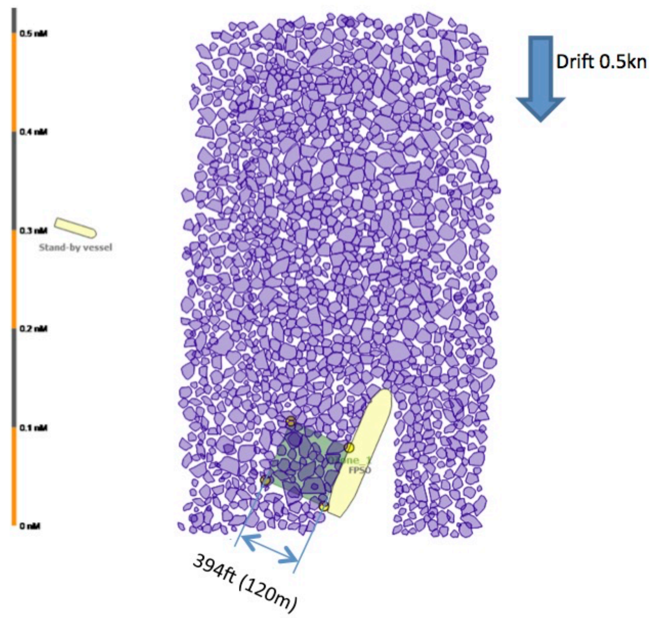
## Time: 30min

- Stand-by vessel support is required to clear the ice under port lifeboat launch zone
- FPSO's starboard side is already clear due to ice drift direction

- ➢ Maintain a safe speed of 3kn
- ➢ The Atlantic Hawk has unprotected rudders while reversing; reverse in ice with caution

- ➢ Current: 0.6kn
- ➢ Current direction: 180deg S
- ➢ Wind: Light
- ➢ Ice: 0.3-0.7m first year ice

# Scenario B: Emergency ice management (7tenths concentration)




## Objective: Clear encroaching pack ice from the boxed area shown
## Time: 30min

- Stand-by vessel support is required to clear the ice under port lifeboat launch zone
- FPSO's starboard side is already clear due to ice drift direction

- ➢ Maintain a safe speed of 3kn
- ➢ The Atlantic Hawk has unprotected rudders while reversing; reverse in ice with caution

- ➢ Current: 0.5kn
- ➢ Current direction: 180deg S
- ➢ Wind: Light
- ➢ Ice: 0.3-0.7m first year ice

# Appendix F: Training Content Overview

## Training Session One – Pushing Training Content

Ice Pushing Technique

Training Content

Ice Pushing Technique

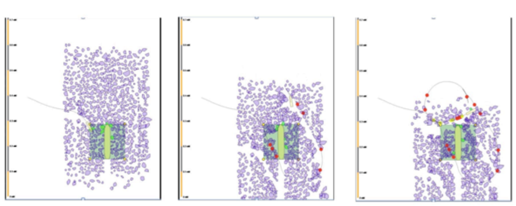
- The ice pushing technique involves using the bow or side of the ice management vessel to push ice away from a target area.

Replay videos

- You are going to see several quick time replay videos of operators using the pushing technique in the simulator.
- The videos are sped up thirty times faster than real time.
- For each video you will get to (1) watch the video, (2) read a brief explanation of what was effective and ineffective in the example and (3) watch the video again.
- You can use your own judgment when watching the videos to see what aspects could be effective or ineffective when using the pushing technique.

Ice Pushing Technique Example 1

Ice Pushing Technique: Example 1 Replay

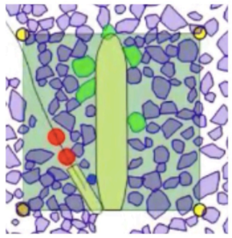


Ice Pushing Technique: Example 1

- In this example the bow of the ownship is used to clear the ice from around the target vessel.
- The ownship's speeds exceed 3 knots in this example. This increases the risk of damage to the ownship according to POLARIS regulations.

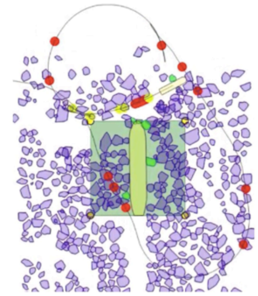
## Ice Pushing Technique: Example 1

- As shown in the image to the right, the ownship collides with the target vessel in this example.
- This is dangerous for both vessels and could lead to damage to both the ownship and target vessel.

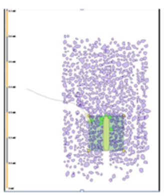


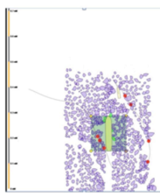
## Ice Pushing Technique: Example 1

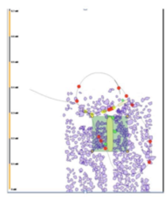
- As indicated by the path lines outside of the green zone in the image to the right, for much of this example the ownship was clearing ice far away from the target vessel.
- This resulted in ineffective ice management.



## Ice Pushing Technique: Example 1 Replay

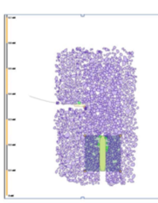


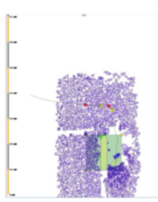


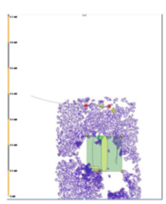


# Ice Pushing Technique Example 2

## Ice Pushing Technique: Example 2 Replay

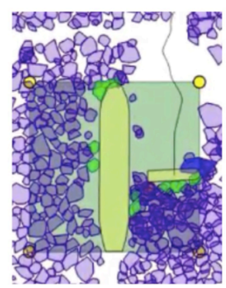






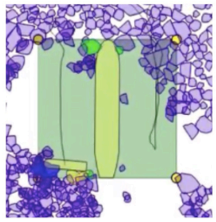
## Ice Pushing Technique: Example 2

- As shown in the image to the right, in this example the broad side of the ownship is used to clear a large area of ice around the target vessel.

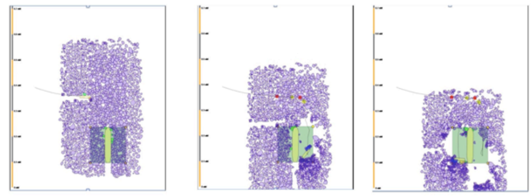


## Ice Pushing Technique: Example 2

- In this example, the ownship is able to effectively clear the ice from around the target vessel, as shown in the image to the right.

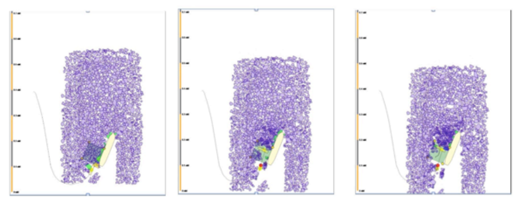


## Ice Pushing Technique: Example 2 Replay



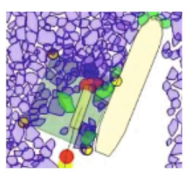
# Ice Pushing Technique Example 3

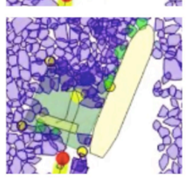
## Ice Pushing Technique: Example 3 Replay



## Ice Pushing Technique: Example 3

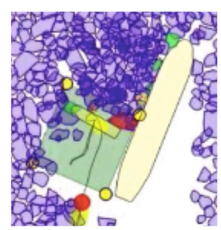
- In this example both the bow (represented in the top image) and side (represented in the bottom image) of the ownship are used to clear the small area of interest on the port aft of the target vessel.



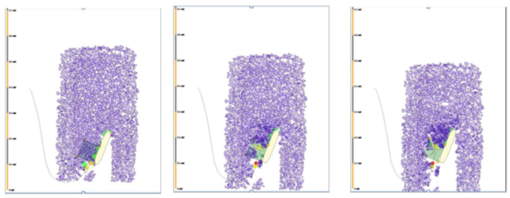


## Ice Pushing Technique: Example 3

- As shown in the image to the right, the area of interest is effectively cleared using this technique.
- Since the ownship is pushing the ice up drift, later in this scenario care must be taken to ensure ice doesn't reenter the area of interest.

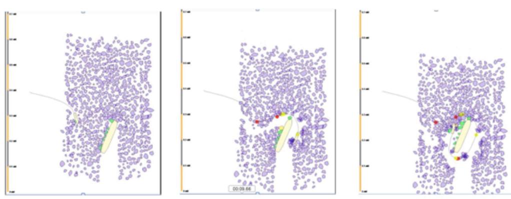


## Ice Pushing Technique: Example 3 Replay



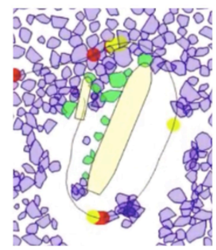
# Ice Pushing Technique Example 4

## Ice Pushing Technique: Example 4 Replay



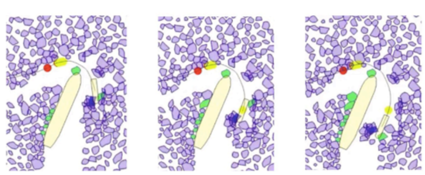
## Ice Pushing Technique: Example 4

- As shown in the image to the right, in this example the ownship pushes the ice in a circle around the vessel of interest in order to clear the area.

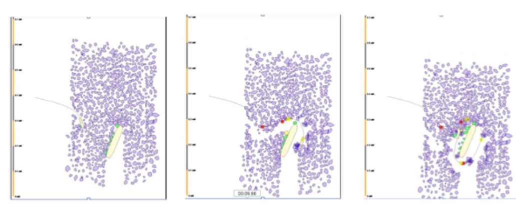


## Ice Pushing Technique: Example 4

- Circling a vessel and pushing the ice can be an effective technique. However, in this example the ice in not effectively cleared.
- As shown in the images below, the ownship is pushing the ice towards the target vessel instead of away from it.

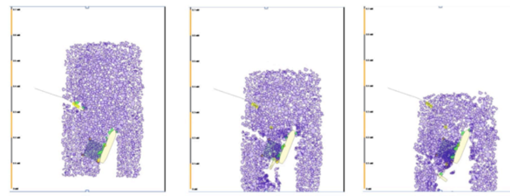


## Ice Pushing Technique: Example 4 Replay



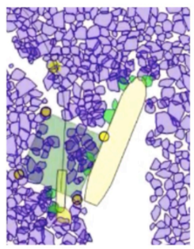
# Ice Pushing Technique Example 5

## Ice Pushing Technique: Example 5 Replay



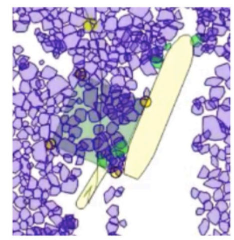
## Ice Pushing Technique: Example 5

- In this example the ownship clears the area of interest by pushing with both its bow and stern.
- As shown in the image to the right, bow pushing is some what effective in clearing ice in the area of interest.



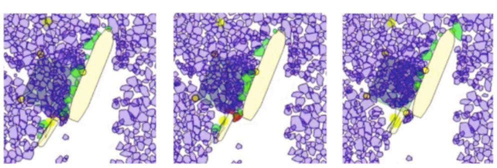
## Ice Pushing Technique: Example 5

- Pushing with the stern of the ownship, as shown in the image on the right, is dangerous and can cause damage to the ownship's propellers and rudders.

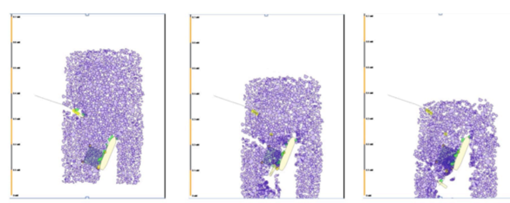


## Ice Pushing Technique: Example 5

- As shown in the images below, the ownship is pushing the ice up drift which is causing the ice to drift back into the area of interest.
- This leads to ice accumulation in higher concentrations than if no ice management had occurred.



## Ice Pushing Technique: Example 5 Replay



## Training Session One – Pushing Feedback Template

Ice Pushing Technique

Session 1 Feedback

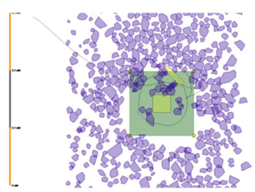
Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 2.5 tenths.

Comparison

Your path

Experienced operator's path

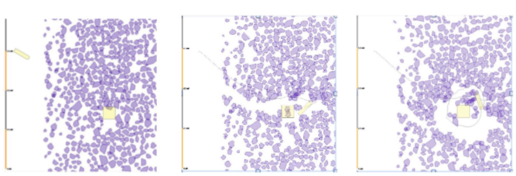


Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



Speed

- Your maximum speed during this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

Collisions

- You *** collide or nearly collide with the target facility during this scenario.

## Training Session One – Prop Wash Training Content

Prop Wash Technique

Training Content

Prop Wash Technique

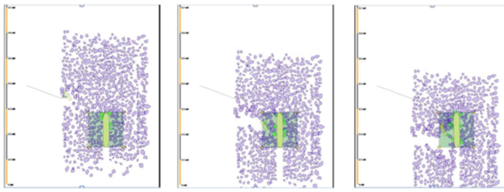
- The prop wash technique involves using the force created by the propellers of the ice management vessel to clear a target area of ice.

Replay videos

- You are going to see several quick time replay videos of operators using the prop wash technique in the simulator.
- The videos are sped up thirty times faster than real time.
- For each video you will get to (1) watch the video, (2) read a brief explanation of what was effective and ineffective in the example and (3) watch the video again.
- You can use your own judgment when watching the videos to see what aspects could be effective or ineffective when using the prop wash technique.

Prop Wash Technique Example 1

## Prop Wash Technique: Example 1 Replay

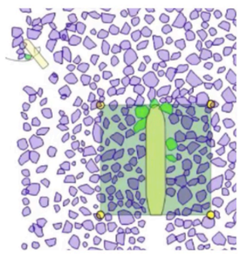


## Prop Wash Technique: Example 1

- In this example the ownship clears a small area using prop wash then moves into the cleared area and prop washes again, clearing a larger area.
- Since the area behind the ownship is cleared of ice the ownship is able to reverse safely. Care must be taken when reversing in icy waters to ensure no damage due to ice occurs to the propellers or rudders.

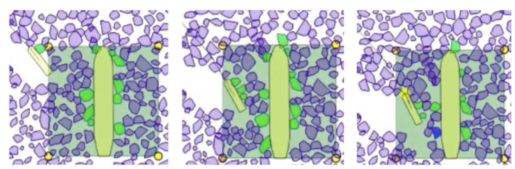
## Prop Wash Technique: Example 1

- As shown in the image to the right, the ownship starts to prop wash a far distance from the area of interest.
- This is not effective because is does not leave enough time to clear the area of interest.

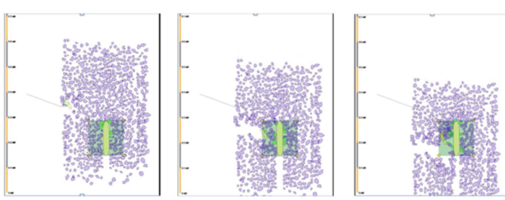


## Prop Wash Technique: Example 1

- As represented in the images below, the ownship is able to clear a small area using prop wash. However, most of the large area of interest on either side of the target vessel is not cleared.

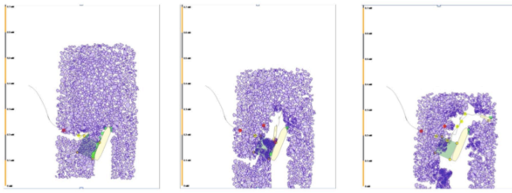


## Prop Wash Technique: Example 1 Replay



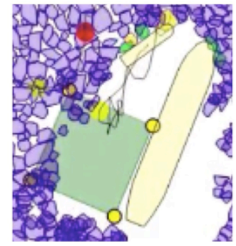
# Prop Wash Technique Example 2

## Prop Wash Technique: Example 2 Replay



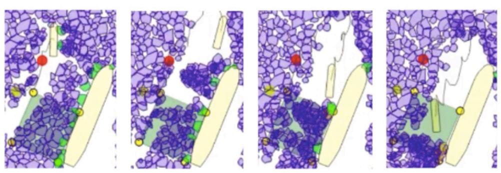
## Prop Wash Technique: Example 2

- In this example, the ownship starts up drift of the area of interest on the port aft of the target vessel and effectively clears the area using the prop wash technique, as shown in the image to the right.

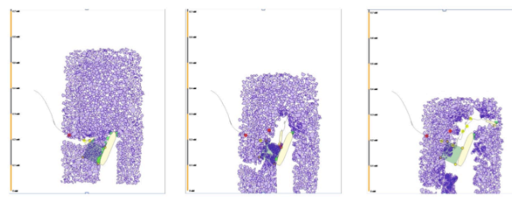


## Prop Wash Technique: Example 2

- As shown in the images below, ice clumps as the ownship prop washes it down drift, which allows the ownship to almost completely clear the ice out of the area of interest.

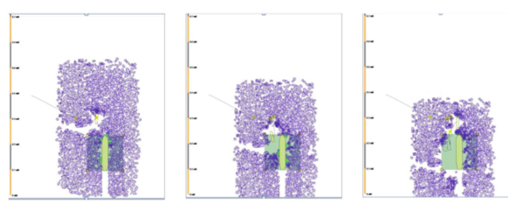


## Prop Wash Technique: Example 2 Replay



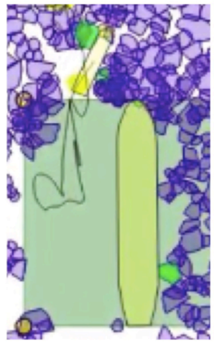
# Prop Wash Technique Example 3

## Prop Wash Technique: Example 3 Replay



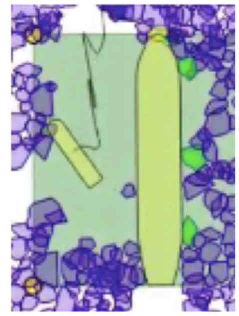
## Prop Wash Technique: Example 3

- As shown in the image to the right near the end of the scenario, the ownship effectively clears ice from the port side of the target vessel by prop washing down drift.

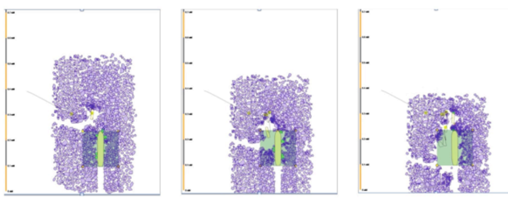


## Prop Wash Technique: Example 3

- In this example the ownship is angled so that its stern is pointed towards the vessel of interest while directed down drift, as shown in the image to the right.
- This allows the ownship to clear almost all of the ice from along the side of the vessel of interest.

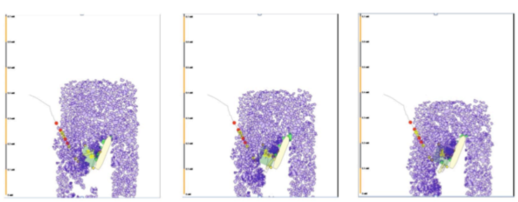


## Prop Wash Technique: Example 3 Replay



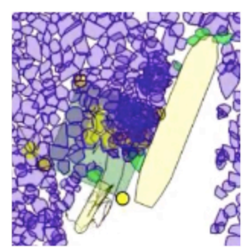
# Prop Wash Technique Example 4

## Prop Wash Technique: Example 4 Replay



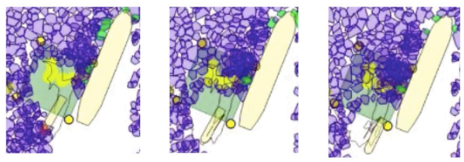
## Prop Wash Technique: Example 4

- In this example, as shown in the image to the right, the ownship is not able to effectively clear the area of interest on port aft of the target vessel using the prop wash technique.

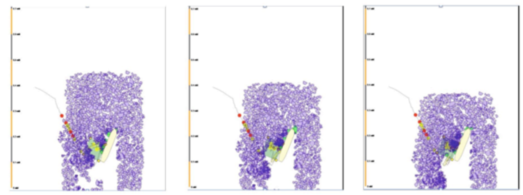


## Prop Wash Technique: Example 4

- The images below show that, in this example, prop washing the ice up drift caused the ice to drift back into the area of interest and accumulate in higher concentrations than without ice management.

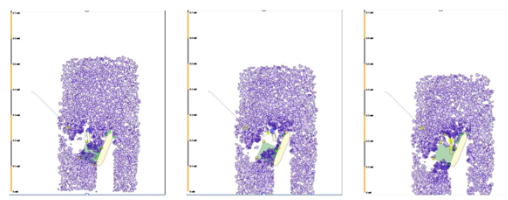


## Prop Wash Technique: Example 4 Replay



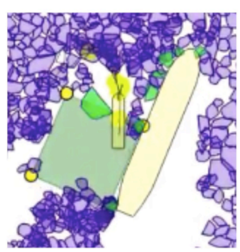
# Prop Wash Technique Example 5

## Prop Wash Technique: Example 5 Replay



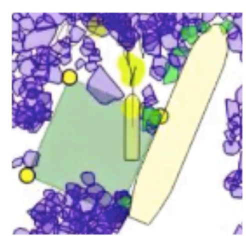
## Prop Wash Technique: Example 5

- In this example, the ownship prop washes down drift and is able to effectively clear ice from the small area of interest on the port aft of the target vessel. This is shown at the end of the scenario in the image to the right.



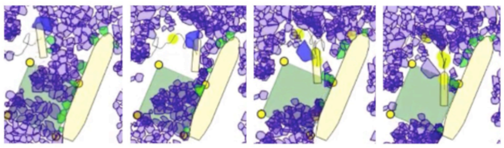
## Prop Wash Technique: Example 5

- As shown in the image to the right, the ownship is able to effectively clear the ice by prop washing down drift close to the target vessel.

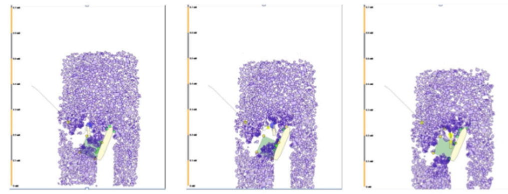


Prop Wash Technique: Example 5

- As represented in the images below, in this example the ice clumps together along the target vessel which makes it easier for the ownship to clear the ice down drift.



Prop Wash Technique: Example 5 Replay



## Training Session One – Prop Wash Feedback Template

Prop Wash Technique

Session 1 Feedback

Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 2.6 tenths.

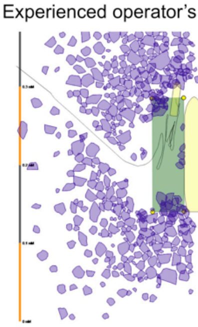
Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

Comparison

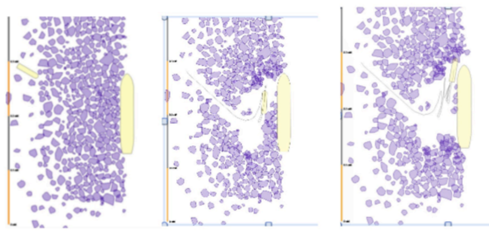
Your path

Experienced operator's path



### Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



### Speed

- Your maximum speed during this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

### Collisions

- You *** collide or nearly collide with the target facility during this scenario.

## Training Session One – Leeway Training Content

### Leeway Technique

Training Content

### Leeway Technique

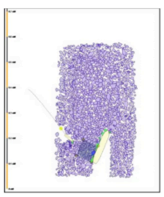
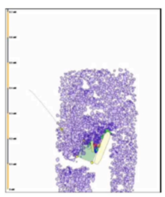
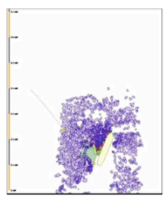
- The leeway technique involves creating a lee with the ice management vessel to keep ice from flowing into a small target area.

## Replay videos

- You are going to see several quick time replay videos of operators using the leeway technique in the simulator.
- The videos are sped up thirty times faster than real time.
- For each video you will get to (1) watch the video, (2) read a brief explanation of what was effective and ineffective in the example and (3) watch the video again.
- You can use your own judgment when watching the videos to see what aspects could be effective or ineffective when using the leeway technique.

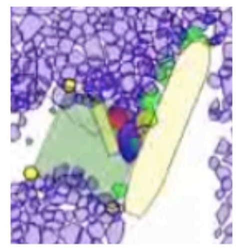
# Leeway Technique Example 1

## Leeway Technique: Example 1 Replay

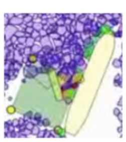
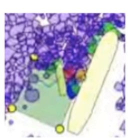
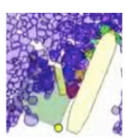
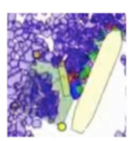
## Leeway Technique: Example 1

- In this example the ownship clears the area of interest using the prop wash technique.
- Then, as shown in the image to the right, the ownship creates an ice barrier by leeing at a forty-five degree angle from the target vessel.



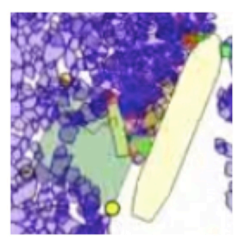
## Leeway Technique: Example 1

- As represented in the images below leeing at a forty-five degree angle allowed ice to flow around the port side of the ownship and into the area of interest.

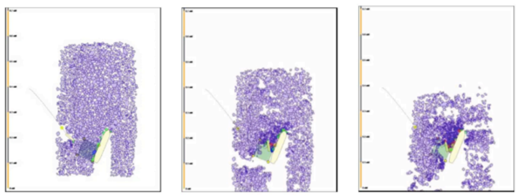





## Leeway Technique: Example 1

- As shown in the image to the right, while this technique was not effective in keeping the whole target area clear, it did keep ice from drifting into a smaller area next to the port aft of the target vessel.

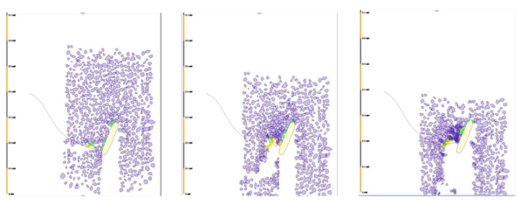


## Leeway Technique: Example 1 Replay



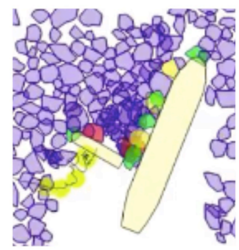
# Leeway Technique Example 2

## Leeway Technique: Example 2 Replay



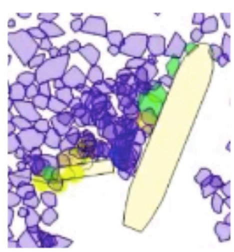
## Leeway Technique: Example 2

- In this example the ownship clears the area around the port aft of the target vessel using the ice pushing technique with its broad side.
- Then the ownship creates a lee perpendicular to the target vessel to keep ice from flowing back into the target area.

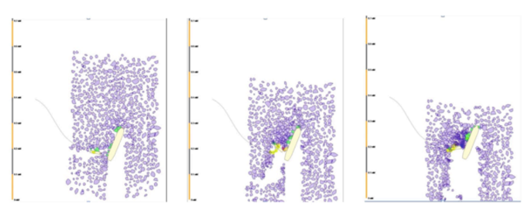


## Leeway Technique: Example 2

- During this example the ownship is able to keep ice from flowing into the area of interest.
- However, as shown in the image to the right, near the end of the scenario the ownship begins to lose its position and likely wouldn't have been able to block the ice much longer.

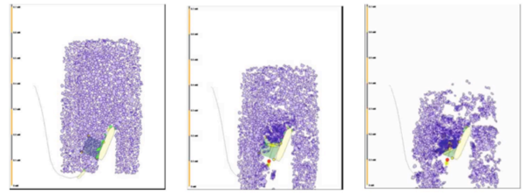


## Leeway Technique: Example 2 Replay



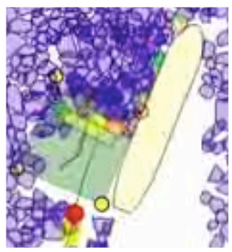
## Leeway Technique Example 3

## Leeway Technique: Example 3 Replay



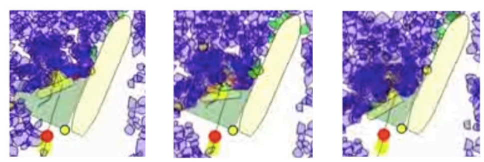
## Leeway Technique: Example 3

- In this example the ownship clears the area of interest using the pushing technique.
- Then the ownship creates a lee perpendicular to the target vessel to keep ice from drifting into the area of interest.

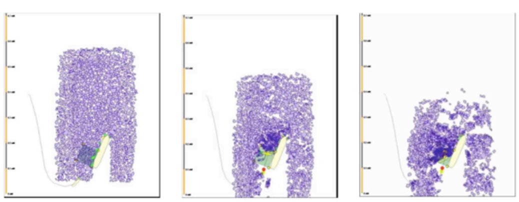


## Leeway Technique: Example 3

- As represented in the images below, the ownship does not maintain its position and is therefore unable to act as an effective ice barrier.
- A lot of ice drifts into the area of interest making this an ineffective use of the leeway technique.

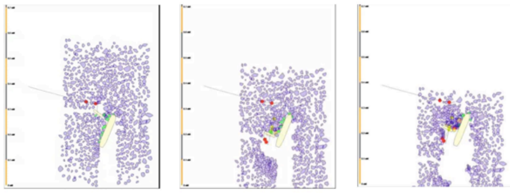


## Leeway Technique: Example 3 Replay



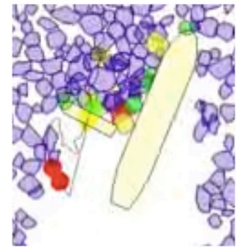
## Leeway Technique Example 4

## Leeway Technique: Example 4 Replay



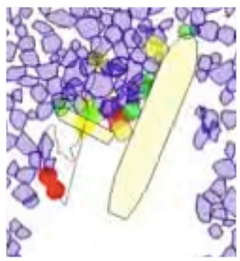
## Leeway Technique: Example 4

- In this example the ownship clears the area of interest on the port aft of the target vessel by pushing with its broad side.
- The ownship then creates a lee perpendicular to the target vessel in order to create a barrier and stop ice from drifting into the area of interest.



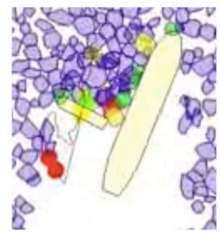
## Leeway Technique: Example 4

- As shown in the image to the right of the end of the scenario, the ownship is able to maintain its position and work as an effective barrier to keep ice from flowing into the area of interest.

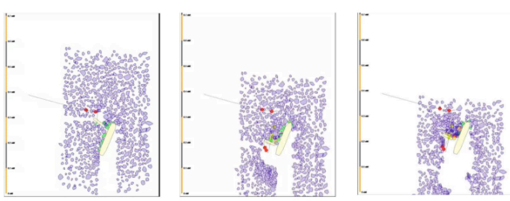


## Leeway Technique: Example 4

- The ownship is also positioned so that its bow is away from the target vessel.
- This is an effective way to reduce the likelihood of collision with the target vessel which is more likely if the bow is facing the target vessel.

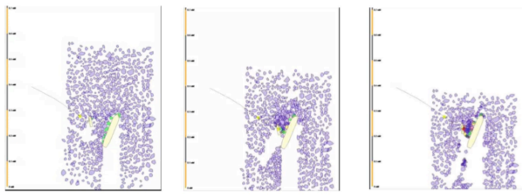


## Leeway Technique: Example 4 Replay



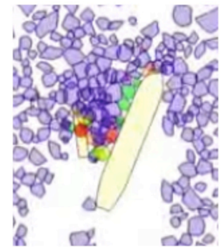
# Leeway Technique Example 5

## Leeway Technique: Example 5 Replay



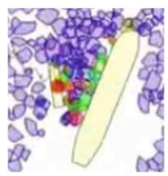
## Leeway Technique: Example 5

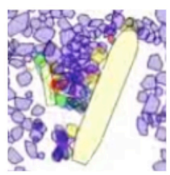
- In this example the ownship clears the area of interest on the port aft of target vessel using the prop wash technique.
- Then, as shown in the image to the right, the ownship creates a lee by lodging ice between its self and the target vessel.



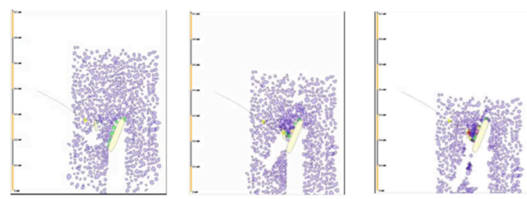
## Leeway Technique: Example 5

- As shown in the images to the right, the lodged ice still eventually drifts into the area of interest.
- Lodgeing the ice did not work as an effective barrier to keep the target area clear.





## Leeway Technique: Example 5 Replay



# Training Session One – Leeway Feedback Template

## Leeway Technique

Session 1 Feedback

## Concentration

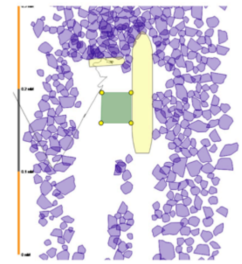
- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 0 tenths.

## Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

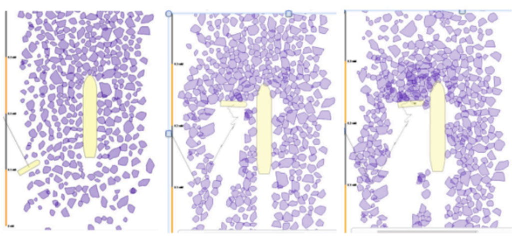
## Comparison

Your path    Experienced operator's path



## Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



## Speed

- Your maximum speed during this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

## Collisions

- You *** collide or nearly collide with the target facility during this scenario.

## Training Session Two – Pushing Feedback from Session One Template

### Pushing Technique

Session 2 Feedback from Session 1

### Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 2.5 tenths.

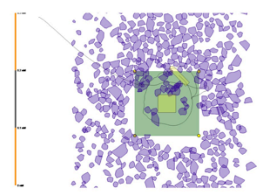
### Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

### Comparison

Your path

Experienced operator's path

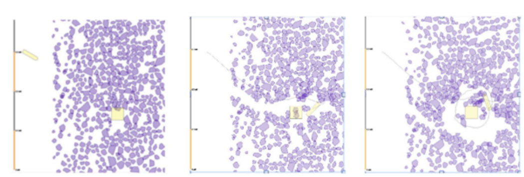


### Performance Replay

- Below is a quick time replay video of you attempting this scenario. (Click video to play)

### Experienced Operator Replay

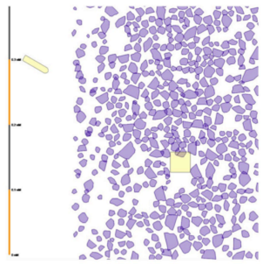
- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



### Experienced Operator Replay

Your scenario

Experienced operator's scenario



### Speed

- Your maximum speed during this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

### Collisions

- You *** collide or nearly collide with the target facility during this scenario.

## Training Session Two – Pushing Training Content Refresher

### Ice Pushing Technique

Training Refresher

### Ice Pushing Technique

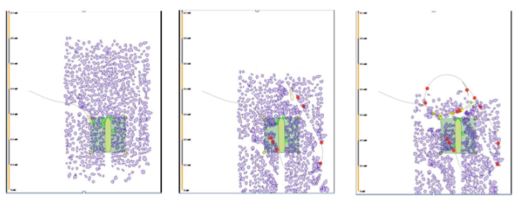
- The ice pushing technique involves using the bow or side of the ice management vessel to push ice away from a target area.

## Replay videos

- You are going to see several quick time replay videos of operators using the pushing technique in the simulator.
- The videos are speed up thirty times faster than real time.
- You can use your own judgment when watching the videos to see what aspects could be effective or ineffective when using the pushing technique.

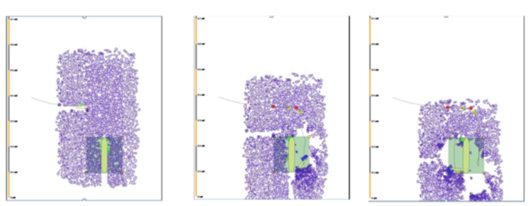
# Ice Pushing Technique Example 1

## Ice Pushing Technique: Example 1 Replay



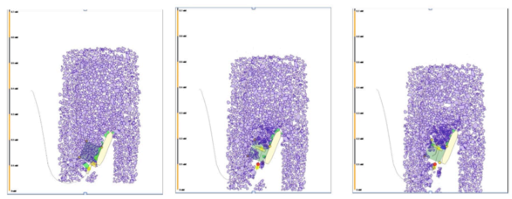
# Ice Pushing Technique Example 2

## Ice Pushing Technique: Example 2 Replay



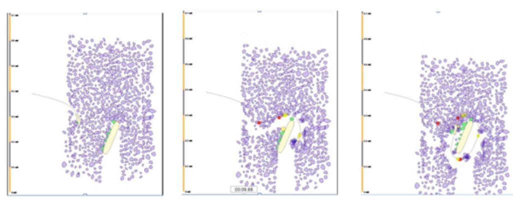
# Ice Pushing Technique Example 3

Ice Pushing Technique: Example 3 Replay



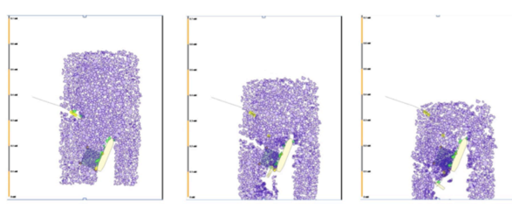
Ice Pushing Technique
Example 4

Ice Pushing Technique: Example 4 Replay



Ice Pushing Technique
Example 5

Ice Pushing Technique: Example 5 Replay



## Training Session Two – Pushing Feedback Template

# Ice Pushing Technique

Session 2 Feedback

### Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- In your last attempt of this scenario the concentration was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 2.5 tenths.

### Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

### Comparison

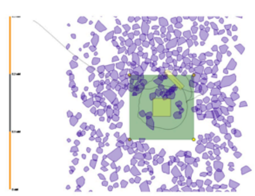
Your path

Your path in previous attempt

### Comparison

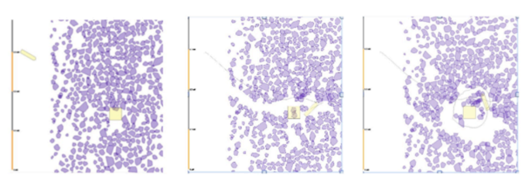
Your path this attempt

Experienced operator's path



### Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



### Speed

- Your maximum speed during this scenario *** above 3 knots.
- Your maximum speed during your previous attempt of this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

### Collisions

- You *** collide or nearly collide with the target facility during this scenario.
- In your last attempt you *** collide or nearly collide with the target facility during this scenario.

## Training Session Two – Prop Wash Feedback from Session One Template

### Prop Wash Technique

Session 2 Feedback from Session 1

### Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 2.6 tenths.

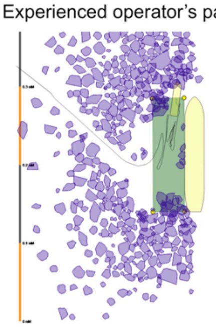
### Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

### Comparison

Your path

Experienced operator's path

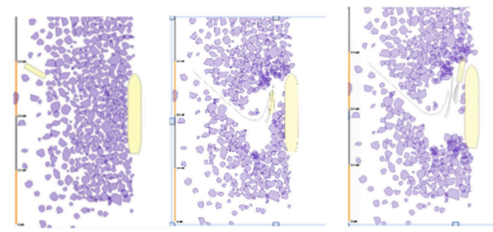


## Performance Replay

- Below is a quick time replay video of you attempting this scenario. (Click video to play)

## Experienced Operator Replay

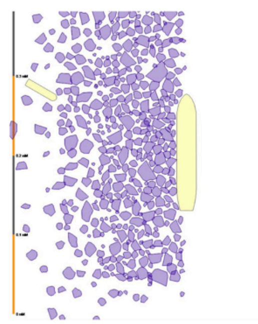
- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



## Experienced Operator Replay

Your scenario

Experienced operator’s scenario



## Speed

- Your maximum speed during this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

## Collisions

- You *** collide or nearly collide with the target facility during this scenario.

## Training Session Two – Prop Wash Training Content Refresher

Prop Wash Technique

Training Refresher

Prop Wash Technique

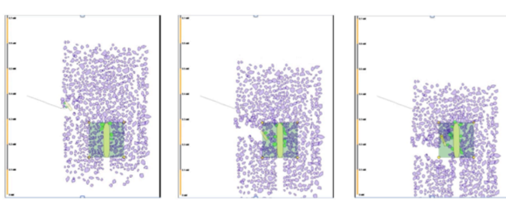
- The prop wash technique involves using the force created by the propellers of the ice management vessel to clear a target area of ice.

Replay videos

- You are going to see several quick time replay videos of operators using the prop wash technique in the simulator.
- The videos are speed up thirty times faster than real time.
- You can use your own judgment when watching the videos to see what aspects could be effective or ineffective when using the prop wash technique.

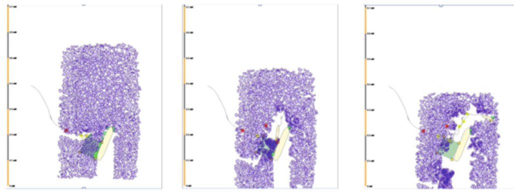
Prop Wash Technique Example 1

Prop Wash Technique: Example 1 Replay



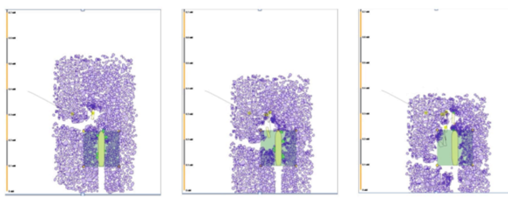
Prop Wash Technique Example 2

Prop Wash Technique: Example 2 Replay



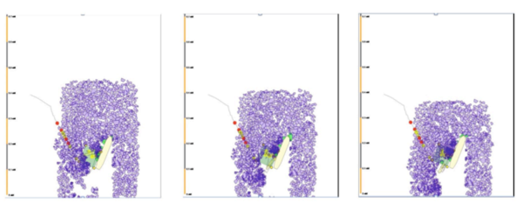
# Prop Wash Technique Example 3

Prop Wash Technique: Example 3 Replay



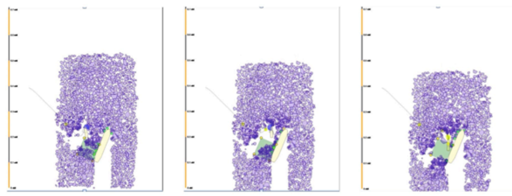
# Prop Wash Technique Example 4

Prop Wash Technique: Example 4 Replay



# Prop Wash Technique Example 5

Prop Wash Technique: Example 5 Replay



## Training Session Two – Prop Wash Feedback Template

Prop Wash Technique

Session 2 Feedback

Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- In your last attempt of this scenario the concentration was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 2.6 tenths.

Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

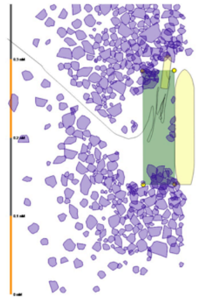
Comparison

Your path | Your path in previous attempt

Comparison

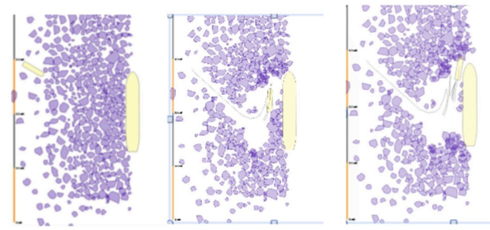
Your path this attempt

Experienced operator's path



Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



Speed

- Your maximum speed during this scenario ** above 3 knots.
- Your maximum speed during your previous attempt of this scenario ** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

Collisions

- You ** collide or nearly collide with the target facility during this scenario.
- In your last attempt you ** collide or nearly collide with the target facility during this scenario.

## Training Session Two – Leeway Feedback from Session One Template

Leeway Technique

Session 2 Feedback from Session 1

Concentration

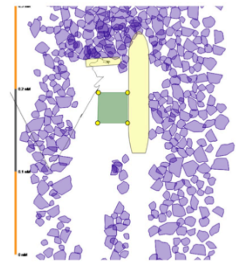
- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 0 tenths.

## Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

## Comparison

Your path — Experienced operator's path

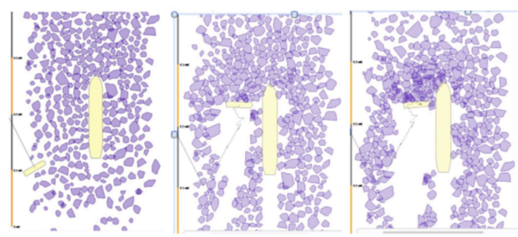


## Performance Replay

- Below is a quick time replay video of you attempting this scenario. (Click video to play)

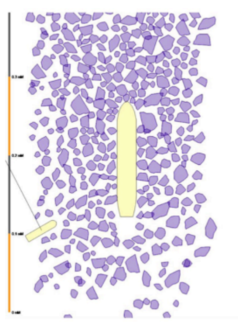
## Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



## Experienced Operator Replay

Your scenario — Experienced operator's scenario



## Speed

- Your maximum speed during this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

### Collisions

- You *** collide or nearly collide with the target facility during this scenario.

## Training Session Two – Leeway Training Content Refresher

### Leeway Technique

Training Refresher

### Leeway Technique

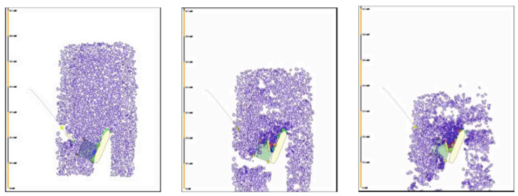
- The leeway technique involves creating a lee with the ice management vessel to keep ice from flowing into a small target area.

### Replay videos

- You are going to see several quick time replay videos of operators using the leeway technique in the simulator.
- The videos are speed up thirty times faster than real time.
- You can use your own judgment when watching the videos to see what aspects could be effective or ineffective when using the leeway technique.

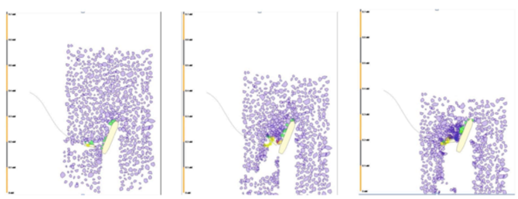
### Leeway Technique Example 1

Leeway Technique: Example 1 Replay



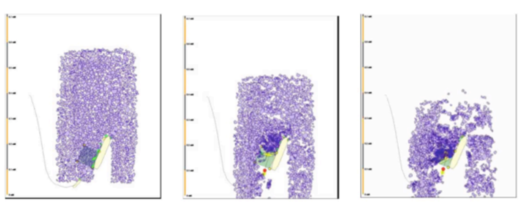
Leeway Technique
Example 2

Leeway Technique: Example 2 Replay



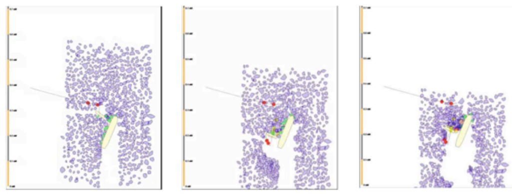
Leeway Technique
Example 3

Leeway Technique: Example 3 Replay



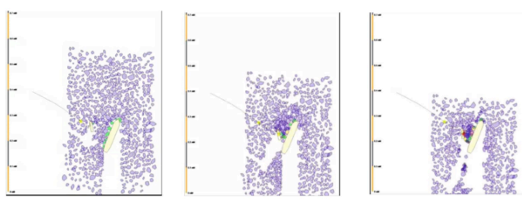
Leeway Technique
Example 4

Leeway Technique: Example 4 Replay



# Leeway Technique
# Example 5

Leeway Technique: Example 5 Replay



## Training Session Two – Leeway Feedback Template

Leeway Technique

Session 2 Feedback

Concentration

- After 15 minutes of ice management the concentration in the area of interest was ** tenths.
- In your last attempt of this scenario the concentration was ** tenths.
- An experienced operator completing the same scenario had an end concentration of 0 tenths.

## Path

- Below is a picture taken at the end of the scenario. The line indicates the path of the vessel during 15 minutes of ice management.

## Comparison

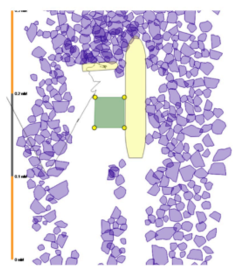
Your path

Your path in previous attempt

## Comparison

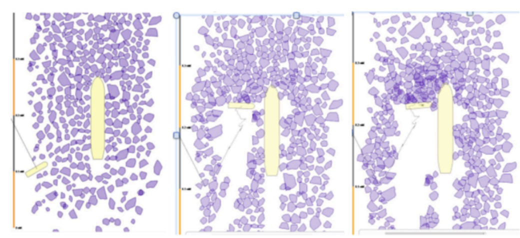
Your path this attempt

Experienced operator's path



## Experienced Operator Replay

- Below is a quick time replay video of an experienced operator completing this scenario. (Click video to play)



## Speed

- Your maximum speed during this scenario *** above 3 knots.
- Your maximum speed during your previous attempt of this scenario *** above 3 knots.
- The maximum POLARIS recommended speed for this vessel and ice conditions is 3 knots.

## Collisions

- You *** collide or nearly collide with the target facility during this scenario.
- In your last attempt you *** collide or nearly collide with the target facility during this scenario.

## Appendix G: Exit Interview Questions

1. Reflect on your performance in the scenario. What was your strategy?
2. What factors do you think were important for success in the scenario?
3. What was the most challenging part of the scenario?
4. Would you change anything about your strategy/approach in the scenario?
5. Do you feel the training adequately prepared you for the scenario?
6. What would you have changed about the training to better prepare you for the scenario?
7. Rate your overall performance in completing the scenario. (1 is not very successful, 3 is somewhat successful, 5 is very successful)

   1 2 3 4 5

8. Other questions or comments.

# Appendix H: POLARIS Calculations

- POLARIS is a risk indexing system that was developed by the IMO based on experience and best practice in the Canadian Arctic (IMO, 2016).
- POLARIS can be used to estimate the maximum speed that should be used for an operation in ice in order to avoid damage to the vessel.

**POLARIS Calculations Procedure:**

1. First, the Risk Index Value (RIV) is determined. For this study the ship is a Polar Class 7 (PC7) and medium first year ice will be used. This means, the RIV value is -1.

| Risk Index Values (RIV) | | | | | | |
|---|---|---|---|---|---|---|
| Ice class | Ice-free | New ice | ... | Medium first year ice (current conditions) | ... | Heavy multi-year ice |
| PC1 (excellent) | 3 | 3 | | 2 | | 1 |
| PC2 | 3 | 3 | | 2 | | 0 |
| ... | | | ... | | ... | |
| PC7 (your ship) | 3 | 2 | | -1 | | -3 |
| ... | | | ... | | ... | |
| 1C (poor) | 3 | 2 | | -4 | | -8 |
| Not ice strengthened | 3 | 1 | | -5 | | -8 |

2. Next, the Risk Index Outcome (RIO) is calculated. In this study the ice concentration will be between four tenths and seven tenths. This means, the range for RIO is -0.4 to -0.7.

RIO = Ice Concentration x Risk Index Value

RIO = 4/10 x -1 = -0.4
to
RIO = 710 x -1 = -0.7

3. Then, the level of risk is estimated. Since the RIOs for this study (-0.4 to -0.7) are between -10 and 0, the scenarios are considered an elevated risk.

| Risk Index Outcome criteria | | |
|---|---|---|
| RIO | PC1-PC7 | Below PC7 |
| RIO ≥ 0 | Normal | Normal |
| -10 ≤ RIO < 0 | Elevated risk | Special consideration |
| RIO < -10 | Special consideration | Special consideration |

4. Finally, the speed limit can be estimated using the table for elevated risk operations. Since this vessel is PC7, and therefore below PC5, the recommended speed limit is 3 knots.

| Ice Class | Recommended Speed Limit |
|---|---|
| PC1 | 11 knots |
| PC2 | 8 knots |
| PC3-PC5 | 5 knots |
| Below PC5 | 3 knots |

# Appendix I: Ranking Tables

**Pushing Scenario**

| | | Average Change in Ice Concentration | End Change in Ice Concentration | Clearing to Distance Ratio | Mean |
|---|---|---|---|---|---|
| Training I | Y06 | 4 | 4 | 4 | 4.0 |
| | E96 | 15 | 23 | 17 | 18.3 |
| | G91 | 13 | 6 | 15 | 11.3 |
| | D76 | 11 | 8 | 9 | 9.3 |
| | L44 | 31 | 20 | 25 | 25.3 |
| | E41 | 8 | 16 | 8 | 10.7 |
| | V55 | 12 | 9 | 12 | 11.0 |
| | A48 | 19 | 15 | 20 | 18.0 |
| | Q76 | 22 | 12 | 21 | 18.3 |
| | X86 | 7 | 7 | 7 | 7.0 |
| | H27 | 5 | 14 | 5 | 8.0 |
| | F69 | 6 | 3 | 6 | 5.0 |
| | E43 | 3 | 5 | 3 | 3.7 |
| | M47 | 26 | 32 | 29 | 29.0 |
| | Y93 | 21 | 28 | 24 | 24.3 |
| | T00 | 1 | 1 | 1 | 1.0 |
| | S49 | 2 | 2 | 2 | 2.0 |
| Training II | S51 | 27 | 27 | 27 | 27.0 |
| | B19 | 34 | 30 | 32 | 32.0 |
| | L87 | 28 | 25 | 28 | 27.0 |
| | W63 | 24 | 29 | 26 | 26.3 |
| | O54 | 30 | 26 | 30 | 28.7 |
| | E38 | 17 | 21 | 14 | 17.3 |
| | Z46 | 16 | 11 | 13 | 13.3 |
| | O59 | 14 | 13 | 16 | 14.3 |
| | T23 | 9 | 22 | 10 | 13.7 |
| | G54 | 10 | 10 | 11 | 10.3 |
| | G69 | 25 | 17 | 22 | 21.3 |
| | N08 | 32 | 34 | 34 | 33.3 |
| | O07 | 20 | 18 | 19 | 19.0 |
| | A96 | 23 | 24 | 23 | 23.3 |
| | L88 | 33 | 31 | 35 | 33.0 |
| | Y42 | 18 | 19 | 18 | 18.3 |
| | X44 | 35 | 33 | 31 | 33.0 |
| | L96 | 29 | 35 | 33 | 32.3 |

**Prop Wash Scenario**

| | | Average Change in Ice Concentration | End Change in Ice Concentration | Clearing to Distance Ratio | Mean |
|---|---|---|---|---|---|
| **Training I** | Y06 | 4 | 2 | 4 | 3.3 |
| | E96 | 16 | 16 | 17 | 16.3 |
| | G91 | 14 | 7 | 15 | 12.0 |
| | D76 | 1 | 1 | 1 | 1.0 |
| | L44 | 6 | 10 | 5 | 7.0 |
| | E41 | 21 | 22 | 21 | 21.3 |
| | V55 | 23 | 20 | 22 | 21.7 |
| | A48 | 3 | 5 | 3 | 3.7 |
| | Q76 | 8 | 8 | 8 | 8.0 |
| | X86 | 17 | 18 | 18 | 17.7 |
| | H27 | 18 | 32 | 16 | 22.0 |
| | F69 | 7 | 9 | 7 | 7.7 |
| | E43 | 2 | 3 | 2 | 2.3 |
| | M47 | 12 | 17 | 10 | 13.0 |
| | Y93 | 22 | 13 | 23 | 19.3 |
| | T00 | 10 | 4 | 11 | 8.3 |
| | S49 | 5 | 6 | 6 | 5.7 |
| **Training II** | S51 | 13 | 11 | 13 | 12.3 |
| | B19 | 33 | 33 | 32 | 32.7 |
| | L87 | 28 | 27 | 24 | 26.3 |
| | W63 | 30 | 25 | 30 | 28.3 |
| | O54 | 29 | 26 | 31 | 28.7 |
| | E38 | 20 | 21 | 20 | 20.3 |
| | Z46 | 35 | 34 | 34 | 34.3 |
| | O59 | 31 | 30 | 33 | 31.3 |
| | T23 | 15 | 19 | 14 | 16.0 |
| | G54 | 27 | 29 | 29 | 28.3 |
| | G69 | 19 | 14 | 19 | 17.3 |
| | N08 | 25 | 23 | 26 | 24.7 |
| | O07 | 11 | 12 | 12 | 11.7 |
| | A96 | 9 | 15 | 9 | 11.0 |
| | L88 | 32 | 28 | 28 | 29.3 |
| | Y42 | 24 | 24 | 27 | 25.0 |
| | X44 | 34 | 35 | 35 | 34.7 |
| | L96 | 26 | 31 | 25 | 27.3 |

**Leeway Scenario**

| | | Average Change in Ice Concentration | End Change in Ice Concentration | Clearing to Distance Ratio | Mean |
|---|---|---|---|---|---|
| Training I | Y06 | 25 | 19 | 22 | 22.0 |
| | E96 | 11 | 19 | 11 | 13.7 |
| | G91 | 1 | 1 | 1 | 1.0 |
| | D76 | 8 | 7 | 6 | 7.0 |
| | L44 | 9 | 8 | 7 | 8.0 |
| | E41 | 27 | 19 | 13 | 19.7 |
| | V55 | 10 | 10 | 9 | 9.7 |
| | A48 | 5 | 3 | 5 | 4.3 |
| | Q76 | 2 | 2 | 2 | 2.0 |
| | X86 | 26 | 19 | 17 | 20.7 |
| | H27 | 7 | 9 | 10 | 8.7 |
| | F69 | 12 | 19 | 14 | 15.0 |
| | E43 | 4 | 4 | 4 | 4.0 |
| | M47 | 21 | 19 | 18 | 19.3 |
| | Y93 | 14 | 19 | 12 | 15.0 |
| | T00 | 6 | 6 | 8 | 6.7 |
| | S49 | 3 | 5 | 3 | 3.7 |
| Training II | S51 | 13 | 13 | 21 | 15.7 |
| | B19 | 29 | 19 | 33 | 27.0 |
| | L87 | 22 | 18 | 15 | 18.3 |
| | W63 | 19 | 19 | 24 | 20.7 |
| | O54 | 15 | 14 | 16 | 15.0 |
| | E38 | 30 | 17 | 27 | 24.7 |
| | Z46 | 33 | 19 | 35 | 29.0 |
| | O59 | 34 | 15 | 23 | 24.0 |
| | T23 | 23 | 19 | 32 | 24.7 |
| | G54 | 31 | 19 | 28 | 26.0 |
| | G69 | 20 | 11 | 26 | 19.0 |
| | N08 | 32 | 16 | 25 | 24.3 |
| | O07 | 18 | 19 | 20 | 19.0 |
| | A96 | 35 | 19 | 34 | 29.3 |
| | L88 | 17 | 19 | 19 | 18.3 |
| | Y42 | 16 | 12 | 30 | 19.3 |
| | X44 | 28 | 19 | 31 | 26.0 |
| | L96 | 24 | 19 | 29 | 24.0 |

**Precautionary Ice Management Scenario**

| | | | Average Change in Ice Concentration | End Change in Ice Concentration | Clearing to Distance Ratio | Mean |
|---|---|---|---|---|---|---|
| Training I | Mild Ice Cond. | Y06 | 12 | 8 | 14 | 11.3 |
| | | E96 | 13 | 17 | 12 | 14.0 |
| | | G91 | 6 | 6 | 15 | 9.0 |
| | | D76 | 8 | 4 | 1 | 4.3 |
| | | L44 | 16 | 14 | 5 | 11.7 |
| | | E41 | 15 | 16 | 11 | 14.0 |
| | | V55 | 9 | 3 | 10 | 7.3 |
| | | A48 | 2 | 10 | 4 | 5.3 |
| | Severe Ice Cond. | Q76 | 10 | 12 | 13 | 11.7 |
| | | X86 | 11 | 7 | 9 | 9.0 |
| | | H27 | 3 | 4 | 6 | 4.3 |
| | | F69 | 4 | 16 | 4 | 8.0 |
| | | E43 | 13 | 18 | 16 | 15.7 |
| | | M47 | 12 | 11 | 3 | 8.7 |
| | | Y93 | 5 | 6 | 5 | 5.3 |
| | | T00 | 2 | 9 | 2 | 4.3 |
| | | S49 | 6 | 14 | 14 | 11.3 |
| Training II | Mild Ice Cond. | S51 | 1 | 1 | 2 | 1.3 |
| | | B19 | 5 | 12 | 6 | 7.7 |
| | | L87 | 3 | 2 | 3 | 2.7 |
| | | W63 | 14 | 13 | 16 | 14.3 |
| | | O54 | 10 | 11 | 9 | 10.0 |
| | | E38 | 11 | 9 | 13 | 11.0 |
| | | Z46 | 17 | 7 | 17 | 13.7 |
| | | O59 | 4 | 15 | 7 | 8.7 |
| | | T23 | 7 | 5 | 8 | 6.7 |
| | Severe Ice Cond. | G54 | 16 | 10 | 15 | 13.7 |
| | | G69 | 8 | 2 | 8 | 6.0 |
| | | N08 | 17 | 13 | 11 | 13.7 |
| | | O07 | 14 | 15 | 17 | 15.3 |
| | | A96 | 1 | 1 | 1 | 1.0 |
| | | L88 | 15 | 17 | 12 | 14.7 |
| | | Y42 | 7 | 5 | 10 | 7.3 |
| | | X44 | 18 | 3 | 18 | 13.0 |
| | | L96 | 9 | 8 | 7 | 8.0 |

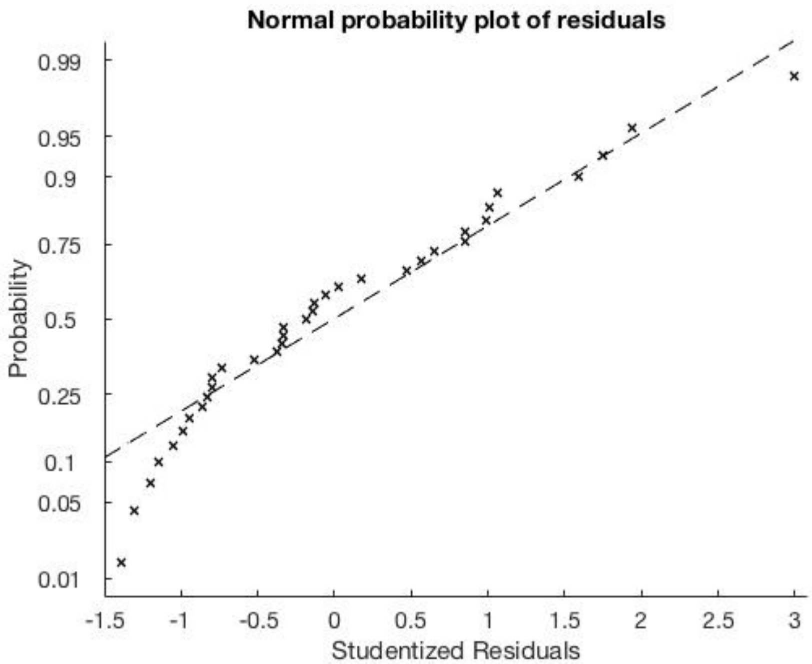
**Emergency Ice Management Scenario**

| | | | Average Change in Ice Con. | End Change in Ice Con. | Clearing to Distance Ratio | Lifeboat Launch Zone | Mean |
|---|---|---|---|---|---|---|---|
| Training 0 | Mild Ice Cond. | Z00 | 6 | 9 | 4 | 3 | 5.5 |
| | | Z43 | 26 | 15 | 16 | 10 | 16.8 |
| | | X38 | 16 | 2 | 10 | 14 | 10.5 |
| | | R60 | 3 | 20 | 5 | 5 | 8.3 |
| | | G40 | 13 | 22 | 6 | 3 | 11.0 |
| | | E73 | 12 | 5 | 7 | 13 | 9.3 |
| | | N25 | 4 | 28 | 9 | 35 | 19.0 |
| | | S28 | 1 | 24 | 1 | 1 | 6.8 |
| | | O35 | 2 | 10 | 3 | 32 | 11.8 |
| | Severe Ice Cond. | R13 | 15 | 19 | 8 | 7 | 12.3 |
| | | W28 | 4 | 5 | 5 | 11 | 6.3 |
| | | J42 | 9 | 22 | 11 | 1 | 10.8 |
| | | Z70 | 6 | 10 | 6 | 32 | 13.5 |
| | | T69 | 18 | 20 | 12 | 10 | 15.0 |
| | | Z11 | 3 | 12 | 2 | 6 | 5.8 |
| | | C07 | 1 | 1 | 1 | 3 | 1.5 |
| | | R98 | 17 | 23 | 10 | 19 | 17.3 |
| | | L90 | 26 | 25 | 20 | 16 | 21.8 |
| Training I | Mild Ice Cond. | Y06 | 29 | 27 | | 15 | 23.7 |
| | | E96 | 14 | 13 | 13 | 18 | 14.5 |
| | | G91 | 10 | 7 | | 6 | 7.7 |
| | | D76 | 5 | 4 | 2 | 17 | 7.0 |
| | | L44 | 34 | 26 | 24 | 28 | 28.0 |
| | | E41 | 35 | 35 | 27 | 31 | 32.0 |
| | | V55 | 22 | 3 | 22 | 11 | 14.5 |
| | | A48 | 31 | 12 | | 8 | 17.0 |
| | Severe Ice Cond. | Q76 | 13 | 27 | 16 | 28 | 21.0 |
| | | X86 | 21 | 2 | 22 | 15 | 15.0 |
| | | H27 | 30 | 31 | 33 | 24 | 29.5 |
| | | F69 | 14 | 30 | 14 | 13 | 17.8 |
| | | E43 | 7 | 4 | 23 | 18 | 13.0 |
| | | M47 | 8 | 32 | 9 | 17 | 16.5 |
| | | Y93 | 23 | 26 | 25 | 27 | 25.3 |
| | | T00 | 5 | 14 | 7 | 4 | 7.5 |
| | | S49 | 36 | 34 | 35 | 8 | 28.3 |
| | | | | | | | |

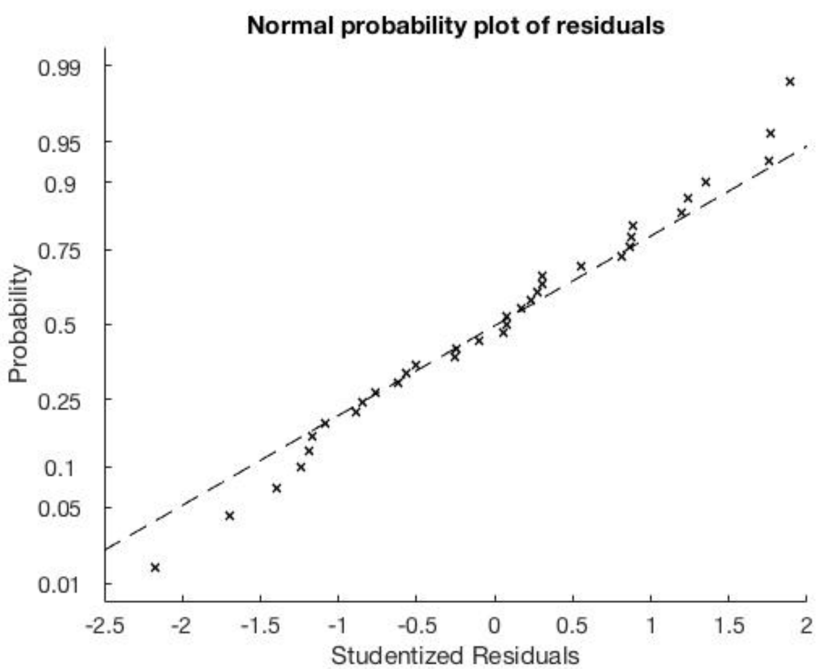
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Training II** | **Mild Ice Cond.** | S51 | 9 | 14 | 12 | 8 | 10.8 |
| | | B19 | 30 | 21 | 23 | 20 | 23.5 |
| | | L87 | 25 | 11 | 18 | 22 | 19.0 |
| | | W63 | 18 | 25 | 26 | 2 | 17.8 |
| | | O54 | 19 | 32 | 25 | 30 | 26.5 |
| | | E38 | 33 | 30 | 28 | 24 | 28.8 |
| | | Z46 | 32 | 29 | 15 | 15 | 22.8 |
| | | O59 | 20 | 31 | | 26 | 25.7 |
| | | T23 | 17 | 33 | 14 | 21 | 21.3 |
| | **Severe Ice Cond.** | G54 | 35 | 35 | 29 | 8 | 26.8 |
| | | G69 | 11 | 8 | 13 | 33 | 16.3 |
| | | N08 | 20 | 13 | 18 | 29 | 20.0 |
| | | O07 | 24 | 28 | 31 | 25 | 27.0 |
| | | A96 | 25 | 11 | 15 | 21 | 18.0 |
| | | L88 | 32 | 21 | 32 | 31 | 29.0 |
| | | Y42 | 34 | 36 | 30 | 20 | 30.0 |
| | | X44 | 10 | 15 | | 29 | 18.0 |
| | | L96 | 16 | 33 | 19 | 22 | 22.5 |
| **Seafarers** | **Mild Ice Cond.** | K50 | 15 | 16 | 19 | 25 | 18.8 |
| | | D67 | 11 | 6 | | 29 | 15.3 |
| | | V53 | 21 | 19 | | 34 | 24.7 |
| | | B97 | 7 | 8 | 8 | 26 | 12.3 |
| | | K82 | 27 | 18 | 17 | 23 | 21.3 |
| | | Z53 | 23 | 1 | 21 | 18 | 15.8 |
| | | A57 | 28 | 34 | 20 | 33 | 28.8 |
| | | G54 | 8 | 23 | 11 | 6 | 12.0 |
| | | G69 | 24 | 17 | | 11 | 17.3 |
| | **Severe Ice Cond.** | R73 | 31 | 18 | 3 | 22 | 18.5 |
| | | C79 | 22 | 16 | 34 | 36 | 27.0 |
| | | S41 | 12 | 7 | 24 | 2 | 11.3 |
| | | M85 | 28 | 9 | 26 | 34 | 24.3 |
| | | Q55 | 33 | 29 | 17 | 12 | 22.8 |
| | | A90 | 19 | 6 | 21 | 35 | 20.3 |
| | | U85 | 27 | 23 | 27 | 14 | 22.8 |
| | | M90 | 29 | 17 | 28 | 26 | 25.0 |
| | | R94 | 2 | 3 | 4 | 5 | 3.5 |

# Appendix J: Normal Probability Plots of Residuals

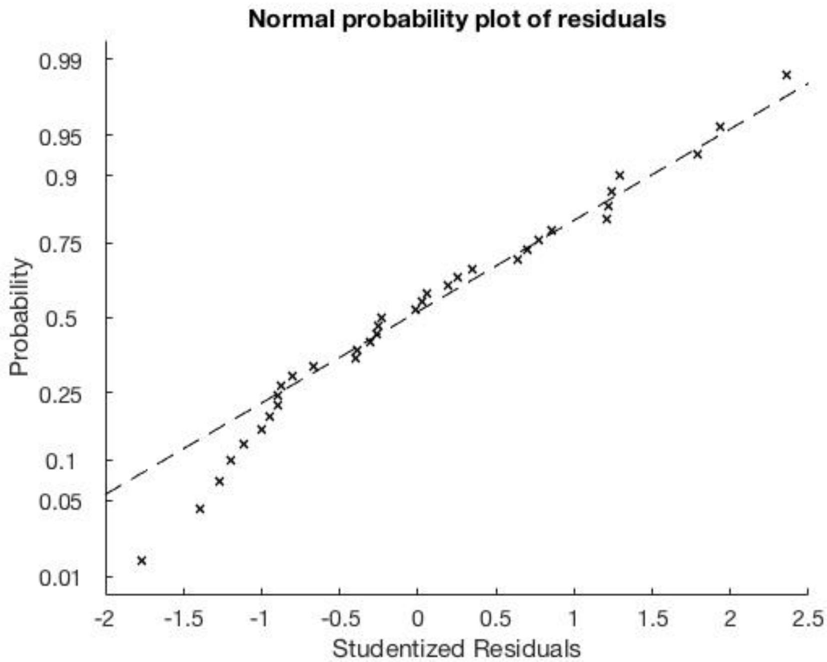
### Pushing Scenario – Average Change in Ice Concentration



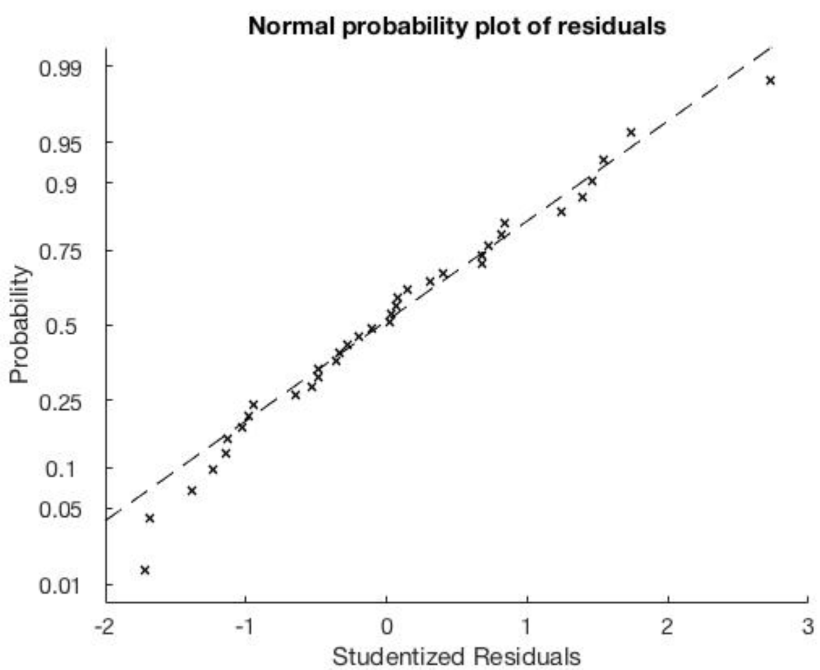

### Pushing Scenario – End Change in Ice Concentration



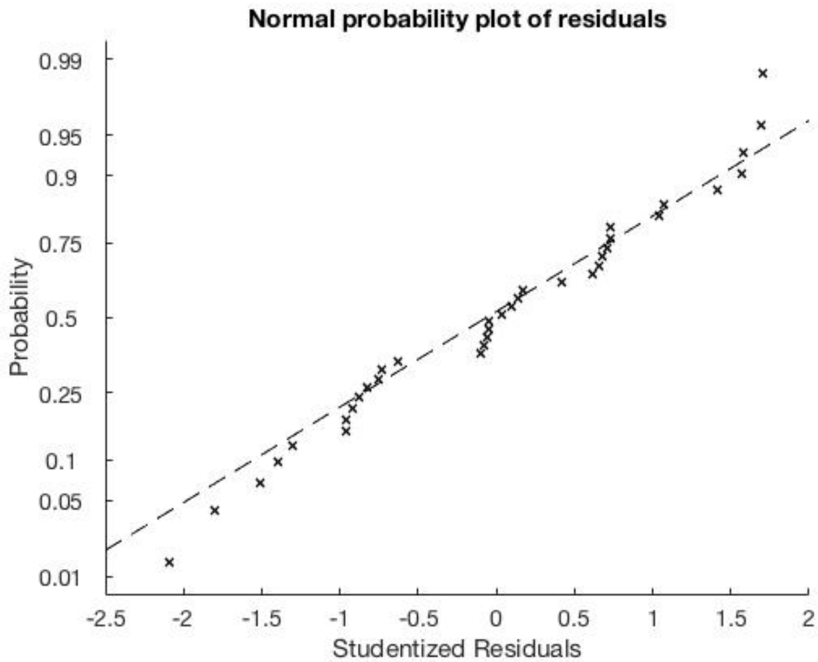
### Pushing Scenario – Clearing to Distance Ratio



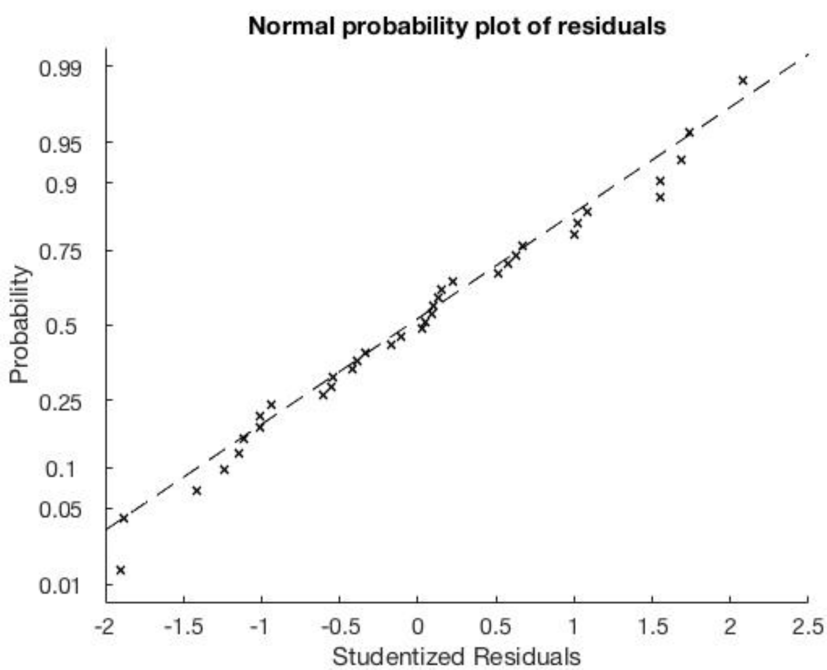

### Pushing Scenario – Within Subject – Average Change in Ice Concentration



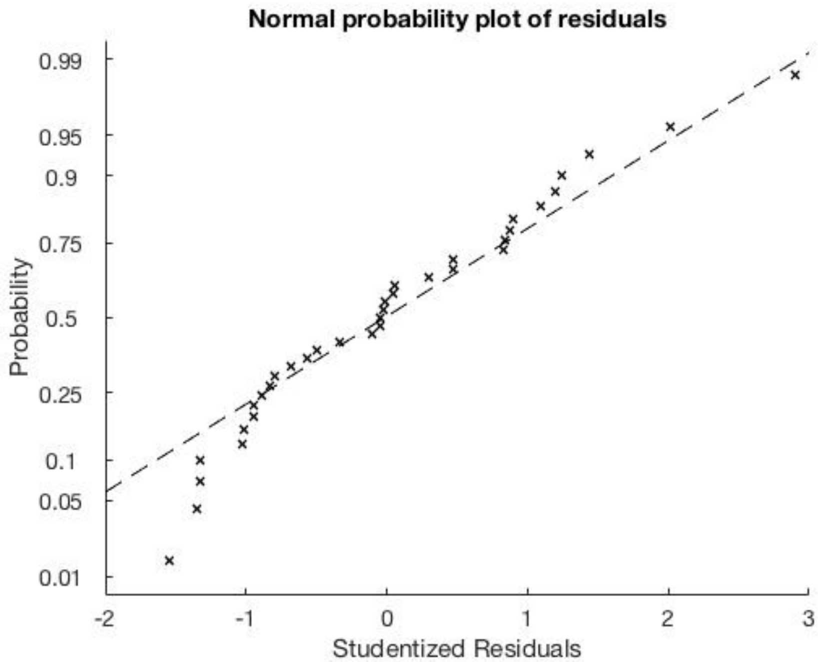
**Pushing Scenario – Within Subject – End Change in Ice Concentration**



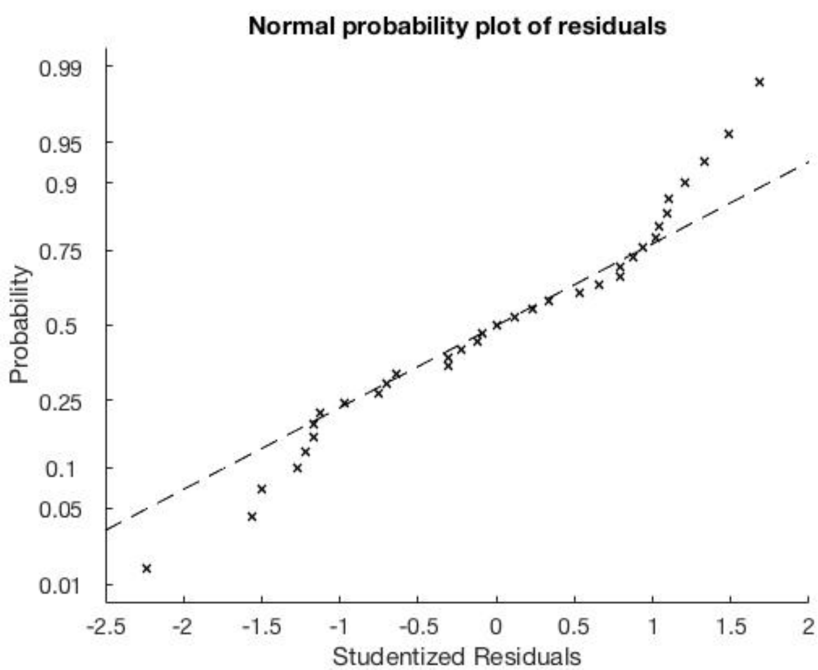

**Pushing Scenario – Within Subject – Clearing to Distance Ratio**



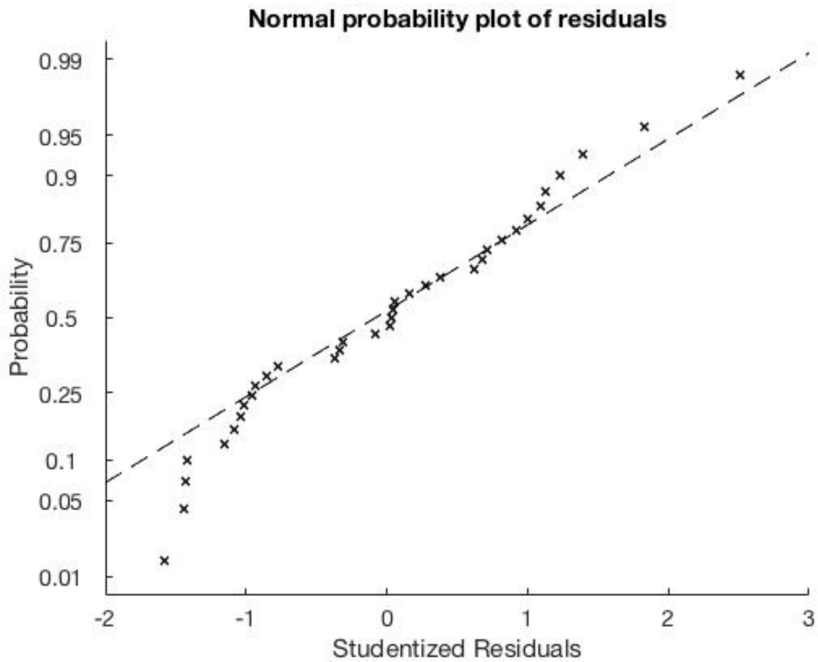
**Prop Wash Scenario – Average Change in Ice Concentration**



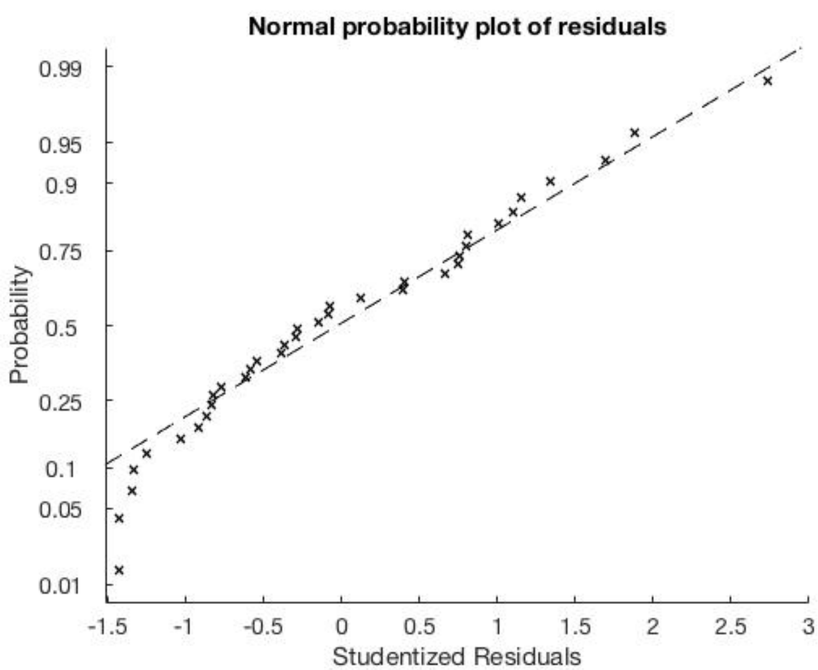

**Prop Wash Scenario – End Change in Ice Concentration**



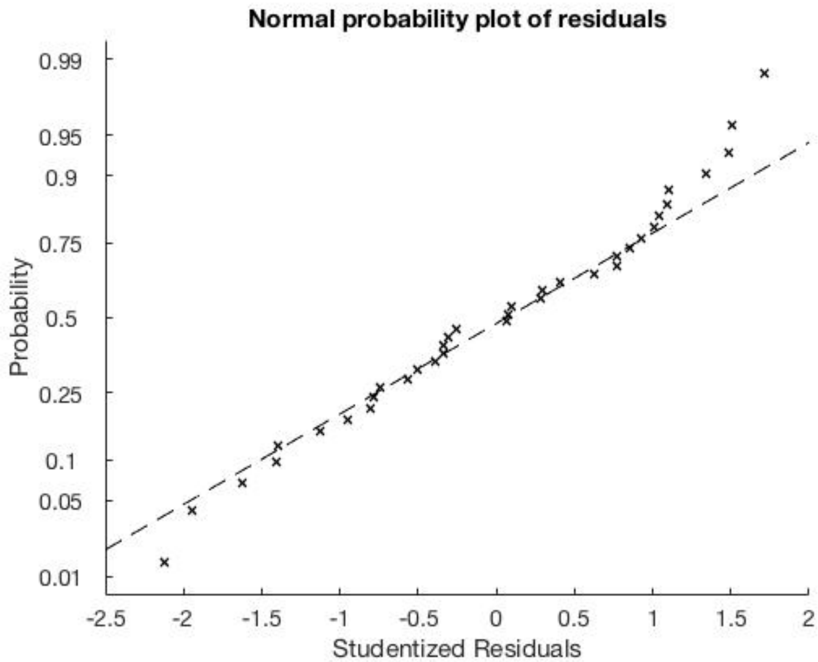
### Prop Wash Scenario – Clearing to Distance Ratio



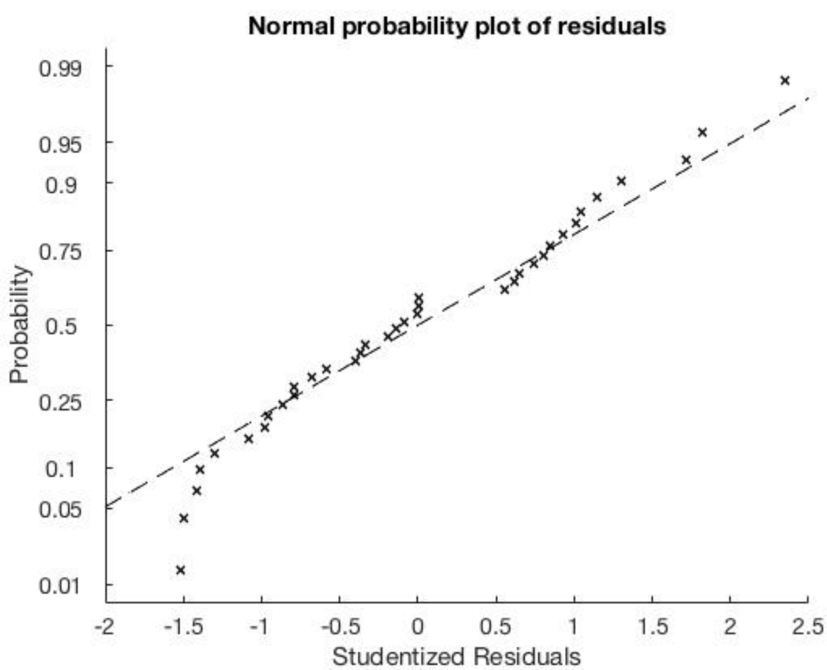

### Prop Wash Scenario – Within Subject – Average Change in Ice Concentration



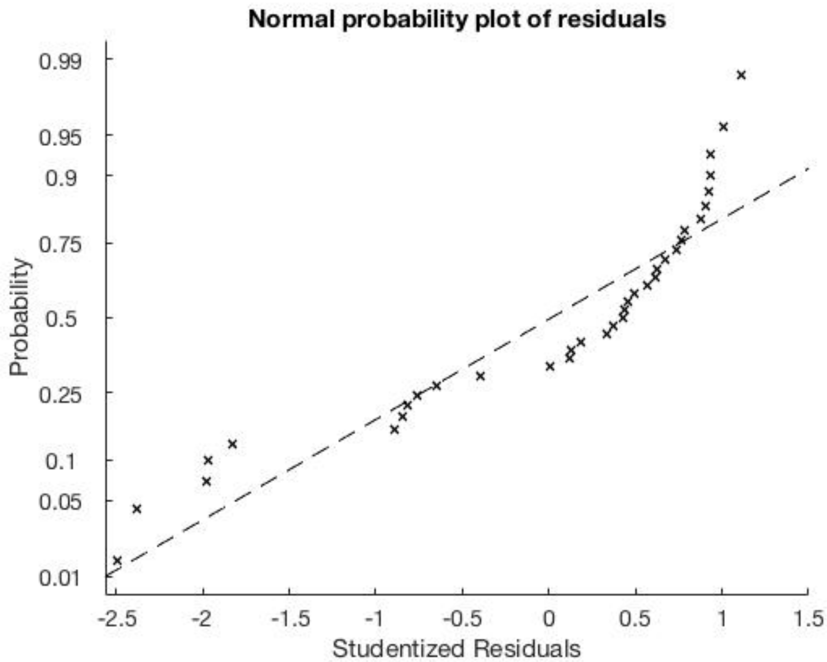
**Prop Wash Scenario – Within Subject – End Change in Ice Concentration**



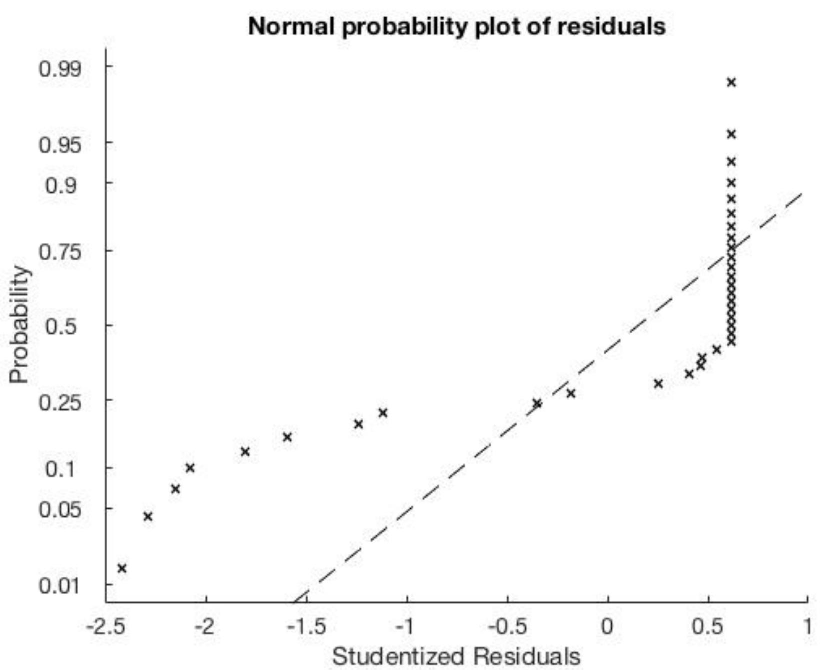

**Prop Wash Scenario – Within Subject – Clearing to Distance Ratio**



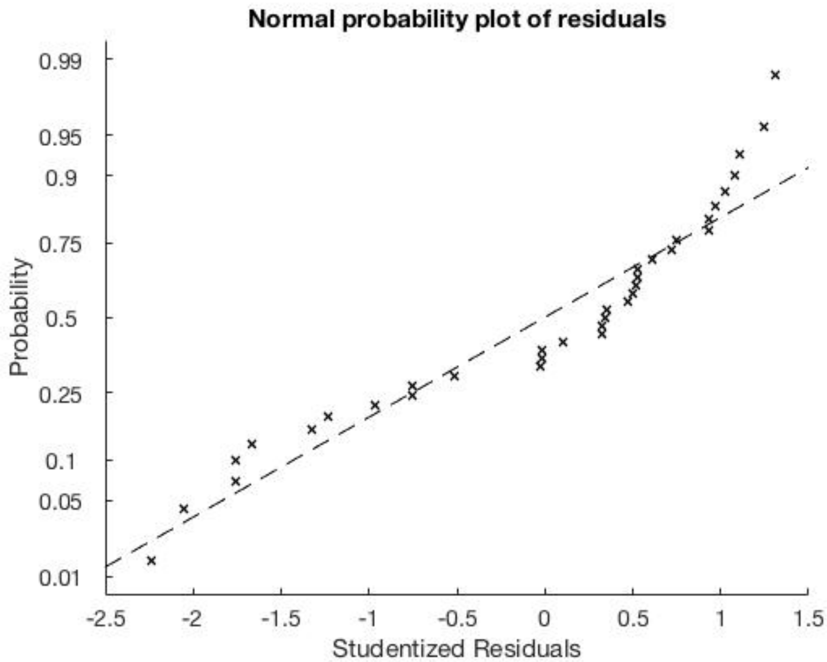
## Leeway Scenario – Average Change in Ice Concentration



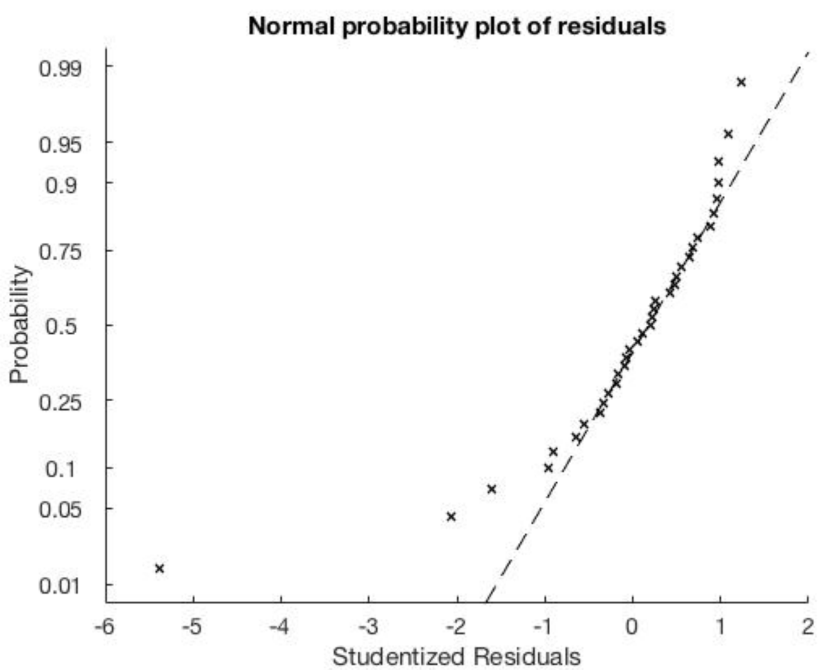

## Leeway Scenario – End Change in Ice Concentration



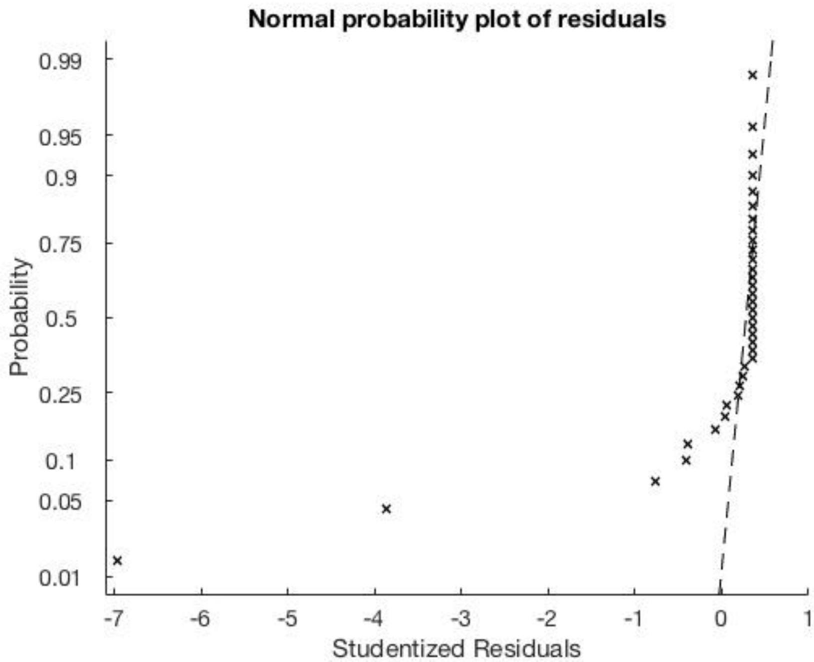
**Leeway Scenario – Clearing to Distance Ratio**



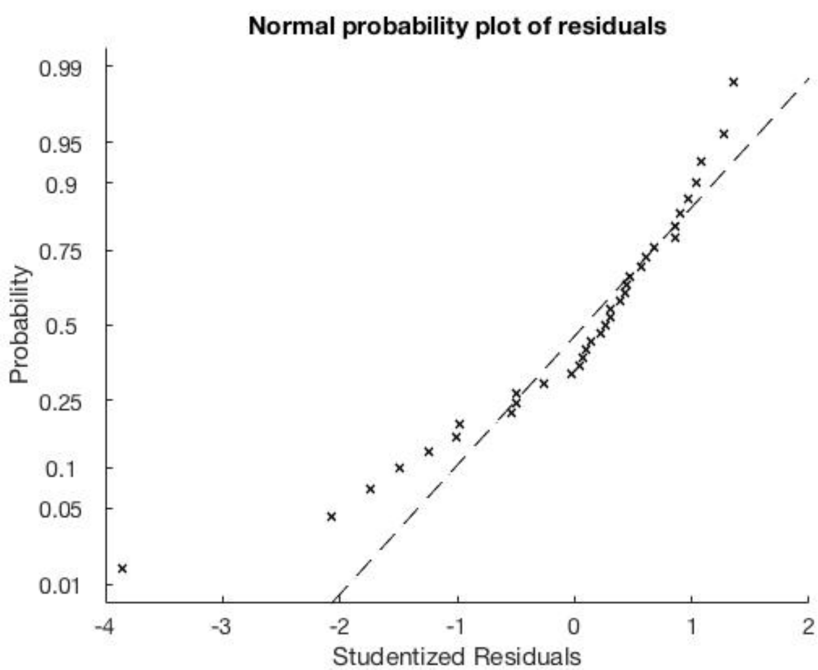

**Leeway Scenario – Within Subject – Average Change in Ice Concentration**



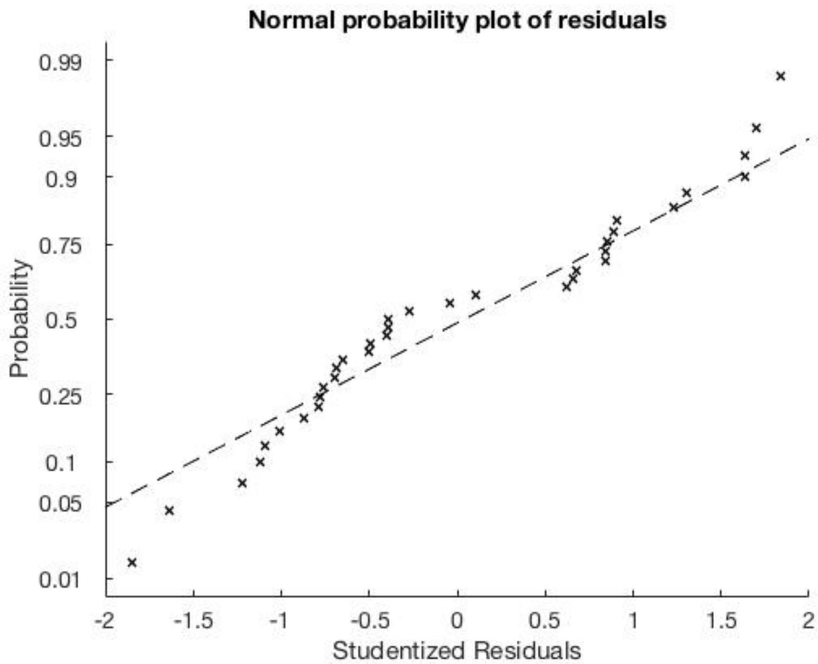
**Leeway Scenario – Within Subject – End Change in Ice Concentration**



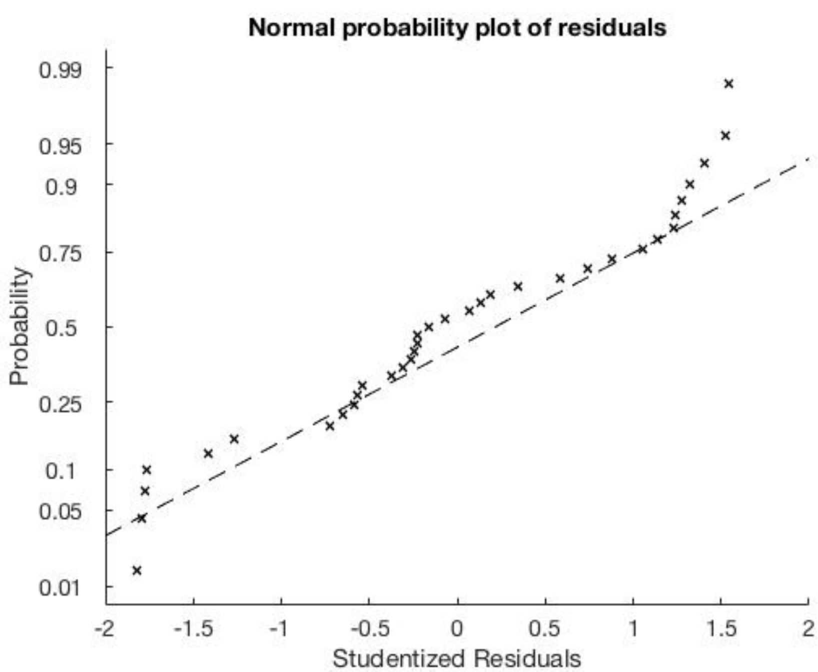

**Leeway Scenario – Within Subject – Clearing to Distance Ratio**



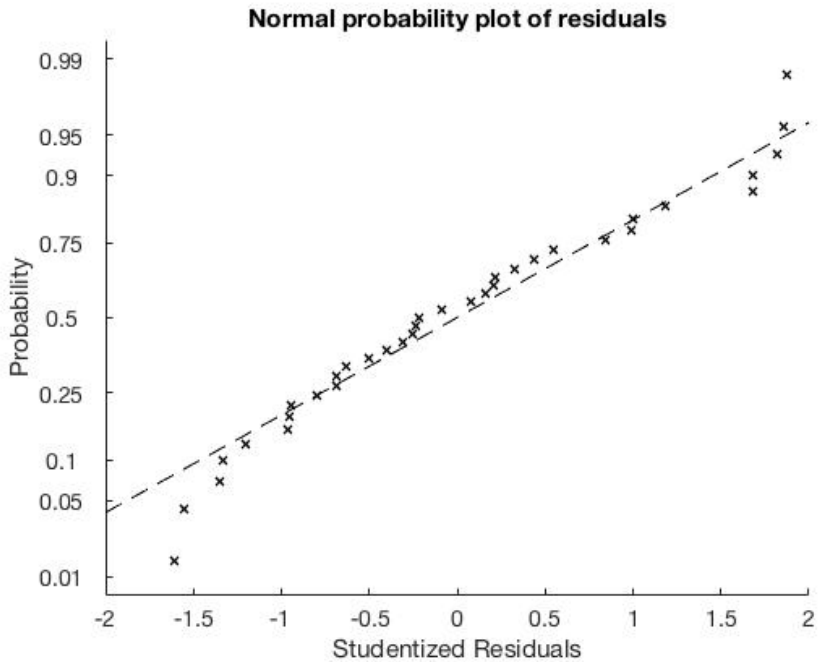
**Precautionary Ice Management Scenario – Average Change in Ice Concentration**



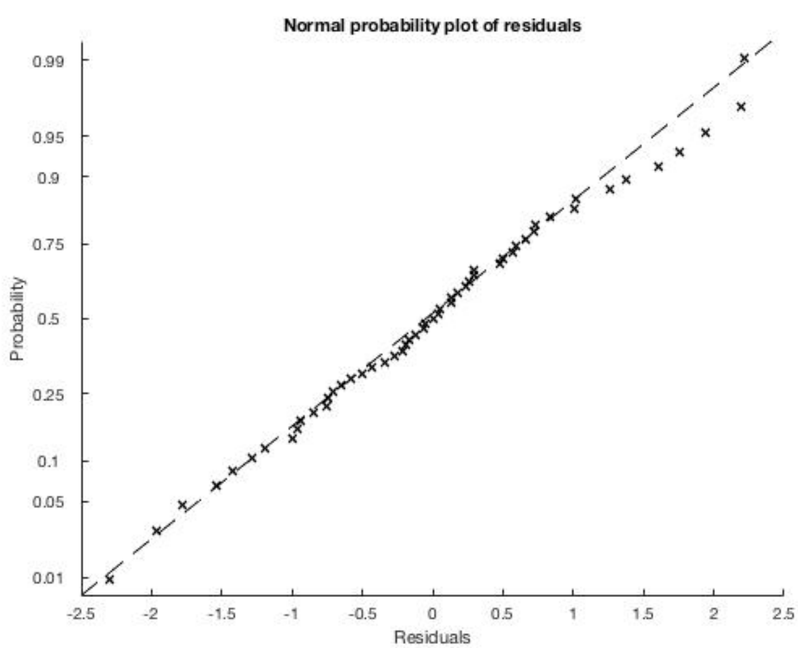

**Precautionary Ice Management Scenario – End Change in Ice Concentration**



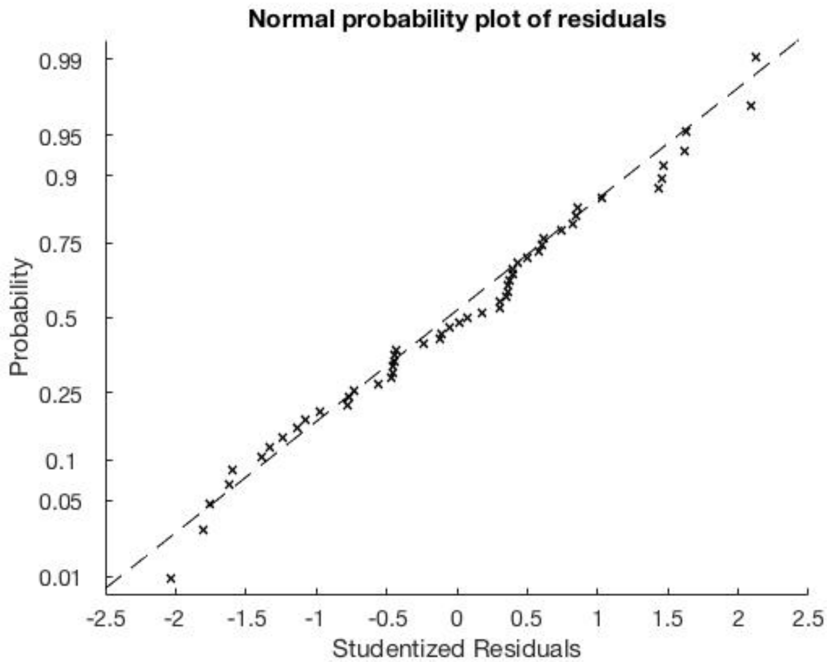
### Precautionary Ice Management Scenario – Clearing to Distance Ratio



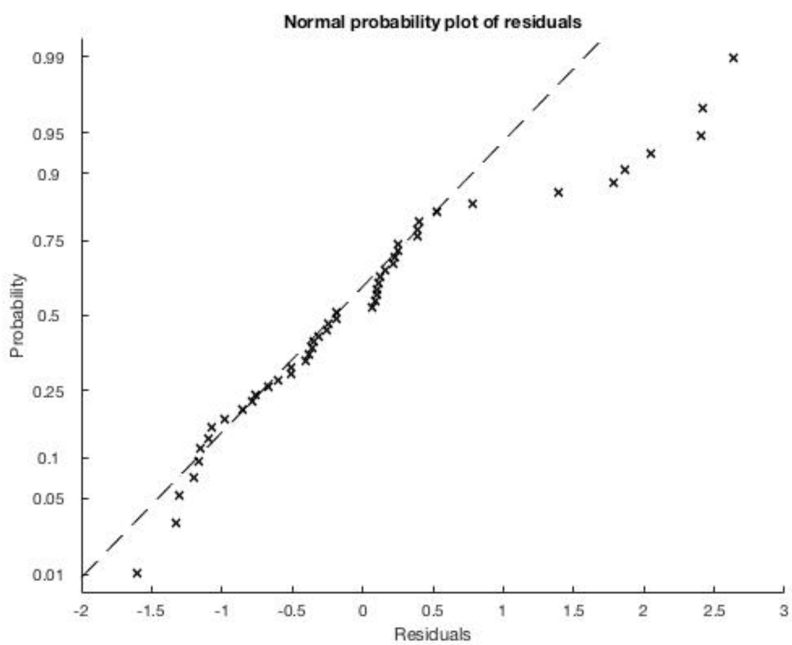

### Emergency Ice Management Scenario – Average Change in Ice Concentration



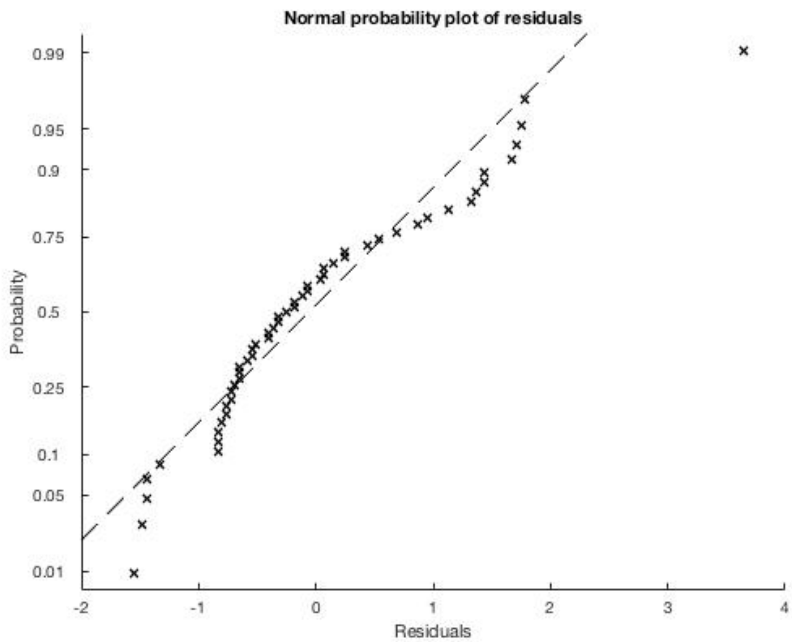
**Emergency Ice Management Scenario – End Change in Ice Concentration**



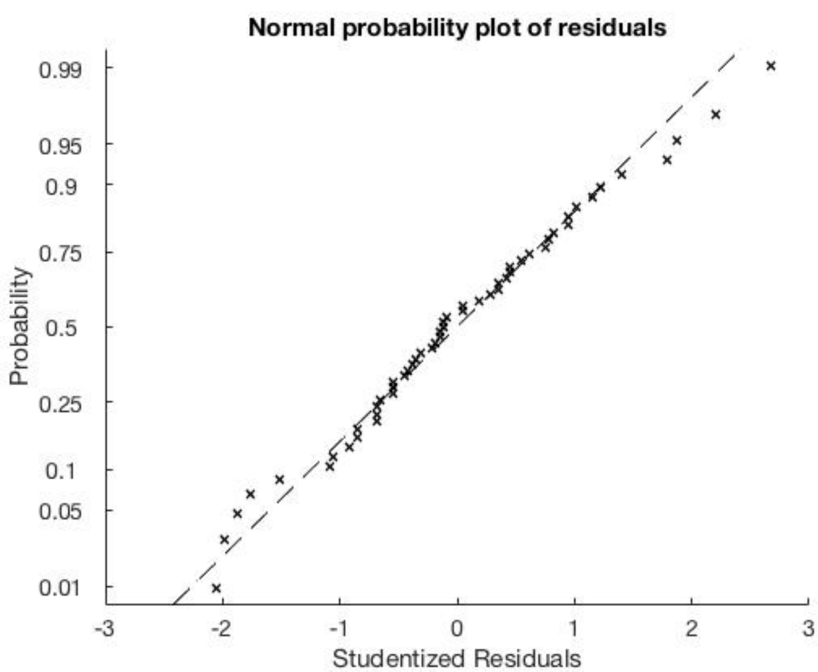

**Emergency Ice Management Scenario – Clearing to Distance Ratio**



## Emergency Ice Management Scenario – Longest Time Lifeboat Launch Zone is Clear

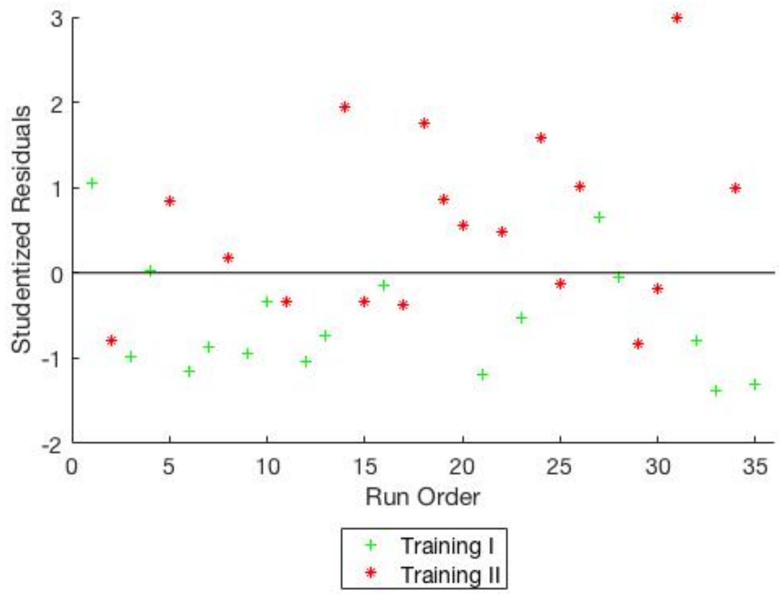



## Emergency Ice Management Scenario – Total Time Lifeboat Launch Zone is Clear

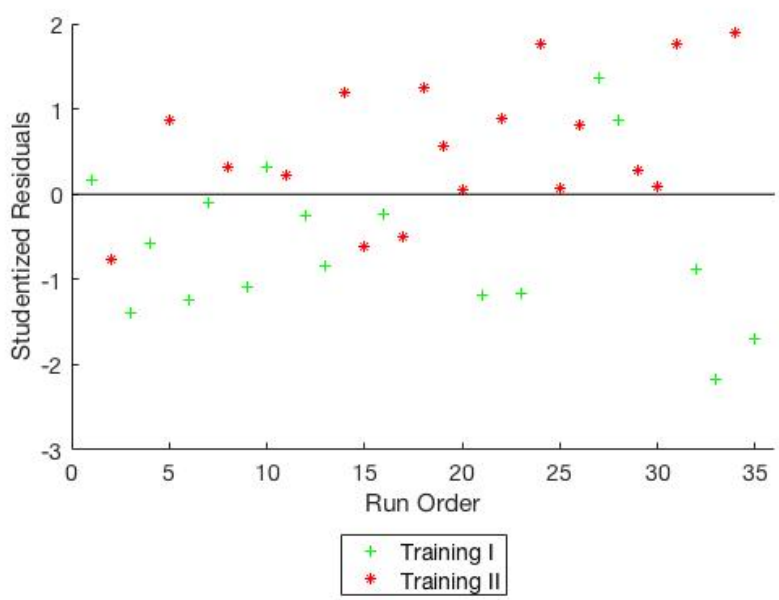


## Appendix K: Residuals vs. Run Order Plots

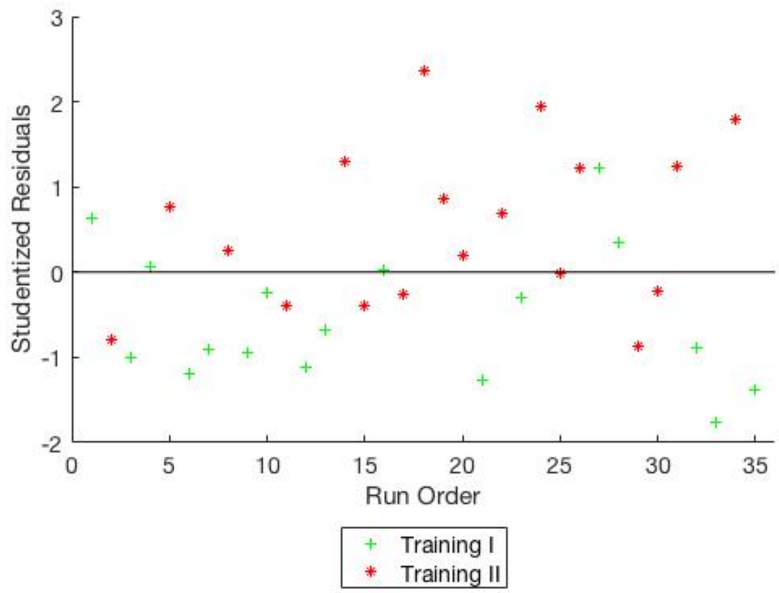
### Pushing Scenario – Average Change in Ice Concentration



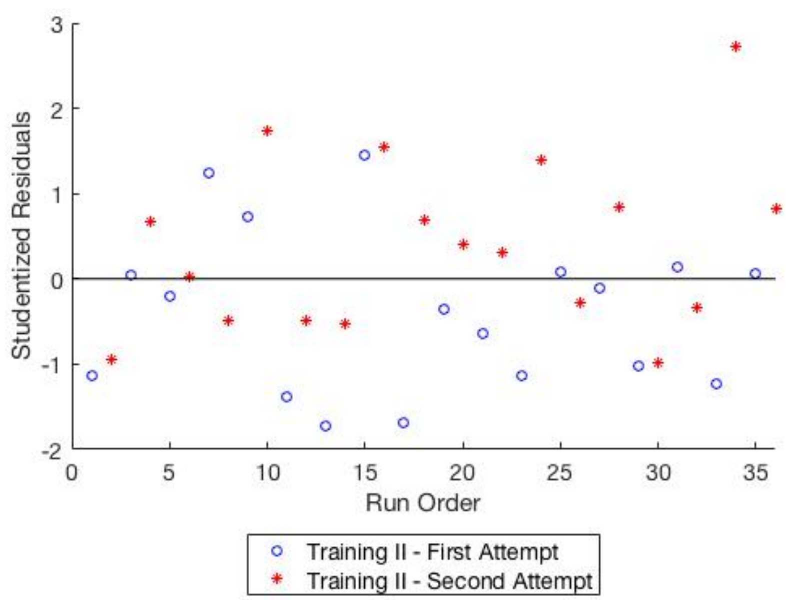

### Pushing Scenario – End Change in Ice Concentration



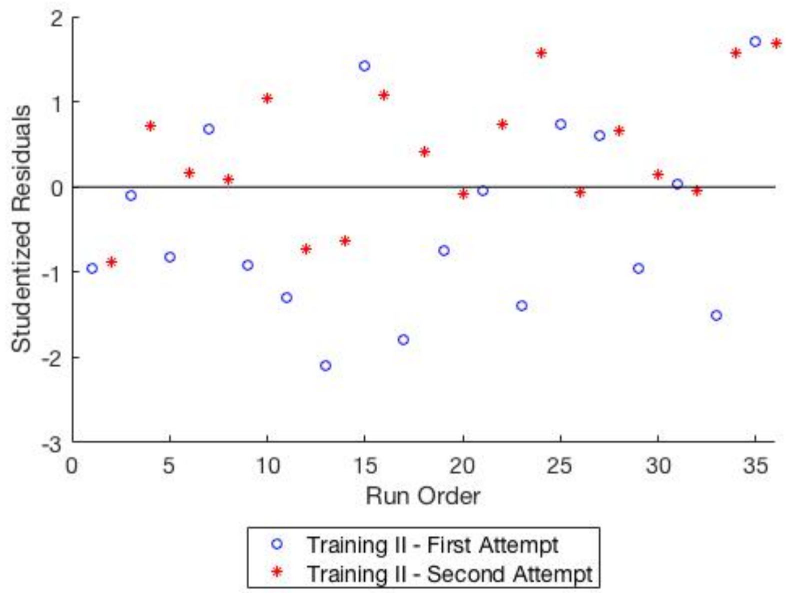
**Pushing Scenario – Clearing to Distance Ratio**



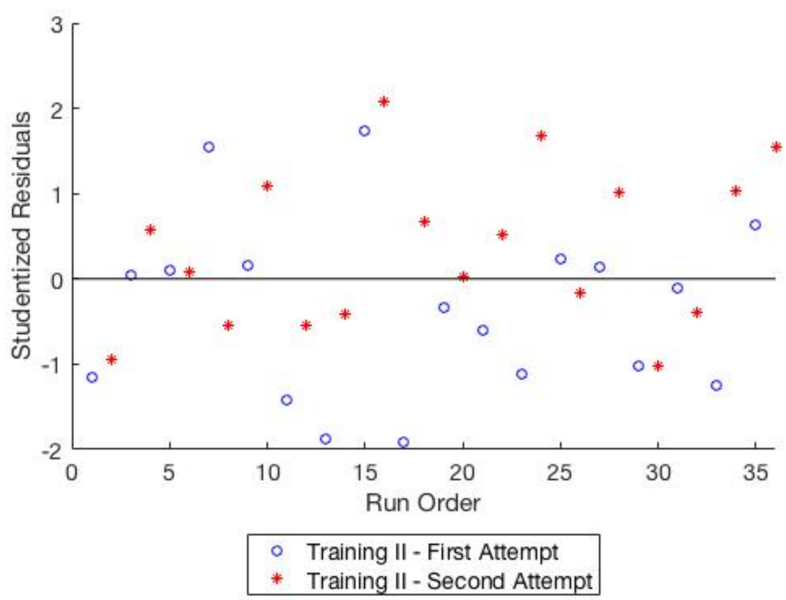

**Pushing Scenario – Within Subject – Average Change in Ice Concentration**



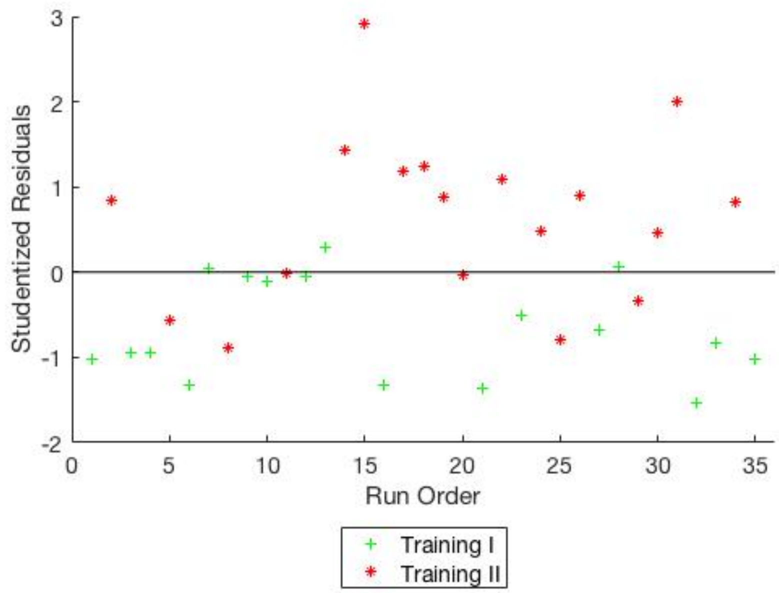
**Pushing Scenario – Within Subject – End Change in Ice Concentration**



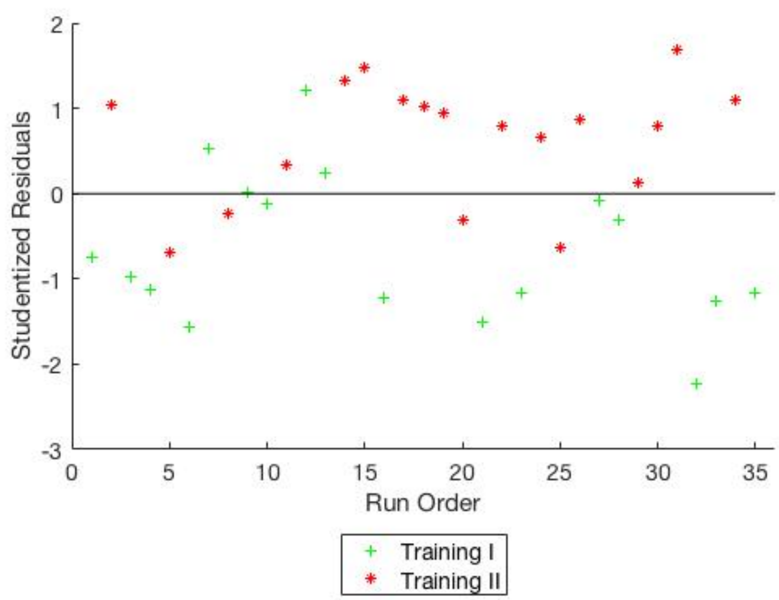

**Pushing Scenario – Within Subject – Clearing to Distance Ratio**



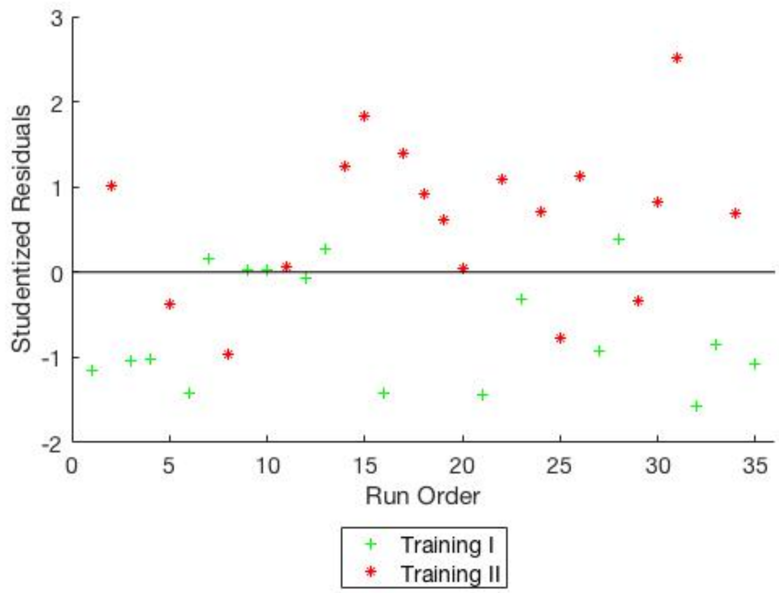
**Prop Wash Scenario – Average Change in Ice Concentration**



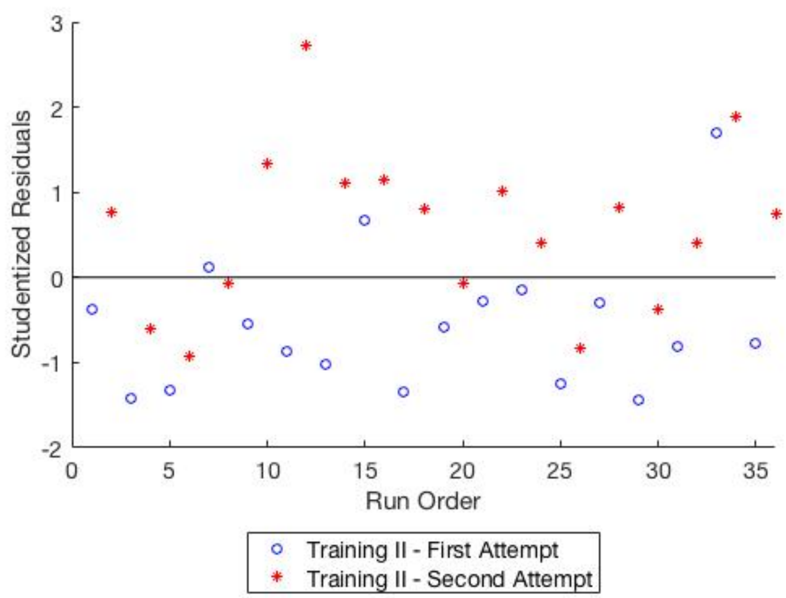

**Prop Wash Scenario – End Change in Ice Concentration**



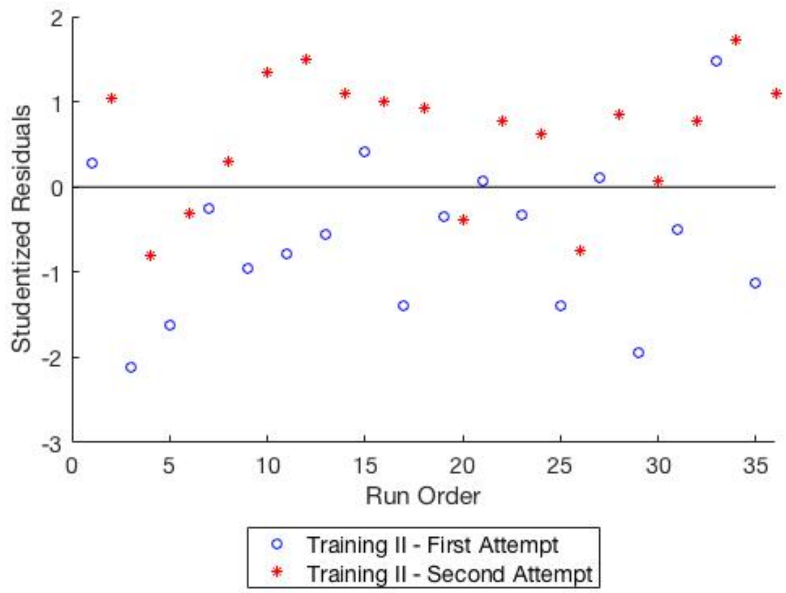
**Prop Wash Scenario – Clearing to Distance Ratio**



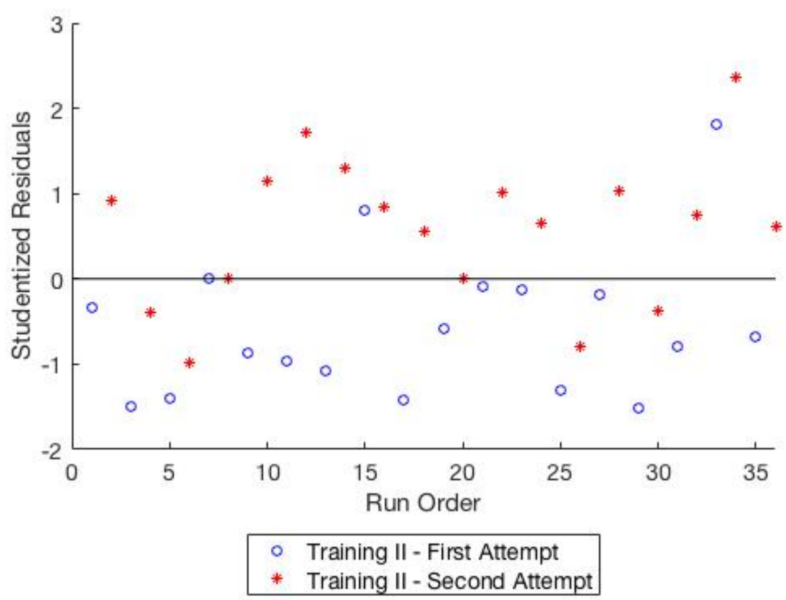

**Prop Wash Scenario – Within Subject – Average Change in Ice Concentration**



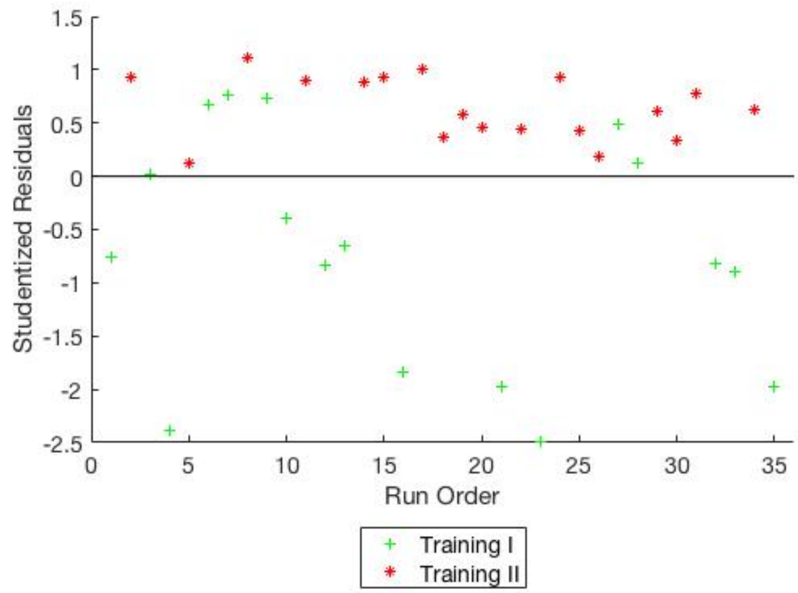
**Prop Wash Scenario – Within Subject – End Change in Ice Concentration**



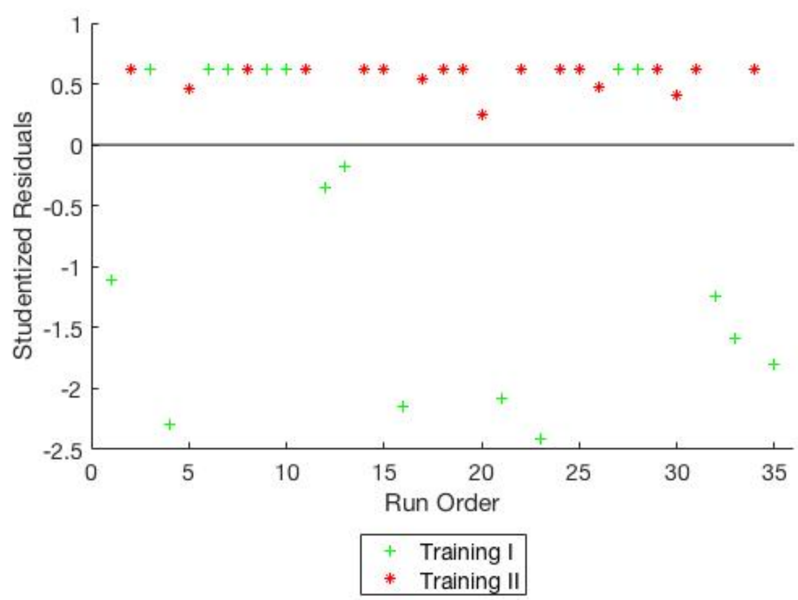

**Prop Wash Scenario – Within Subject – Clearing to Distance Ratio**



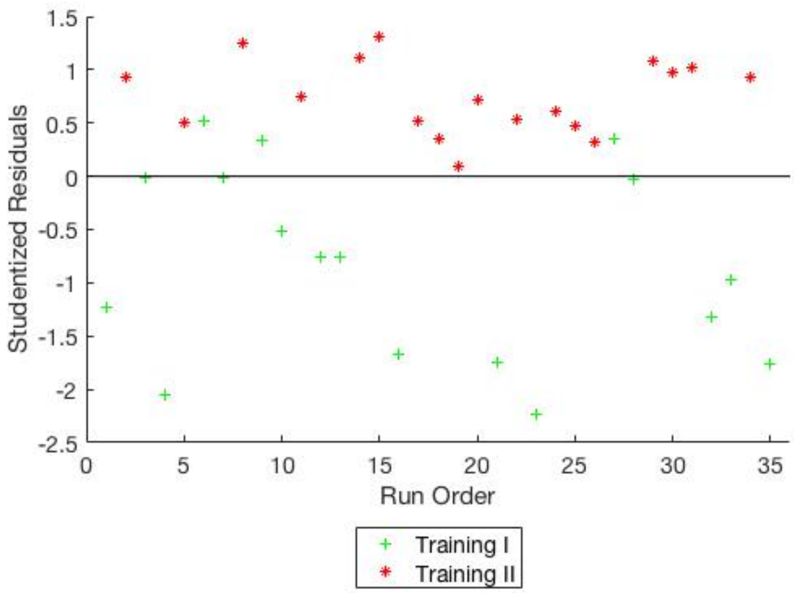
**Leeway Scenario – Average Change in Ice Concentration**



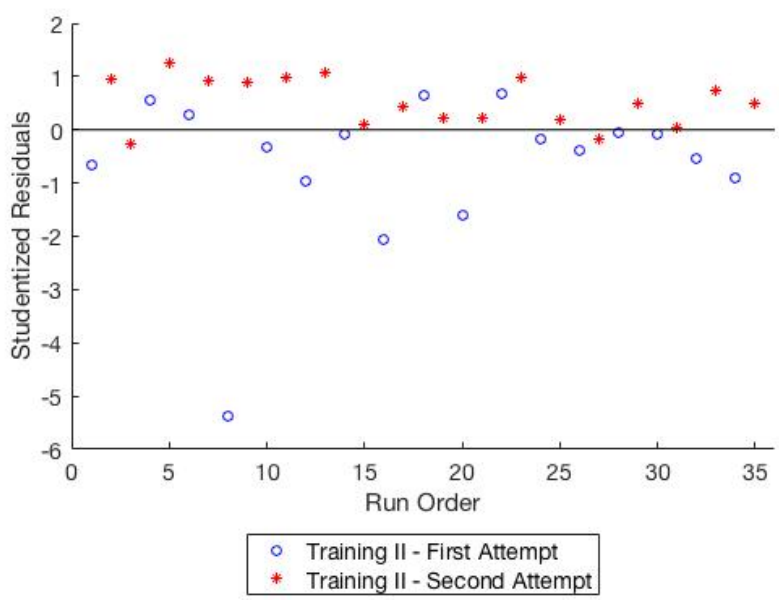

**Leeway Scenario – End Change in Ice Concentration**



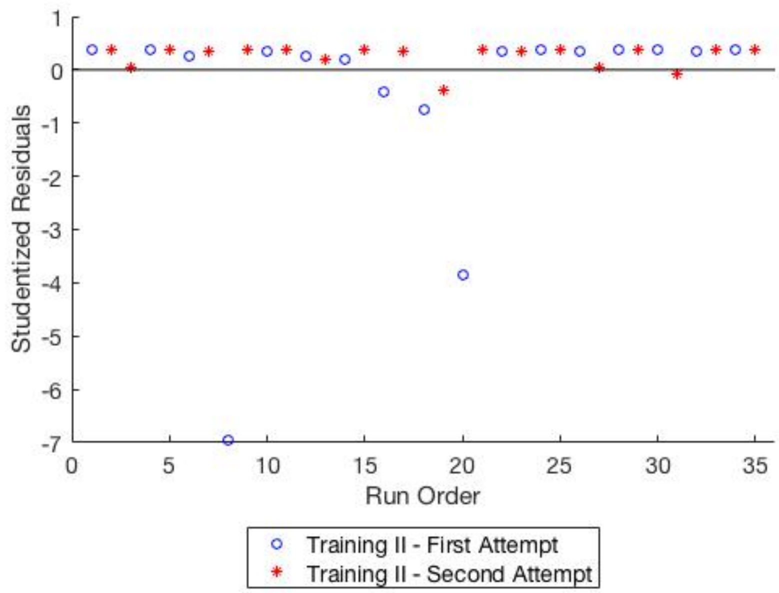
**Leeway Scenario – Clearing to Distance Ratio**



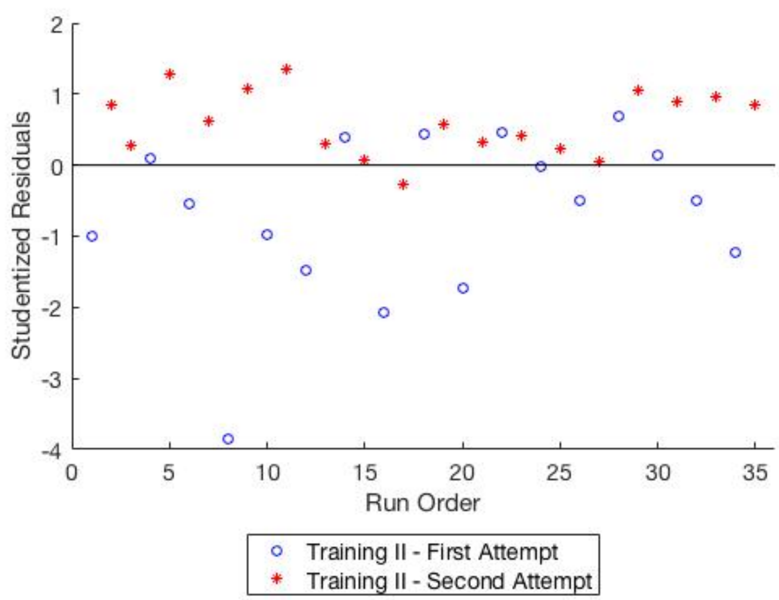

**Leeway Scenario – Within Subject – Average Change in Ice Concentration**



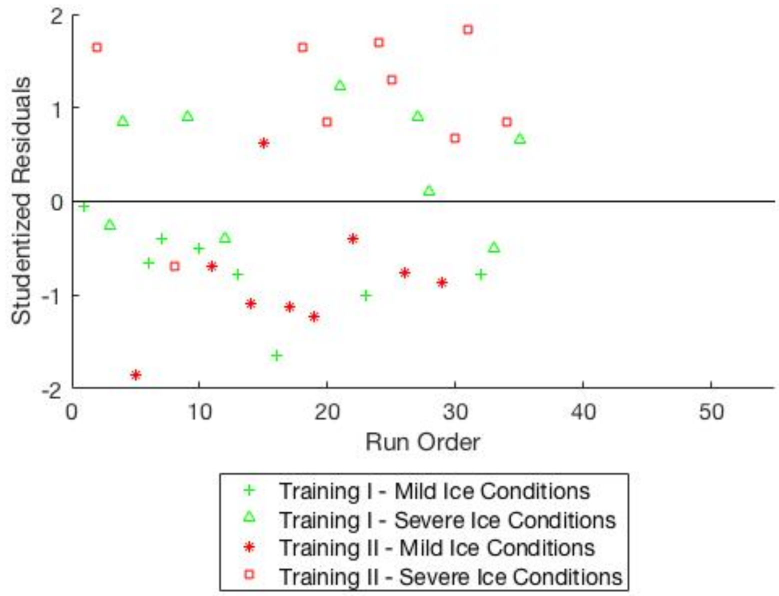
**Leeway Scenario – Within Subject – End Change in Ice Concentration**



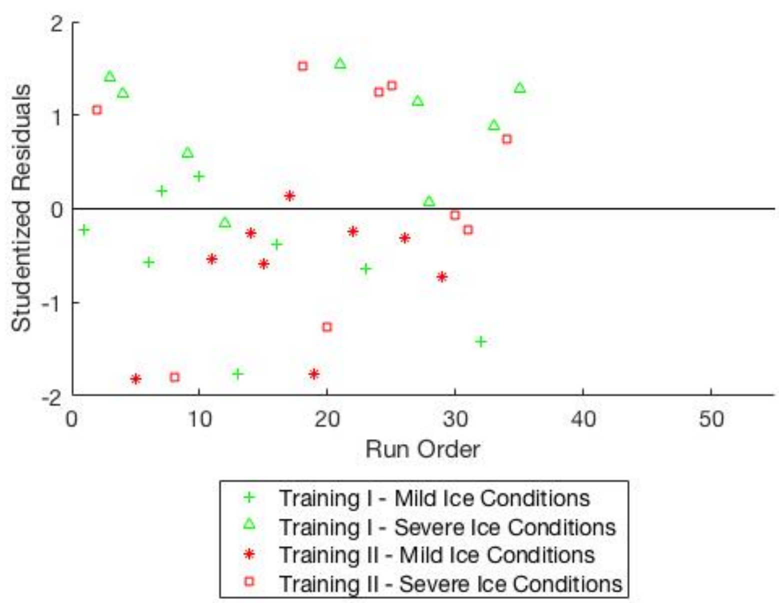

**Leeway Scenario – Within Subject – Clearing to Distance Ratio**



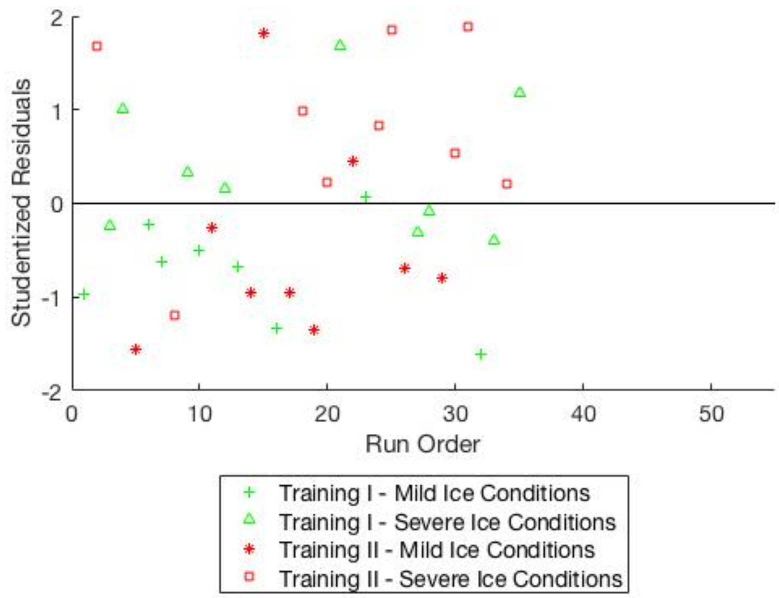
## Precautionary Ice Management Scenario – Average Change in Ice Concentration



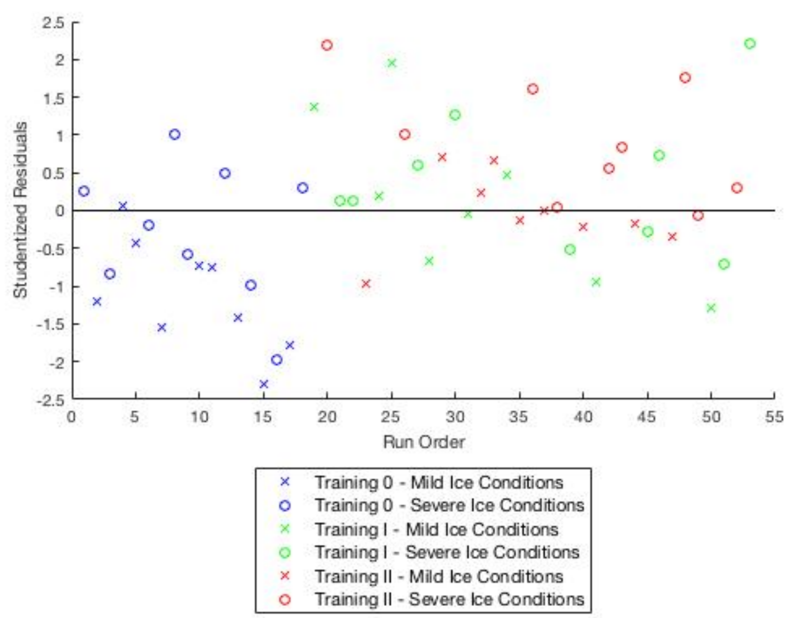

## Precautionary Ice Management Scenario – End Change in Ice Concentration



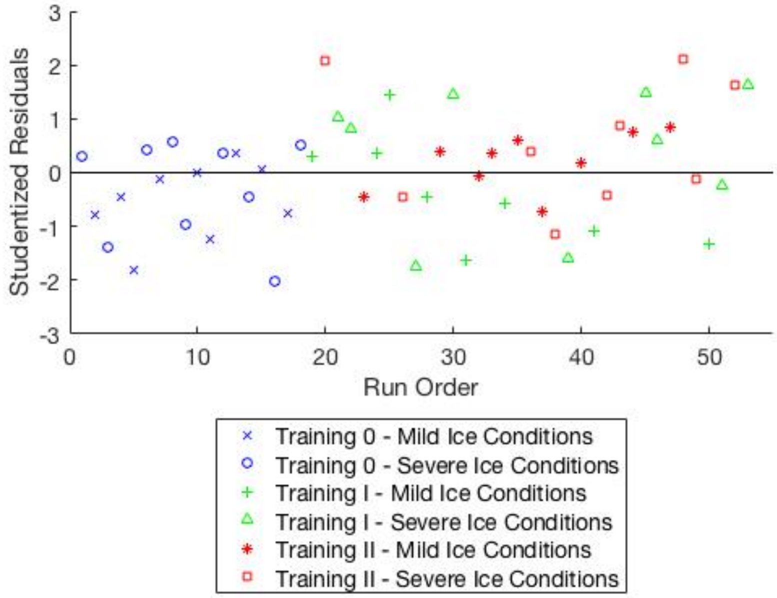
**Precautionary Ice Management Scenario – Clearing to Distance Ratio**



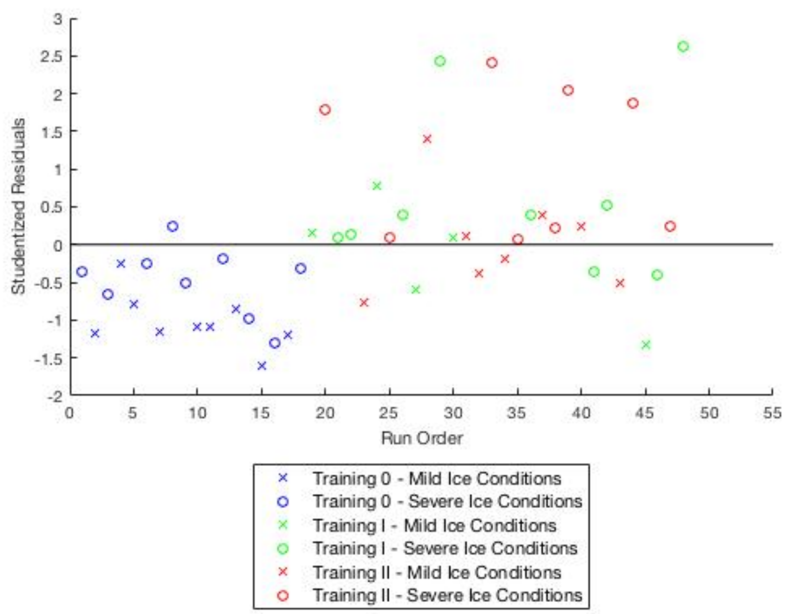

**Emergency Ice Management Scenario – Average Change in Ice Concentration**



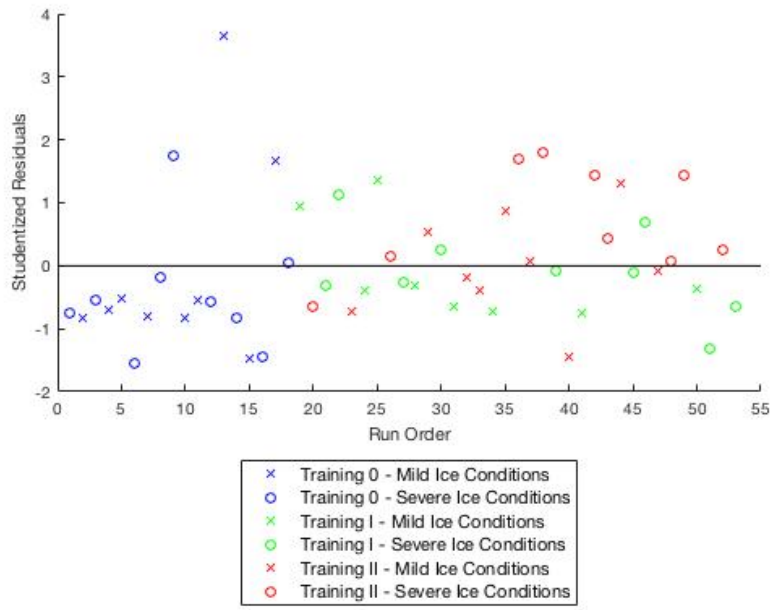
**Emergency Ice Management Scenario – End Change in Ice Concentration**




**Emergency Ice Management Scenario – Clearing to Distance Ratio**



**Emergency Ice Management Scenario – Longest Time Lifeboat Launch Zone is Clear**




**Emergency Ice Management Scenario – Total Time Lifeboat Launch Zone is Clear**