Investigating Work Processes to Manage Noise Exposure for Crew Members On-Board Fishing Vessels

by

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Abstract

Occupational noise exposure is a major health hazard on fishing vessels and can cause noise-induced hearing loss in crew members. Previous studies have suggested different solutions to mitigate noise exposure, such as the use of hearing protections in accordance with relevant standards, the increase of insulation of on board spaces, and the insulation and structural decoupling of acoustic sources. The current study identifies human factors that cause high-level noise during whelk and crab fishing operations.

The daily noise exposure levels of the workers are highly impacted by job tasks characterized by hazardous noise levels. In this work, the Functional Resonance Analysis Method (FRAM) is used to model the fishing operations. Connecting the FRAM model to the noise contribution of each task can help to find the job tasks that could lead to high noise exposure. The methodology presented in this study uses the FRAM and the task-based noise measurement method to (a) examine the feasibility of administrative controls to mitigate noise exposure of fish harvesters during fishing operations, and (b) identify human factors responsible for high noise levels on board fishing vessels. Work pattern modifications are suggested that can be helpful to reduce impact noise during whelk and crab fishing.

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1 Introduction

As of January 1, 2021, the number of merchant ships worldwide was around 55,000, and almost 70% of them are cargo ships, bulk carriers and crude oil tankers (Statista Research Department, 2021). The estimated number of fishing vessels worldwide was around 4.1 million in 2020 (The State of World Fisheries and Aquaculture, 2022). The number of people engaged in fisheries worldwide was around 37.88 million in 2020 (The State of World Fisheries and Aquaculture, 2022). In 2018, there were approximately 45,000 registered fish harvesters in Canada (Transportation Safety Board of Canada, 2020).

Fish harvesters face several occupational health hazards on board fishing vessels. Eckert et al. (2018) evaluated chronic health risks before and during the fishing season among fish harvesters in Alaska. The authors observed that the risk of hearing loss, upper extremity disorders, and sleep apnea was higher among commercial fishermen compared to the general population (Eckert et al., 2018). Myers et al. (2018) studied various work-related diseases and disorders among fish harvesters in the Gulf of Mexico, such as musculoskeletal disorders caused by joint and back pain, skin, lip, and eye cancer, engine-related hearing loss, and bites and stings from aquatic animals.

Noise-induced hearing loss (NIHL) is the leading occupational disease among fish harvesters. The statistics released by WorkplaceNL show that between 2017 and 2021, fish harvesting was one of the most frequent occupations, with 106 hearing loss-related claims in Newfoundland and Labrador (WorkplaceNL, 2022). Levin et al. (2016) performed audiometric tests among commercial fishermen on the Gulf Coast and correlated their hearing loss with their noise exposure level aboard the fishing vessels. Almost 99.1% of the participants in their study were related to shrimp fishery. It was observed that for participants whose duration in commercial fishing was higher than 15 years, their hearing threshold shift lies in the moderate hearing loss area at notch 4 and 6 kHz. Arumugam et al. (2015) performed a hearing assessment of 63 fish harvesters who work in motor boats in the town of Karaikal in India. Hearing loss, tinnitus and hyperacusis were reported among 18, 12, and 7 fish harvesters, respectively (Arumugam et al., 2015). Arumugam et al. (2015) found that 44.44% of fish harvesters who participated in the study had a slight hearing impairment. Paini et al. (2009) performed personal noise exposure measurement and audiometry tests on fish harvesters from small-scale fisheries in the state of Parana in Brazil. The authors observed that 90% of the participants who worked in fishing vessels with an engine had hearing losses with the high-frequency notch configuration (Paini et al., 2009). Paini et al. (2009) found that tinnitus, difficulty in hearing and sensitivity to loud sounds, were common among fish harvesters. Noise levels vary from vessel to vessel due to differences in machinery that produces noise, the number of noise sources present on the ship, and variability in the operational parameters of machinery, such as engine speed. Noise exposure levels of fish harvesters also vary depending on their role (Burella et al., 2021; Zytoon, 2013).

Most research on high noise level mitigation on board ships focuses on engineering controls. D'Amore et al. (2022) presented a metamaterial solution for noise insulation on board ships. The authors evaluated the acoustic performance of the metamaterial panel. They showed that metasolutions have better soundproofing performance in terms of sound transmission loss compared to traditional mineral wool products. The fire test performed on metasolution showed that it is safe to install on board a ship. Burella and Moro (2021) developed a procedure to reduce high noise levels on board fishing vessels. The authors built a Statistical Energy Analysis (SEA) model to predict sound transmission through the structure. They identified seven tiers of intervention to mitigate on board noise and updated them on the SEA model to find their effectiveness in reducing overall noise levels on board the case-study fishing vessel. Depending on the fishing season of the target species, the fishing trip duration may consist of multiple days. The authors observed that the measured sound pressure levels at various spaces of the surveyed case-study fishing vessels were beyond the International Maritime Organization (IMO) limit (Burella et al., 2019). International Maritime Organization (IMO) Code on Noise Levels on board Ships sets standards to prevent the occurrence of potentially high noise levels on board vessels. This standard only applies to large vessels such as commercial and passenger, excluding fishing vessels. The "IMO Code on Noise Levels On Board Ships" Maritime Safety Committee (MSC) (Maritime Safety Committee MCS (MSC.337(91)), 2012) does not apply to fishing vessels, but it was used in the study because the proposed IMO limit values set minimum standards for the habitability of accommodation spaces and working spaces on board vessels (Burella et al., 2019). Continuous noise exposure during the rest period of fish harvesters can affect their sleep quality (Burella et al., 2021). The authors mentioned that installing soundproofing material could improve the habitability of the crew spaces and reduce the risk of noise-induced fatigue of fish harvesters (Burella et al., 2021).

Due to the lack of information on fishing operations, the studies often ignore the feasibility of administrative controls on fishing vessels to reduce noise exposure of fish harvesters during their work hours. There is no expense involved in implementing administrative controls, making it an attractive alternative for reducing noise exposure of fish harvesters. Implementation of engineering controls in a fishing vessel can be costly. To my knowledge, only two studies have recommended administrative controls as one of the control measures to reduce noise exposure in fishing vessels (Zytoon, 2013; Levin et al., 2016). Neitzel et al. (2006) highlighted the possibility of utilizing administrative controls to reduce the noise exposure of fishing workers. The authors noted that the production demands and crew size could make implementing administrative controls on fishing vessels challenging.

Zytoon (2013) reported the duration of crew member presence in various spaces aboard small and medium-scale fishing vessels. In the surveyed fishing vessels, he observed that the crew members spent most of their time on a deck rather than in the engine room and crew spaces while working in a fishing vessel. Fish harvesters perform various activities on the deck, such as setting the gear, fishing and storing the catch. They work closely with multiple noise sources such as hauler, fishing gear impacts and muffler, and the noise levels can reach beyond the acceptable limit on a deck (Burella et al., 2021). Prolonged noise exposure on a deck can cause noise-induced hearing loss in fish harvesters. Provincial lawmakers set occupational exposure limits for workplace noise, including fishing vessels in Canada. The research presented here investigated the operational procedure that may cause hearing loss among fish harvesters and explored how work process management of tasks can help achieve the desired safe noise exposure levels by adjusting the work patterns of the crew on board fishing vessels.

The objectives of the present study were to: (a) study the feasibility of administrative controls to reduce noise exposure of fish harvesters during fishing operations; (b) identify human factors that are responsible for high noise levels on board fishing vessels; and (c) identify solutions to prevent hearing loss among fish harvesters. In this study, human factors that can cause high noise levels during job tasks of fish harvesters were linked with hearing loss.

2 Literature Review

Continuous noise exposure of fish harvesters on board fishing vessels is a main concern in the fish harvesting industry as it can cause hearing loss. The severity of noise hazards on fish vessels is examined by assessing the noise exposure levels of the fish harvesters on board fishing vessels and measuring the noise levels at various spaces where fish harvesters work. Previous studies evaluated the noise exposure levels of people involved in fisheries and aquaculture using the international organization for standardization (ISO) Standard 9612:2009 (E) noise measurements strategies. Numerous studies have been conducted on controlling noise on vessels using engineering controls. Soundproofing of various spaces of vessels is the most effective design solution that significantly reduces noise transmission from on board sources. Previous studies on occupational noise exposure on fishing vessels showed that fish harvesters spend most of their work shift on the deck, where they are directly exposed to noise sources such as hauler, muffler and gear impacts. The current literature recommends crew members wear hearing protection while working in noisy locations. Previous studies also pointed out that most workers do not want to wear hearing protection even when hearing protections were provided as they disturb communication with their coworkers while working, constituting a safety hazard. In addition, some fish harvesters indicated that they do not wear hearing protections as they cause discomfort.

2.1 Engineering Controls to Reduce Worker Exposure to Noise

Sü et al. (2007) evaluated different materials' acoustical properties for optimum acoustical conditions in spaces of metro stations. The ODEON Room Acoustics Software was used to perform the computer simulations in order to assess different acoustical parameters. The contribution of sound absorption capacities of suspended ceiling and ballast is higher than other materials in the metro stations. The study confirmed that the effectiveness of reverberation control increases by using the lay-in material behind the perforated metal suspended ceiling system. The computer simulation technique proved to be a powerful tool to predict room acoustical parameters, which helped in searching the design solutions to achieve desired acoustical conditions in interior spaces of metro stations.

Burella and Moro (2021) developed a procedure to mitigate noise levels on board fishing vessels which includes i) Statistical Energy Analysis (SEA) to predict the transmission of sound through the structures, ii) noise measurement, iii) the contribution of type of noise sources (airborne or structure-borne) to the overall noise on board and iv) K-dominant transmission path ranking using the MPS algorithm to identify the paths from the noise source to the targeted subsystems that mostly contribute to the sound pressure level on the fishing vessel. The results showed that this procedure is a powerful tool for analyzing the noise propagation on small fishing vessels and the effectiveness of noise control solutions to mitigate noise on board.

The procedure was applied to a case-study fishing vessel from the NL small-scale fisheries. The length overall (LOA) of the case-study fishing vessel was 19.81 m. During the fishing season, the operators and crew work and live for several weeks on board the fishing vessel. It is essential to guarantee that crew members have proper rest in the vessel's living quarters to avoid noise-induced fatigue. Seven tiers of intervention to mitigate on board noise were identified in the study. It was concluded that the use of mineral wool to insulate the walls and ceiling of the engine room, insulating the doorway gaps of the engine room, installation of a floating floor in the space above the engine room and application of viscoelastic materials in constrained layer damping configurations (VEM-CLD) on the surface that separates the engine room from the crew quarters reduces the noise levels on small-scale decked fishing vessels to an acceptable level.

Stone (2020) assessed long-term design solutions to reduce noise transmission and improve the working conditions for employees in aquaculture facilities. A model of an aquaculture research facility was developed to assess the engineering design solutions to mitigate noise levels. The dimensions of the entire aquaculture facility obtained were used to create a model of the aquaculture research facility using the 3D modelling computer program SketchUp®. The model was exported into ODEON Room Acoustics Software® to perform the numerical simulations. The materials were assigned to each surface of the model in the ODEON software. The simulated reverberation time and A-weighted sound pressure levels obtained from the model were compared with the experimental measurements taken at the aquaculture research facility in order to validate the model. The absorption coefficients were adjusted within their prescribed limits, so the simulated reverberation time matched the measured reverberation time. The material's transmission coefficients were modified, and the sound levels of noise sources were adjusted to get simulated and measured sound pressure levels equal for further model validation. Engineering design solutions were applied after model validation to mitigate noise transmission throughout the aquaculture research facility. The noise measurement results showed that the sound pressure levels were high in the filtration room due continuous operation of machinery. The noise was easily transmitted from the filtration room across the facility. Closing doors connected to the filtration room reduced A-weighted sound pressure levels by 6 dB in prep room and 1 dB in the broodstock room. Using acoustic insulation inside the walls of the filtration room proved highly effective, reducing noise levels in the office up to 20 dB.

2.2 Documented Noise Levels in Fishing Vessels and Aquaculture Facilities

Burella et al. (2019) measured noise levels on board fishing vessels in Newfoundland and Labrador (NL) during seven fishing trips. Fisheries and Oceans of Canada (DFO) and Transport Canada

(TC) provided the NL fleet data, which was used to compose a sample of fishing vessels of length ≤ 65' (19.81 m) for the noise surveys. Noise levels were measured according to the International Organization for Standardization (ISO) 2923 using the data acquisition system composed of hardware and software end (International Organization for Standardization (ISO), 1996). Sound levels were measured in different locations of the vessels where the crew are expected to be during fishing activities at different engine speeds (slow-downs and transfers).

Sound power spectra analysis was performed to identify peaks associated with noise sources in the narrowband and 1/3 octave band spectrum. Peaks were identified in the spectra at the noise sources operating frequencies and higher harmonics. A narrow band spectrum was used to identify spectral peaks associated with harmonic sources operating at frequencies lower than 20 Hz, which is below the hearing range (20 Hz–2 kHz). In contrast, a 1/3 octave band spectrum was used to identify the peaks of the noise sources operating at higher frequencies. The comparison between the measured noise levels and the International Maritime Organization (IMO) noise level limits showed that the continuous noise levels at various measurement locations of the vessels were higher than the respective IMO limits.

Stone and Moro (2022) documented the noise exposure levels and hazardous noise sources at four aquaculture facilities. The narrow band analysis was used to identify each relevant noise source, while 1/3 octave band analysis was used to estimate noise levels. Noise exposure levels measured at each facility were compared with the regulatory limits of an 8-hour time-weighted averaged 85 dB(A) exposure level. The task-based measurement strategy was used to identify the employees' tasks involving hazardous noise levels, while the full-day measurement strategy was used to measure the daily noise exposure level of employees. Dosimeters were used to measure the personal noise exposure levels of employees during their working shifts at the aquaculture facilities. Furthermore, noise levels were measured using the handheld microphone to map noise exposures across the facilities and identify any hazardous noise sources in each room. The recommendations for hearing protection were made as per the Canadian Standards Association (CSA) standard "Hearing Protection Devices - Performances, Selection, Care and Use". It was found that there were high noise levels at the salmon farm, where the noise sources, i.e. the blowers and the engines, were the main contributors to these hazardous noise levels.

Burella et al. (2021) documented noise exposure levels of fish harvesters using dosimeters during fishing trips. The fishing vessel skippers were interviewed to obtain information about their work patterns and awareness of noise hazards. Job tasks and noise sources were identified which are associated with any hazardous noise levels. The tasks of the fish harvesters were identified by interviewing them and observing their work patterns. The activity logs were used to note the tasks of the fish harvesters, locations where they carry out their activities and the duration of each task when personal noise exposure measurements of fish harvesters were performed during fishing operations. The task-based noise measurement strategy was used to identify the tasks during the fishing operations involving hazardous noise levels. The A-weighted equivalent sound pressure level associated with each task was assessed using the information in the activity log filled out by the participants. This approach enabled the identification of tasks related to hazardous noise levels. The job-based noise measurement strategy was used to measure the daily noise exposure level of the fish harvesters during fishing operations. Impulse noise was identified during sound level measurements performed using fast-time weighting near the ear of a fish harvester while hauling a single pot on a crab fishing trip. The peak sound pressure level using the C-frequency weighting was also extracted from the noise measurement in order to assess the risk of impact noise, such as pot and catch impact with a metal sorting table on a crab fishing trip. The noise exposure levels of fish harvesters were compared with the recommended levels to check whether noise levels were beyond the limits or not. It was found that the fish harvesters are exposed to hazardous noise levels. The results revealed that skippers are not completely aware of the noise hazard.

Burella et al. (2021) performed a comparative study among four existing methods to assess fish harvesters' noise exposure levels. Noise exposure surveys were conducted on board 11 fishing vessels from Newfoundland and Labrador. A comparison was performed among three noise measurement strategies provided by ISO Standard 9612:2009, i.e. the full-day measurement method (FDM), the task-based method (TBM) and the job-based method (JBM), and the International Maritime Organization method (IMO) simplified procedure for determining noise exposure. In the study, the FDM was considered a benchmark to assess the effectiveness of the other methods, i.e. JBM, TBM, and IMO method, to evaluate noise exposure levels. The results revealed that the combined effect of the mean exposure level and uncertainty are levelling out the estimates of the JBM, TBM, and FDM when the engine dominates the crew noise exposure. In contrast, the difference between the noise exposure between TBM and FDM was higher than the difference between JBM and FDM when the noise exposure is dominated by fishing gear which shows that TBM fails to represent the average exposure level accurately when compared with FDM. The results indicated that the IMO method underestimates the noise exposure of fish harvesters because the difference between the IMO method and FDM is always greater than 1 dB. It was concluded that the JBM is the most effective method to assess noise exposure on small fishing vessels. The advantage of using JBM includes the use of shorter samples of noise measurement duration. The JBM considers the uncertainties and the high variance of noise exposure samples from fishing operations better than TBM and FDM.

Burella et al. (2019) used sound pressure levels measured on board the fishing vessels to study their acoustic transmission characteristics. The sound pressure levels measured on board the fishing vessels were used to identify the airborne 1/3 octave band transmission losses (TL) between spaces. The transmission losses between the spaces were used to determine critical acoustic hot spots on the visited fishing vessels. The International Standard Organization (ISO) procedure was followed to compute the standardized level differences to characterize the acoustic insulation from the noise source to the receiver spaces on the fishing vessels. The TL curves of 7 fishing vessels were analyzed, and it was observed that acoustic insulation could be poor when the spaces are adjacent and share a dividing surface. The design solutions suggested were using resilient mounts for the engine and auxiliaries and a proper design of the engine foundation to reduce the airborne transmission of sound.

Zytoon (2013) assessed the noise exposure of fishermen working on small and medium-scale fishing vessels using a combined measurement and questionnaire approach. The sound pressure levels were measured using the sound level meter aboard 24 fishing vessels at various locations and different engine speeds. Results revealed that the noise exposure levels of engine mechanics were beyond the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit of 85 dB(A). In contrast, other crew noise exposure levels were slightly lower than the recommended limits. The noise measurement results showed that the sound pressure levels were higher in the engine room of all the surveyed fishing vessels. It was observed that higher sound pressure levels were found in fishing vessels during the speeding mode, while lower sound pressure levels were found during the slow-down mode. Various factors were considered which can affect the noise levels on board the fishing vessels, such as maintenance interval of machinery, manufacturer of marine engines, and the reduction in sound pressure level due to an increase in the distance between the noise source and receiver. The duration of the crew's presence at various locations of the fishing vessel was considered an essential factor related to noise exposure of fishermen.

Personal noise exposure measurements were also performed on five crew members. Task-based measurement and full-day measurement strategies were used to calculate the noise exposure of the crew. It was concluded that noise exposure could be reduced by applying various control measures such as noisy engine replacement, use of sound-absorbing materials in the engine room, preventive maintenance of machinery, use of ear plugs or ear muffs for hearing protection, conducting safety training program, and following proper job rotation schedule to manage the duration of the crew at a location with high noise levels.

Neitzel et al. (2006) performed personal noise exposure measurements of United States fishing workers abroad in two catcher/processors fishing vessels. The noise exposure measurements showed that nearly all the worker's 24 hr overall noise exposure levels were beyond the United States Coast Guard (USCG) and International Maritime Organization (IMO) limits. The contribution of the non-work-shift noise was not significant to the 24 hr overall noise exposure levels. It was observed that hearing protection devices reduced the average noise exposure levels by 10 dB(A), but the fishing workers don't wear them consistently during work shifts. It was found that the work shift noise is the primary risk of hearing loss aboard the surveyed fishing vessels because it is the dominant source of noise exposure among fishing workers. It was also observed that the risk of hearing damage might be high in smaller fishing vessels from non-work periods. The authors recommended fishing workers wear hearing protection consistently during work shifts to reduce the risk of hearing loss among the fishing workers.

2.3 Effect of Impact Noise

The combination of high-level impact and continuous noise produces greater injuries to the spiral organ than either the impact or the continuous noise alone (Henderson and Hamernik, 2007). Impact noise causes more severe hearing loss than continuous noise (Starck et al., 2003). The Committee on Hearing, Bioacoustics and Biomechanics of the National Research Council (CHABA) damage risk criteria set 140 dB(C) as the level beyond which the impact noise becomes hazardous (Coles et al., 1967). Repeated exposure to impact noise exceeding 140 dB(C) in the ear canal of the listener can cause significant hearing loss (Ward, 1968).

The study performed by Coles et al. (1967) reported that the amount of temporary threshold shift produced by impact noise is greater than the steady-state noise. A repeated temporary threshold shift can eventually become a permanent threshold shift (Coles et al., 1967). The development of permanent threshold shift occurs at a greater rate when the workers are exposed to impact noise compared to continuous noise (Coles et al., 1967). Suvorov et al. (2001) studied the impact noise exposure on forge hammering workers. He found a significant correlation between hearing loss with impact noise parameters, i.e. peak sound pressure levels and the number of impacts.

2.4 Functional Resonance Analysis Method

It has been seen in previous studies that engineering design solutions were presented to control noise in the workplace. The functional resonance analysis method (FRAM) is a modelling technique used to gain an understanding of the inner workings of an operation. FRAM models socio-technical systems, which comprise human, technological and organizational factors. Using FRAM, human factors can be identified if they contribute to overall noise levels during an operation. The information obtained by using FRAM can help to suggest a work pattern in which the possibility of workers' exposure to high noise levels could be low.

Smith et al. (2017) examined three approaches, i.e. Fault Tree Analysis (FT), Bayesian Networks (BN), and the Functional Resonance Analysis Method (FRAM), to assess the safety of the system. It was shown that Fault Tree Analysis (FT) and Bayesian Networks (BN) focus on a system's failure probability, which may not provide enough information to assess the safety of a system entirely. The propane feed control system was used as an example to examine its safety by applying above mentioned three approaches. The probabilistic models of the Fault Tree and Bayesian Network of the propane feed control system were shown, which consists of automatic and manual control systems used to maintain the propane feed control. Human error was shown as an event in the models, which affects the probability of failure of the manual valve. The failure probability of human error taken from the literature was 0.2696, which includes all the human elements of the control system. There was no clear information about human error in the probabilistic models that why humans cause an error 26.96% of the time. The functional Resonance Analysis Method (FRAM) modelling technique was used to gain information on the propane feed control system. The propane feed control system was described in terms of the functions that carry out the process. The FRAM explains the human interaction in the system to be understood by illustrating the operation, which helps in identifying informed safety solutions. FRAM uses a structured framework which can help to understand how human actions affect the success and failures of industrial operations. To further enhance the understanding of the human factors involved in an operation, it was suggested in the study to collect information about work patterns and variability from the operators to identify humans' role in industrial accidents. The variability of the function outputs was assessed with respect to time and precision. The study considered the variability of only the pressure sensor failure in the FRAM model to illustrate the information gained by using FRAM. It was shown that incorporating FRAM with other probabilistic approaches, such as Fault Tree Analysis and Bayesian Network, can help to improve the understanding of the system's safety.

Smith et al. (2020) presented a methodology to assess the resilient capacities of an operation that can be useful for safety management decisions. The procedure connects system performance measurement and functional execution from the functional resonance analysis method to assess the robustness and rapidity of a system. It was observed that elements that contribute to the operation's resilient capacities could not be identified by monitoring the system performance alone. It was shown that the system elements that give rise to robustness and rapidity could be identified by connecting the functional signatures of an operation to each system performance measurement which can help operators more effectively manage their operations. To visualize functional dynamics that occurred during a process, the active functions that were mutually coupled together at an instant were shown in bold red in the FRAM model. The collection of FRAM models of a system for a given time represents the functional signatures. This procedure allows learning from successful operations instead of conventional methods focusing on failures to inform safety and operational management.

França et al. (2020) developed a FRAM model to understand the levels of complexity of offshore oil well drilling and construction. The relevant human factors necessary for the safe operations of offshore oil well drilling and construction were identified. The most significant variabilities were observed in the function 'Perform drilling operations', which caused a large resonance within the FRAM model. After the identification of relevant functions of the activities for the FRAM model, the Analytic Hierarchy Process (AHP) methodology was used to measure the subjectivity of the variability decisions of the function output in terms of precision and time in a mathematically objective way. The purpose of using AHP was to validate the decision process of experts in order to bring certain objectivity to the subjectivity of individual human decisions. Experts validated the FRAM model in order to produce a model that can reproduce the reality of the work performed. The instantiations of the FRAM model were analyzed to find the critical variabilities and relevant human factors that may contribute to developing a safe work environment for the oil rig workers.

There is a gap in the literature to examine the feasibility of administrative controls to reduce the noise exposure level of fish harvesters. Administrative controls are the policies and rules that reduce workers' occupational risk by changing the way their work is performed to improve safety in a workplace (Safeopedia, 2019). Previous studies showed that FRAM is used for improving the system's safety, accident investigation, risk management and complexity management in complex socio-technical systems. The feasibility of administrative controls cannot be evaluated without understanding an operation. The advantage of using the FRAM methodology is that the FRAM model can help to understand the operation in order to examine the feasibility of administrative controls in a workplace to reduce noise exposure of workers, and it can also identify human factors that may be responsible for high noise levels.

3 Methodology

The contribution of the task associated with hazardous noise levels to the worker's daily noise exposure level is always high. Reducing the noise levels of the task can help to reduce the worker's daily noise exposure level. The methodology presented here uses the functional resonance analysis method (FRAM) and the task-based noise measurement method (TBM) to: (a) examine the feasibility of administrative controls to reduce noise exposure of tasks associated with hazardous noise levels during the fishing operations; (b) identify human factors responsible for high noise levels of the task. Human elements present in the tasks that contribute to the noise exposure level of a worker can be identified by connecting the FRAM model of the task(s) with its noise levels. Figure 3.1 shows the flowchart of activities performed in the research presented in this thesis.

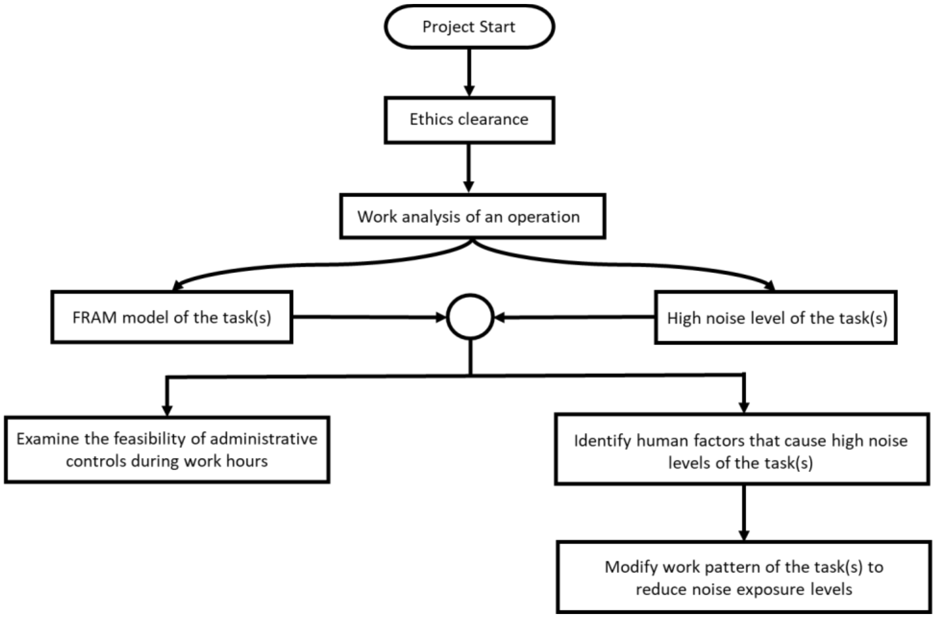

Figure 3.1: Flowchart for the research outlined in this thesis

3.1 FRAM

The functional resonance analysis method (FRAM) is a modelling technique used to analyze how work tasks are performed (Hollnagel, 2018). The work analysis helps to develop a FRAM model, which represents the functionality of an operation. The FRAM is used to model socio-technical systems to describe how the system works. The socio-technical system comprises people, technology and organization that works together as a whole to achieve a specific goal (Foster, 2018). The purpose of the FRAM methodology is to understand the functionality of an operation. The FRAM modelling technique has the ability to model the human factor interactions necessary to complete tasks present in the socio-technical system. Human factors are the human elements that influence work actions in a way which can affect health and safety (Health and Safety Executive (HSE)). The concept of human factors is used in various academic disciplines, such as psychology, physiology, anthropometry, biomechanics, biology, and statistics, mainly concerned with human interaction with their working environments. The human factor is considered a contributing element in an accident investigation due to a lack of awareness of workers, poor workforce management, misinformation, miscommunication between workers, over-reliance on automation, and breach of standard operating procedures. In the current study, the human factor was considered an element affecting workers' health due to the work patterns of the workers. The FRAM model includes two main parameters: functions and variability.

Failure is considered to occur due to malfunctioning of a system or its components. This concept assumes that success and failure are fundamentally different. The functional resonance analysis method is based on the principle of equivalence of success and failure, and the principle of approximate adjustments. According to the FRAM concept, things go right and wrong in basically the same way. Variation of outcomes does not mean that the underlying processes must be different

(Hollnagel, 2018). According to the principle of approximate adjustments, the work conditions never entirely match what has been prescribed to achieve the desired outcomes (Hollnagel, 2018). Individuals, groups, and organizations adjust their performance to achieve the desired results. The resulting performance variability is the reason why the outcomes become acceptable (success) or unacceptable (failure). The functional Resonance Analysis Method comprises four steps. The first step is to identify and describe the functions involved during the operation and then characterize each function using six aspects. The hexagon represents a function in the FRAM model, as shown in Figure 3.2. Each function is characterized using six aspects in the FRAM model: Time, Control, Output, Resource, Precondition and Input. The description of the six aspects is as follows:

1. **Input**: The input initiates the functions, and it can represent matter, energy, or information.
2. **Output:** The output represents the outcome of a function having been carried out.
3. **Precondition:** Conditions that must be completed before a function is carried out.
4. **Resources:** Resource is something that is consumed during the processing of a function.
5. **Time:** Time aspect is something that function cannot start before a particular time or within a certain period.
6. **Control:** Control aspect directs or regulates the function.

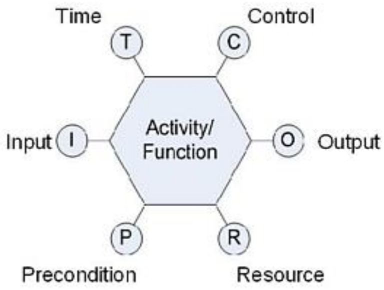

Figure 3.2: Function

A function can be human, technological, or organizational, depending on its nature in the socio-technical system. After describing the system functions, the second step is to identify the function's variability of output and characterize each function's potential and actual variability. The FRAM can be used to understand how the variability of one function can affect the variability of other function(s) and, thereby, an operation as a whole. Potential variability explains what may occur under different conditions, while actual variability describes what might happen under given conditions. The variability of a function's output is examined in terms of time and precision. In terms of time, the output can be too early, on time, too late or not at all. In terms of precision, the output can be precise, acceptable or imprecise. The third step is to examine the instantiations of the model to understand how the potential or actual variability of each function and the coupling among functions can lead to unexpected outcomes; this is called functional resonance. An instantiation of a FRAM model shows the coupling among a subset of functions under different conditions or a given time period. The variability of function(s) can increase the variability of other function(s), and the consequence may spread through the coupling between the functions. The last step is to identify ways to monitor the variability and then manage the variability in a system based on monitoring results. The variability can be managed either by reducing the variability that can lead to undesirable outcomes or by increasing variability that can lead to desired outcomes. In this study, the FRAM model visualizer was used to build the FRAM model and show the instantiation of coupled active functions.

3.2 Methods to Assess Noise Exposure Levels

The international organization for standardization (ISO) 9612:2009(E) provides an approach to assess occupational noise exposure. There are three methods to assess noise exposure levels which are as follows:

1. Task-based measurement
2. Job-based measurement
3. Full-day measurement

The selection of the noise measurement method depends on several aspects, such as the objective of the noise measurements, the complexity of the work patterns, the number of workers involved and work shift duration.

3.2.1 Full-day measurement

Full-day measurement is performed when the work patterns are complex and unpredictable. Sound pressure levels are measured continuously over full working days.

3.2.2 Task-based measurement

Task-based measurement (TBM) is used to identify the tasks associated with hazardous noise levels. Task-based measurement can be used if the number of activities is limited and well-defined.

3.2.3 Job-based measurement

Job-based measurement (JBM) is performed if it is hard to accomplish task analysis or if task analysis is not desirable. In Job-based measurement, several random samples of sound pressure levels are taken during the performance of particular jobs.

An example illustrating the hierarchy of jobs and tasks is shown in Figure 3.3. In the fishing vessel, only the skipper and crew members works. The crew member and skipper are the jobs while fishing, storing fish, travelling to the fishing ground and operating vessels are the tasks of the jobs.

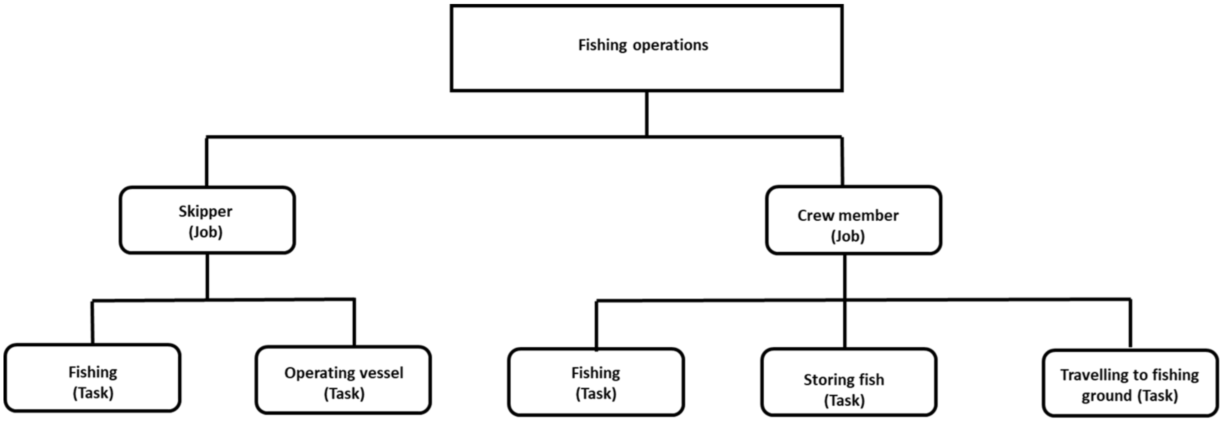

Figure 3.3: Illustration of Hierarchy of Jobs and Tasks Involved during Fishing Operations

Due to the high variability in tasks involved during fishing operations, the task-based measurement method is not an appropriate measurement strategy for assessing the worker's noise exposure levels (Burella and Moro, 2021). For instance, travelling to the fishing ground is one of the tasks involved during fishing operations. The speed of the fishing vessel varies with respect to time during travelling. Previous studies showed that the noise levels vary with vessel speed (Zytoon, 2013; Burella et al., 2019). According to the ISO Standard 9612:2009(E), the results of the three measurements of a task should not differ by 3 dB or more. The study performed by Burella et al. (2021) showed that noise levels of travel to and from the fishing grounds for various fisheries vary more than 3 dB. The strength of the task-based method is that it can identify the tasks associated with high noise levels, which other noise measurement strategies lack. In the current study, the methodology presented uses a task-based method because FRAM can investigate the inner workings of an operation by dividing the work tasks into sub-tasks. The FRAM can help to identify the sub-tasks which cause high noise levels of the task. The information obtained by using FRAM can help to manage the tasks by adjusting the work patterns of the workers so that the desired safe exposure level can be achieved.

3.3 Ethics

This study uses data collected by (Burella et al., 2019; Burella et al., 2021) during fishing trips for noise exposure measurements conducted on fishing vessels. The use of this data required approval from the Interdisciplinary Committee on Ethics in Human Research (ICEHR) of Memorial University of Newfoundland. See appendix A for the ethics application for secondary use of data and appendix B for the ICEHR ethics approval letter. The ICEHR number of the approved ethics application is 20230590-EN.

4 Administrative Controls to Reduce Noise Exposure of Fish Harvesters

Burella et al. (2021) measured noise exposure levels of fish harvesters on various fishing vessels in the Canadian province of Newfoundland and Labrador. He used the job-based method to assess the personal noise exposure levels of fish harvesters and the task-based method to measure the noise levels of the tasks involved during fishing operations, as indicated in Tables 4.1 and 4.2, respectively. The 8-h noise exposure levels $L_{EX,8h}$ of fish harvesters for various fisheries were beyond 80 dB(A), as reported in Table 4.1. The permissible noise exposure level in Newfoundland and Labrador is 85 dB(A) (Canadian Centre for Occupational Health & Safety, 2020). The risk of hearing damage is low when the noise exposure level is below 80 dB(A) (European Committee for Standardization, 2016).

Table 4.1: Noise Exposure Levels of Fish Harvesters of the Surveyed Fishing Vessels (Burella et al., 2021)

Vessel ID	Length (m)	Fishery	Fishing Gear	$L_{EX,8h}$ + $U_{(95\%)}$ dB(A)
FSH001	5.8	Lobster	Traps	81.8 + 4.2
FSH004	10.7	Cod	Gillnet	83.7 + 3.3
FSH005	11.9	Whelk	Pots	83.1 + 3.1
FSH008	10.7	Crab	Traps	91.4 + 4.6

Table 4.2: Noise Levels of Tasks Involved during the Fishing Operations (Burella et al., 2021)

Fishery	Tasks	$L_{A,eq}$ dB(A)
Whelk	Fishing on deck	86 – 91

	Travel to and from the fishing ground	76 – 80
Lobster	Fishing on deck	77 – 82
	Travel to and from the fishing ground	86 – 92
Cod	Fishing on deck	77 – 93
	Travel to and from the fishing ground	76 – 78

Previous studies recommended different solutions to mitigate noise on fishing vessels, such as soundproofing the engines and generators, periodic maintenance of engines, rubber coating of pots, sorting tables and deck to reduce the impact noise, noisy engine replacement, and use of resilient mountings of machinery to reduce the structure-borne noise (Burella et al., 2021; Zytoon, 2013). To my knowledge, the feasibility of implementing administrative controls to reduce noise exposure of fish harvesters has not been studied. Burella et al. (2021) pointed out that fish harvesters are exposed to high noise levels during the whelk fishing task, as indicated in Table 4.2. In the current study, the possibility of implementing each administrative control during the whelk fishing task was examined based on information Burella et al. (2021) collected during the whelk fishing trip. According to the Occupational Safety and Health Administration (OSHA), the administrative controls to reduce noise exposure levels are as follows (Occupational Safety and Health Administration (OSHA)):

1. Use of noisy machinery during shifts when fewer workers are exposed
2. Control noise exposure by increasing the distance between the noisy machinery and the workers
3. Limit the amount of time a worker spends in a noisy location based on noise levels

4. Provide rest periods between work periods in quiet spaces where workers can gain relief from hazardous noise levels

The FRAM was not used for the first two administrative controls because a complete understanding of the fishing operations is not required to examine their feasibility during the work hours of fish harvesters.

4.1 Use of Noisy Machinery during Shifts When Fewer Workers are Exposed

Figure 4.1 shows various spaces of the single-decked fishing vessel where whelk fishing was performed. The length of the surveyed fishing vessel was 11.9 meters (LOA). In the surveyed fishing vessel where whelk fishing was carried out, it was noted that the crew members spent 10 hrs and 16 min on the deck, which is 79% of the time they stayed on the deck during the fishing trip, as indicated in Table 4.3. Fish harvesters perform various tasks on the deck, such as fishing, preparing for fishing and storing the catch. Fishing is one of the tasks which is associated with hazardous noise levels during whelk fishing operations. The maximum measured A-weighted equivalent sound pressure levels $L_{A,eq}$ of the whelk fishing task were 91 dB(A), which is beyond the 85 dB(A) limit, as shown in Table 4.2. According to the IMO code on noise levels on board ships, the permitted noise levels in open deck workspaces where communication is relevant are 85dB(A) (Maritime Safety Committee MCS (MSC.337(91)), 2012). Fish harvesters are exposed to noise sources such as the engine, pot hauler, fishing gear impacts and muffler while fishing on a deck task. During the fishing trip, it was observed that all the fish harvesters on board the vessel were involved in various activities during whelk fishing, as shown in Table 4.4. Completing a whelk fishing task is impossible without using noisy machineries such as a pot hauler and engine. The administrative control 'use of noisy machinery when few harvesters are exposed to noise on a deck' is challenging to implement on a fishing vessel because of the small crew size; all fish harvesters work during fishing and are exposed to hazardous noise levels.

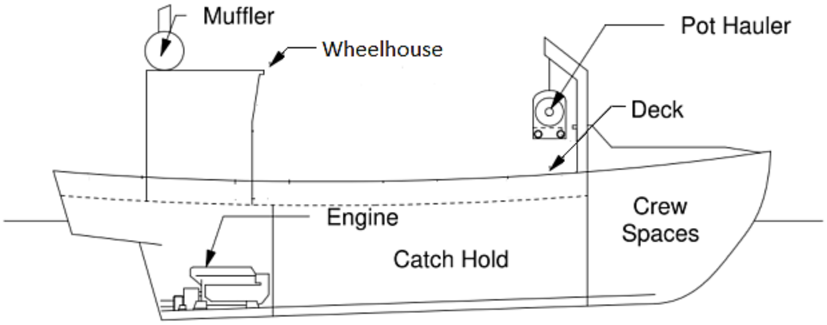

Figure 4.1: Single-Decked Fishing Vessel – Lateral View (Burella et al., 2019)

Table 4.3: Duration of Crew Member's Presence at Various Spaces aboard the Surveyed Single-Decked Fishing Vessel

Vessel Type	Duration of the Crew Member's Presence at Various On-Board Spaces during their Work Hours (h)				
Single Decked	Deck	Engine Room	Crew Space	Wheelhouse	Trip Duration
	10 h 16 m	26 m	1 h 9 m	1 h 9 m	13 h

Table 4.4: Tasks of Fish Harvesters during Whelk Fishing aboard the Surveyed Fishing Vessel

Vessel ID	Vessel Type	Species	No. of Fish Harvesters	Fish Harvester Role	Fish Harvester ID	Tasks of Fish Harvesters during Whelk Fishing

FSH005	Single Decked	Whelk	3	Skipper	WK01S	Pulling the line of pots
				Crew member	WK02C	Shifting the whelk from the pots to the sorting table
				Crew member	WK03C	Stacking the whelk pots

4.2 Control Noise Exposure by Increasing the Distance between the Noisy Machinery and the Workers

Figure 4.2 shows the locations 1, 2 and 3 of the fishing vessel's deck where whelk fishing was performed. In the surveyed fishing vessel, it was noted that crew member WK03C spent at least 50% of the time at locations 1 and 2 of the deck to stack the empty pots while fishing, as indicated in Table 4.5. During fishing, crew member WK02C spent 100% of the time at location 2 of the deck shifting the whelk from the pots to the sorting table, while the skipper WK01S spent 100% of the time at location 3 of the deck pulling a line of whelk pots using the pot hauler. They were directly exposed to noise sources such as the pot hauler, muffler, and pot impacts with the sorting table and catch hold while working on a deck. The fish harvesters work closer to the noise sources such as pot hauler, muffler and gear impacts during fishing due to limited space on the deck, which makes it difficult to control noise exposure levels by increasing the distance between the noisy machinery and the fish harvesters, as shown in Figure 4.2.

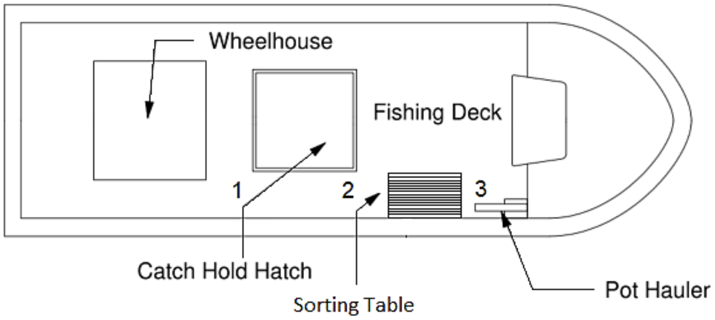

Figure 4.2: Single-Decked Fishing Vessel – Planer View (Burella et al., 2019)

Table 4.5: Duration of Crew Member (WK03C) Presence at Various Locations of Deck during Whelk Fishing

Vessel Type	Duration of the WK03C Presence at Various Locations of Deck While Fishing			Duration of Fishing on Deck Task
Single Decked	Location 1	Location 2	Location 3	4 h
	2 h	2h	0 h	
Percentage of Time Spent (%)	50 %	50 %	0 %	

4.3 Limit the Amount of Time a Worker Spends in a Noisy Location Based on Noise Levels

Burella et al. (2021) identified that the whelk fishing task is associated with hazardous noise levels, as reported in Table 4.2. Based on the maximum noise levels of the whelk fishing task, the maximum duration of exposure in hours was calculated using equation (4.1).

$$T_{max} = 8 \times 2^{\frac{85- \text{LA,eq}}{3}} \tag{4.1}$$

Where T_{max} is the maximum duration of exposure and $L_{A,eq}$ is the A-weighted equivalent sound pressure level. The maximum permitted exposure for 91 dB(A) based on a 3 dB exchange rate for whelk fishing on deck task is 2 hours per day, as shown in Table 4.6. The fish harvesters perform fishing on multiple fishing grounds depending on their target to catch the minimum amount of whelk. In a whelk fishing trip, Burella et al. (2021) noted that the fish harvesters retrieved 16 lines of pots, which took up to 4 h.

Table 4.6: Noise Levels and Maximum Permitted Exposure Based on 3 dB Exchange Rate for a Fishing on Deck Task aboard the Surveyed Vessels

Exposure Index	Fishery		
	Lobster	Crab	Whelk
$L_{A,eq}$ dB(A)	82	90	91
Maximum Permitted Exposure, T_{max} (Hours/Day)	-	2.52	2
Duration of Task	5 h	6 h	4 h
Trip Duration	5 h 30 m	16 h 30 m	13 h

The feasibility of reducing noise exposure by decreasing the exposure time cannot be made without understanding the fishing operations. The Functional Resonance Analysis Method (FRAM) can help to understand the whelk fishing operations. Fishing operations are a socio-technical system because it comprises human interaction with technology to harvest fish on a large scale. The work tasks of the fish harvesters are the human factors, while the fishing vessel and the machinery that supports fishing, retrieving and setting gear are the technological factors. All these factors work together to achieve the goal of harvesting the amount of fish sufficient to make a profit. The FRAM methodology was used to examine whether whelk fishing can be completed in 2 h.

4.3.1 Work Analysis of the Fishing Operations

Work analysis is required, as explained in the ISO Standard 9612:2009(E), to identify and describe the tasks involved during an operation. During the fishing trip, Burella et al. (2021) carried out the work analysis on board fishing vessels to gain information about the fishing operations so that an appropriate noise measurement strategy can be selected and noise measurements can be planned. The work analysis was performed using interviews with the fish harvesters and observing their work patterns on board fishing vessels. Work analysis helped in building the FRAM model of the fishing operations. The activities of the fish harvesters were represented as the FRAM functions of the model.

4.3.2 Description of the Fishing Operations

The fish harvesters first check the fishing chart before starting the fishing trip in order to identify the fishing ground. Once they identify the fishing ground, the skipper of the fishing vessel uses a global positioning system (GPS) installed on their fishing vessel to go towards the fishing ground. The crew members of the fishing vessel prepare for fishing during the voyage before reaching the fishing ground, in which they wash gillnet if they perform cod fishing or attach the bait in the traps if they carry out crab or lobster fishing. When the fish harvesters reach the fishing ground, they can either start setting the fishing gear or perform fishing at the fishing ground, depending on their plan. Fish harvesters during the fishing trip perform fishing and set fishing gear at different spots of fishing grounds depending on their target to catch the species. The fishing trip may consist of multiple days. Fish harvesters return to the dock to sell the species once they achieve their catch target.

4.3.3 FRAM Model of the Fishing Operations

The FRAM model of the fishing operations is shown in Figure 4.3. The rounded rectangles are the tasks involved during the fishing operations, while the functions inside the rounded rectangles represent the sub-tasks, as shown in Figure 4.3. The FRAM model was built for four fisheries, i.e. lobster, whelk, crab and cod. Some functions in the FRAM model are common among these four fisheries. See Appendix C for a description of the functions and aspects of fishing operations.

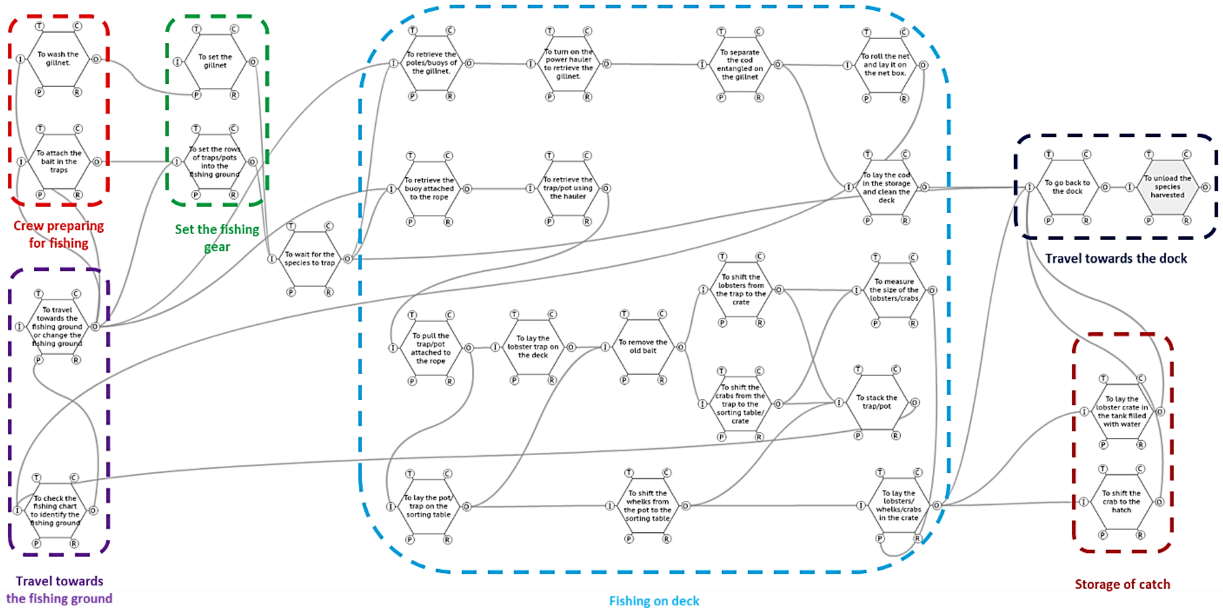

Figure 4.3: FRAM Model of Fishing Operations

4.3.4 FRAM Analysis of Whelk Fishing

Figure 4.4 shows the red highlighted functions inside the light blue round rectangle are the active functions involved while retrieving the first line of pots during the whelk fishing task. In the surveyed fishing vessel, it was noted that there were 60 pots in each line, as shown in Table 4.7.

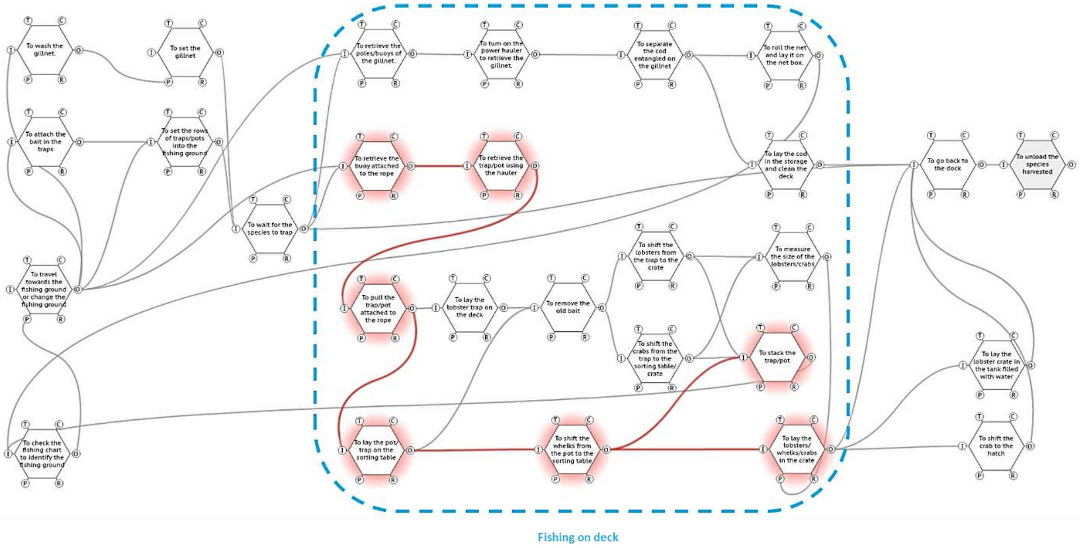

Figure 4.4: Functions Involved While Retrieving the First Line of Pots during the Whelk Fishing

Table 4.7: Fishing Operations of Whelk

Whelk Fishing Operations	
Target amount to catch whelk (tons)	2.5
Number of pots in each line	60
Lines of pots needed to retrieve 2.5 tons	16
Time duration to retrieve each line of pots (min)	15

Time duration to retrieve 16 lines of pots (h)	4
Maximum permitted exposure for fishing on deck task based on 91 dB(A) (hours per day)	2
Lines of pots that can be retrieve in 2 h	8
Estimated amount of whelk catch in 2 hours (tons)	1.25

Figure 4.5 shows the instantiation of a FRAM model, representing the subset of functions coupled together to catch the whelk and stack the pots. Sixty times the functions inside the black curve will be active to retrieve the first line of pots. After retrieving the first line of 60 pots, the function 'to stack the pot' would activate the function 'to check the fishing chart to identify the fishing ground', which is the precondition of the function 'to travel towards the fishing ground or change the fishing ground'. During a fishing trip, fish harvesters change the fishing ground to retrieve or set the other lines of whelk pots.

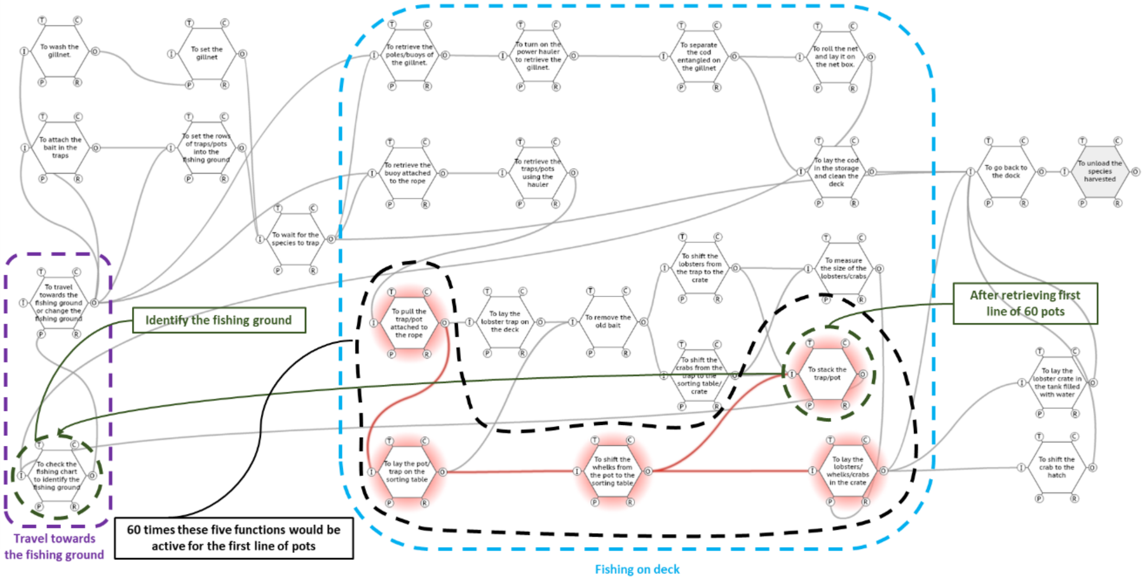

Figure 4.5: FRAM Model of Fishing Operations (Whelk)

The red highlighted functions in Figure 4.6 show all the functions involved during the whelk fishing operations. The FRAM model shown in Figure 4.6 is work-as-done, which is the work observed during the fishing trip. Fisheries and Oceans Canada (DFO) sets fishing season dates in Canada. According to Fisheries and Oceans Canada (DFO), lobster and whelk harvesting season typically starts in May and ends in December. During the whelk harvesting season, the skipper aims to catch at least 2.5 tons of whelk in a day. In order to achieve that target, the fish harvesters travel to multiple fishing grounds to set and retrieve at least 16 lines of pots. During the fishing trip, it was noted that the fish harvesters travelled to 16 different spots of fishing grounds to retrieve 16 lines of pots, which took 4 h.

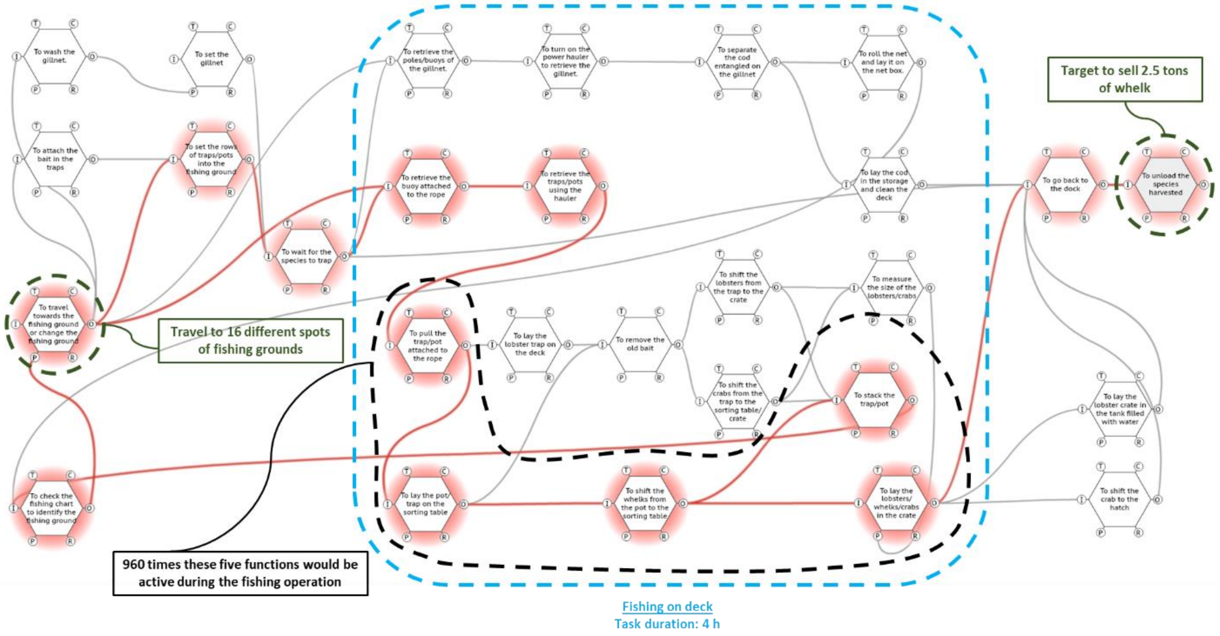

Figure 4.6: FRAM Model of Fishing Operations (Whelk) – Work-as-Done

The time required to retrieve each line of pots can take up to 15 min, and retrieving 16 lines of pots can take up to 4 h, as indicated in Table 4.7. The FRAM model shown in Figure 4.7 is work-asimagine, which is the assumed work that may be done on a fishing vessel. The estimated amount of whelk catch in 2 h is 1.25 tons, as shown in Table 4.7. Fish harvesters can only retrieve eight lines of pots if they perform fishing in 2 h, which is the maximum permitted exposure time for the whelk fishing task based on 91 dB(A), as shown in Table 4.7. Figure 4.7 shows that the function 'to travel towards the fishing ground or change the fishing ground' will be active only eight times while the functions inside the black curve, i.e. to pull the traps attached to the rope, to lay the pot on the sorting table, to shift the whelk from the pot to the sorting table, to lay the whelks in the crate, and to stack the pot will become active 480 times if the fish harvesters plan to complete the whelk fishing in 2 h. The repetition of the fishing on deck task depends on how often the function 'to travel towards the fishing ground or change the fishing ground' will become active. The fish harvesters can catch approximately 1.25 tons of whelk if the function 'to travel towards the fishing ground or change the fishing ground' becomes active eight times, as shown in Figure 4.7. Reducing the duration of whelk fishing reduces the amount of catch. Selling 1.25 tons of whelk might not be sufficient to make a profit. Fish harvesters travel far away from the shore to the fishing ground for whelk harvesting. They change fishing grounds multiple times during the fishing trip, so selling reduced catch would not be enough to cover the operational cost of the fishing trip. Limiting the amount of time the fish harvesters spend in a noisy location is challenging to implement based on the financial aspect involved in whelk fishing operations. The FRAM analysis helped in examining the feasibility of the administrative control, i.e. limiting the exposure time of fish harvester by showing how the variability of a function 'to travel towards the fishing ground or change the fishing ground' can affect the variability of function 'to unload the species harvested', thereby, the fishing operations as a whole, as shown in Figure 4.7. The coupling between the functions of tasks makes it possible to explain how the variability of a function output can affect other functions.

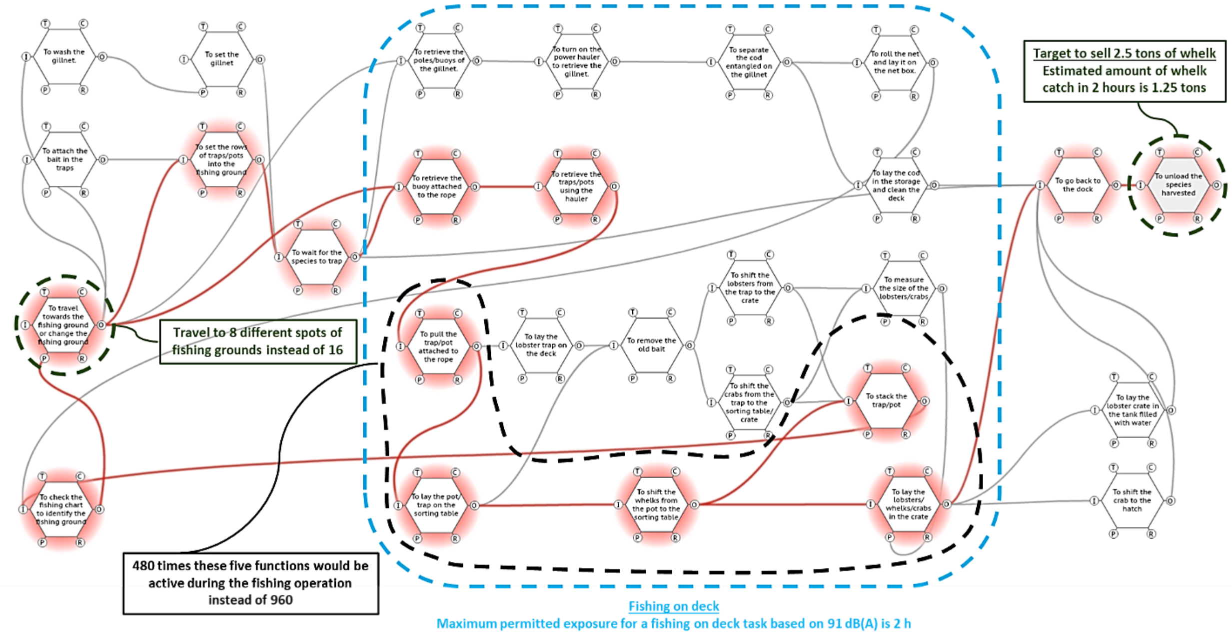

Figure 4.7: FRAM Model of Fishing Operations (Whelk) – Work-as-Imagined

4.4 Provide Rest Periods between Work Periods in Quiet Spaces Where Workers Can Gain Relief from Hazardous Noise Levels

In the surveyed fishing vessel, it was observed that the fish harvesters started their fishing trip by going to the fishing ground for fishing, and then they went to another fishing ground to set the gear to catch the target species. After setting the gear, the fish harvesters went to another fishing ground for fishing. When the function 'to wait for the species to trap' inside the red circle becomes active, the fish harvesters can either: (a) wait for the target species to trap in the fishing ground; (b) go back to the dock; or (c) go to another fishing ground for fishing, as shown in Figure 4.8. During the fishing trip, it was observed that the skippers of the vessels did not allow the crew members to take a break during their work shifts, and they continued performing two tasks, i.e. setting the fishing gear and fishing in the fishing ground. The skipper can give a 15 to 30 min break when the function 'to wait for the species to trap' becomes active so that the crew members can gain relief from hazardous noise levels before starting fishing in other fishing grounds. The crew space is usually quiet, and noise measurement results showed that the noise levels in this space were below the IMO limits (Burella et al., 2019). The crew space is the most suitable location where fish harvesters can gain relief from hazardous noise levels. According to Canada Labour Code, every employee is entitled to and shall be granted an unpaid break of at least 30 minutes during every period of five consecutive hours of work (Justice Laws Website). However, there are no regulations regarding the break duration during the shift for workers working in high-noise locations. High noise levels in a fishing vessel not only cause hearing loss but it causes noise-induced fatigue among fish harvesters (Burella et al. 2021). Research should be done to determine the break duration sufficient for the workers working in high-noise to provide relief from hazardous noise levels during high-noise level tasks.

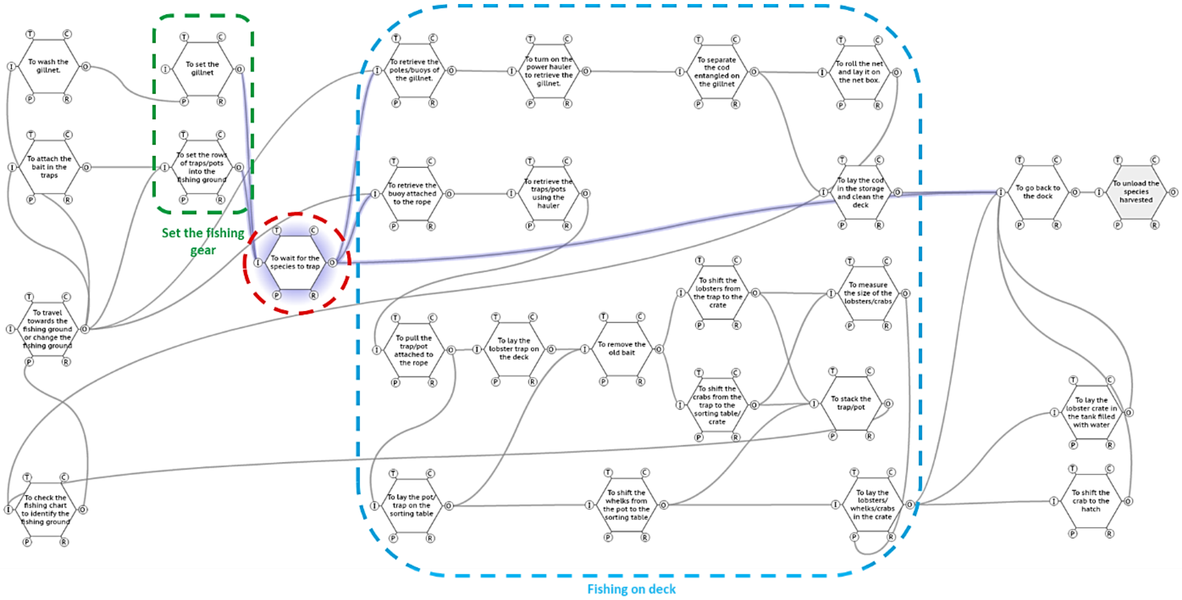

Figure 4.8: FRAM Model of Fishing Operations (Whelk) – Work-as-Imagined

Implementation of administrative controls on small fishing vessels is challenging due to the small crew size on board, limited space on a deck forces fish harvesters to work closer to the noise sources, and financial aspects involved in the fishing operations do not allow the fish harvesters to complete fishing within the permitted exposure time. Reducing noise exposure of fish harvesters using administrative control might be feasible on large fishing vessels, which can be investigated by further vessel surveys using the methodology presented in the current study.

5 Investigating Human Factors Responsible for High Noise Levels during Fishing Task

Hearing loss among workers was recorded as one of the top occupational diseases in the Canadian province of Newfoundland and Labrador between 2017 and 2021 (WorkplaceNL, 2022). The proportion of hearing loss-related claims of fish harvesting occupation was 5.8 %, which is the highest percentage of claims among workers (WorkplaceNL, 2022). Fish harvesters are exposed to many noise sources while working on board the fishing vessels.

In the surveyed fishing vessel where lobster fishing was performed, the maximum measured noise levels were 82 dB(A), while for whelk and crab fishing, the maximum measured noise levels were 91 dB(A) and 90 dB(A), respectively, as shown in Table 5.1. During fishing trips, it was observed that for lobster, crab and whelk fishing tasks, the fish harvesters were exposed to common noise sources, i.e. engine, hauler and gear impacts. Human factors responsible for high noise levels were investigated for the whelk and crab fishing task using the functional resonance analysis method (FRAM). The work patterns of lobster, crab and whelk fishing were compared to identify the reasons for low noise levels during lobster fishing and high noise levels while whelk and crab fishing.

Table 5.1: Noise Levels during Fishing on Deck Task with Gear Impacts (Burella et al., 2021)

Fishery	Noise Sources	$L_{A,eq}$ dB(A)	$L_{C,peak}$ dB(C)
Lobster	1. Engine 2. Gear Impacts 3. Trap hauler	82	131

Whelk	1. Engine 2. Gear Impacts 3. Pot hauler 4. Muffler	91	130
Crab	1. Engine 2. Gear Impacts 3. Trap hauler 4. Muffler	90	142.1

The highlighted functions inside the blue rounded rectangle will become active during the lobster, whelk and crab fishing task, as shown in Figure 5.1. The green highlighted functions are common functions among lobster, crab and whelk fishing; the blue highlighted functions are common functions among lobster and crab fishing; the purple highlighted function is a common function among crab and whelk fishing; the yellow highlighted functions are related to lobster fishing; the grey highlighted function is related to crab fishing, while the red highlighted function is related to whelk fishing.

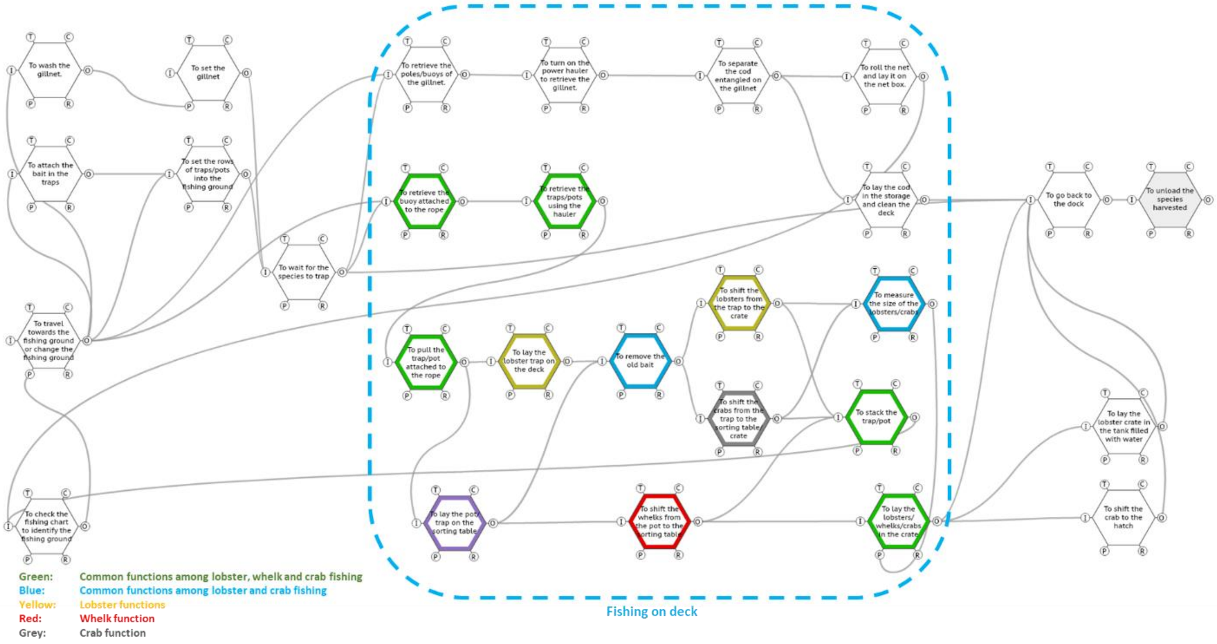

Figure 5.1: FRAM Model of Fishing Operations (Whelk, Crab and Lobster)

The functions 'to retrieve the buoy attached to the rope', 'to retrieve the pot using the hauler', 'to pull the traps attached to the rope', 'to lay the pot on the sorting table', 'to shift the whelks from the pot to the sorting table', 'to stack the pot' and 'to lay the whelks in the crate', will become active during the whelk fishing task, as shown in Figure 5.2. In the surveyed fishing vessel where whelk fishing was performed, it was observed that whelk pots were directly laid into the sorting table after pulling them using the hauler. The whelks were shifted from the pots to the sorting table where sorting of undersized whelks was done.

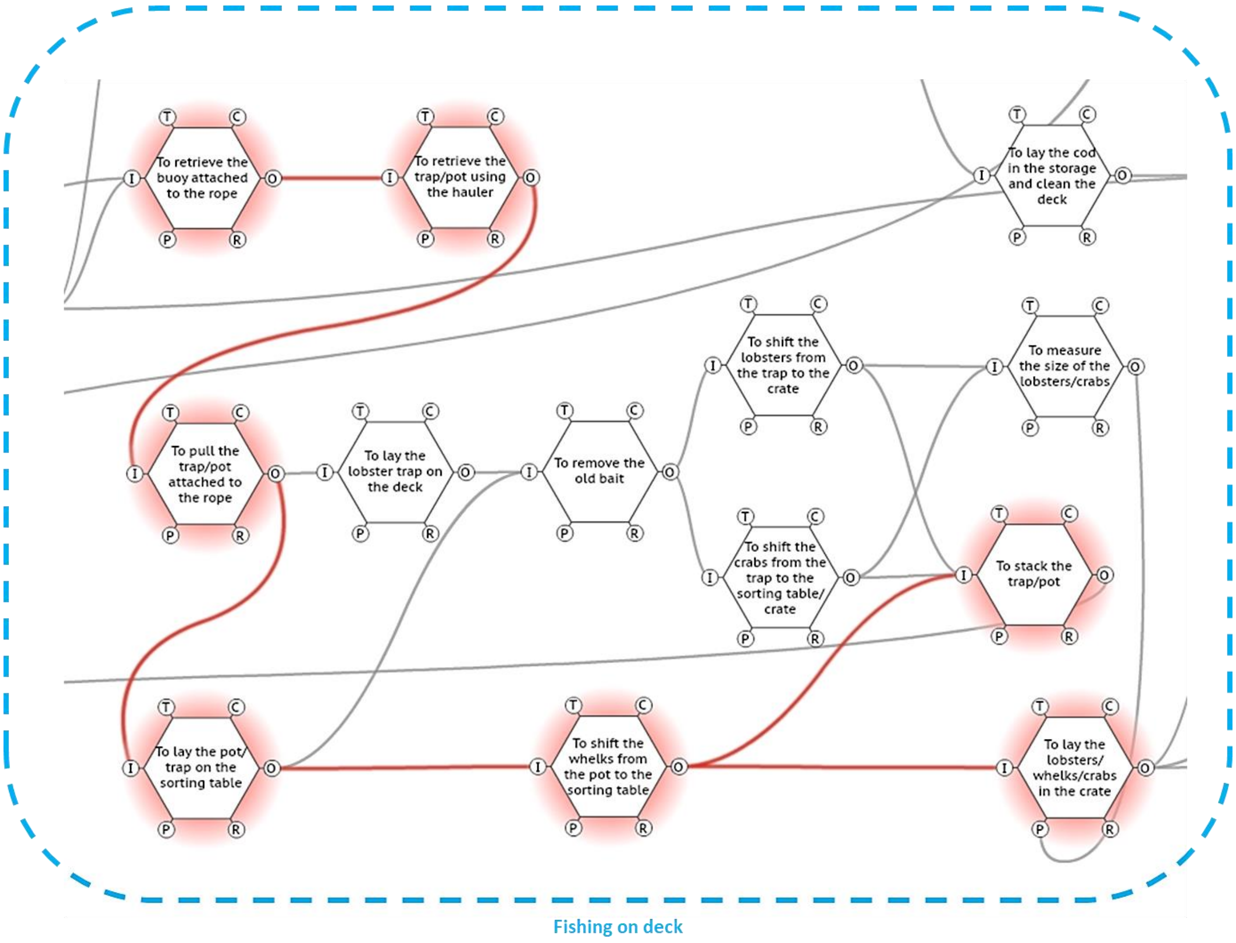

Figure 5.2: Functions Involved during Whelk Fishing Task

The functions 'to retrieve the buoy attached to the rope', 'to retrieve the pot using the hauler', 'to pull the traps attached to the rope', 'to lay the trap on the sorting table', 'to remove the old bait', 'to shift the crabs from the trap to the sorting table', 'to measure the size of the crab', 'to stack the traps' and 'to lay the crabs in the crate', will become active during the crab fishing task, as shown in Figure 5.3. During the crab fishing task, it was observed that crab traps were directly laid into the sorting table after pulling them using the hauler. The crabs were shifted from the traps to the sorting table, then transferred from the sorting table to the crate after measuring the size of the crabs using the crab gauge.

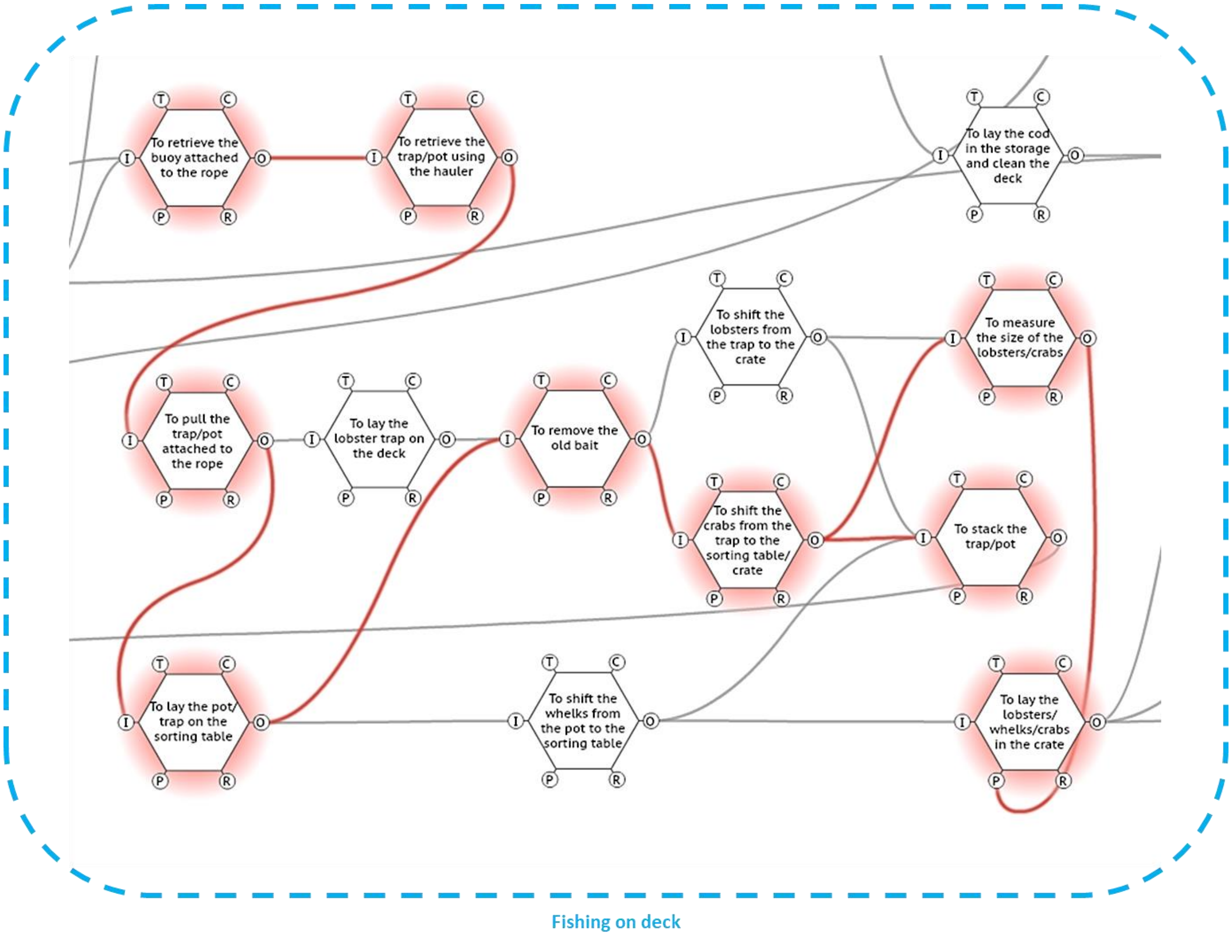

Figure 5.3: Functions Involved during Crab Fishing Task

The functions 'to retrieve the buoy attached to the rope', 'to retrieve the pot using the hauler', 'to pull the traps attached to the rope', 'to lay the lobster trap on the deck', 'to remove the old bait', 'to shift the lobster from the trap to the crate', 'to measure the size of the lobsters', 'to stack the traps' and 'to lay the lobsters in the crate', will become active during the lobster fishing task, as shown in Figure 5.4. During lobster fishing, it was observed that the lobster traps were laid on the deck of the fishing vessel after pulling them using the hauler. A lobster gauge was used to measure the size of the lobster. Undersized crabs, lobsters and whelks were returned to the sea.

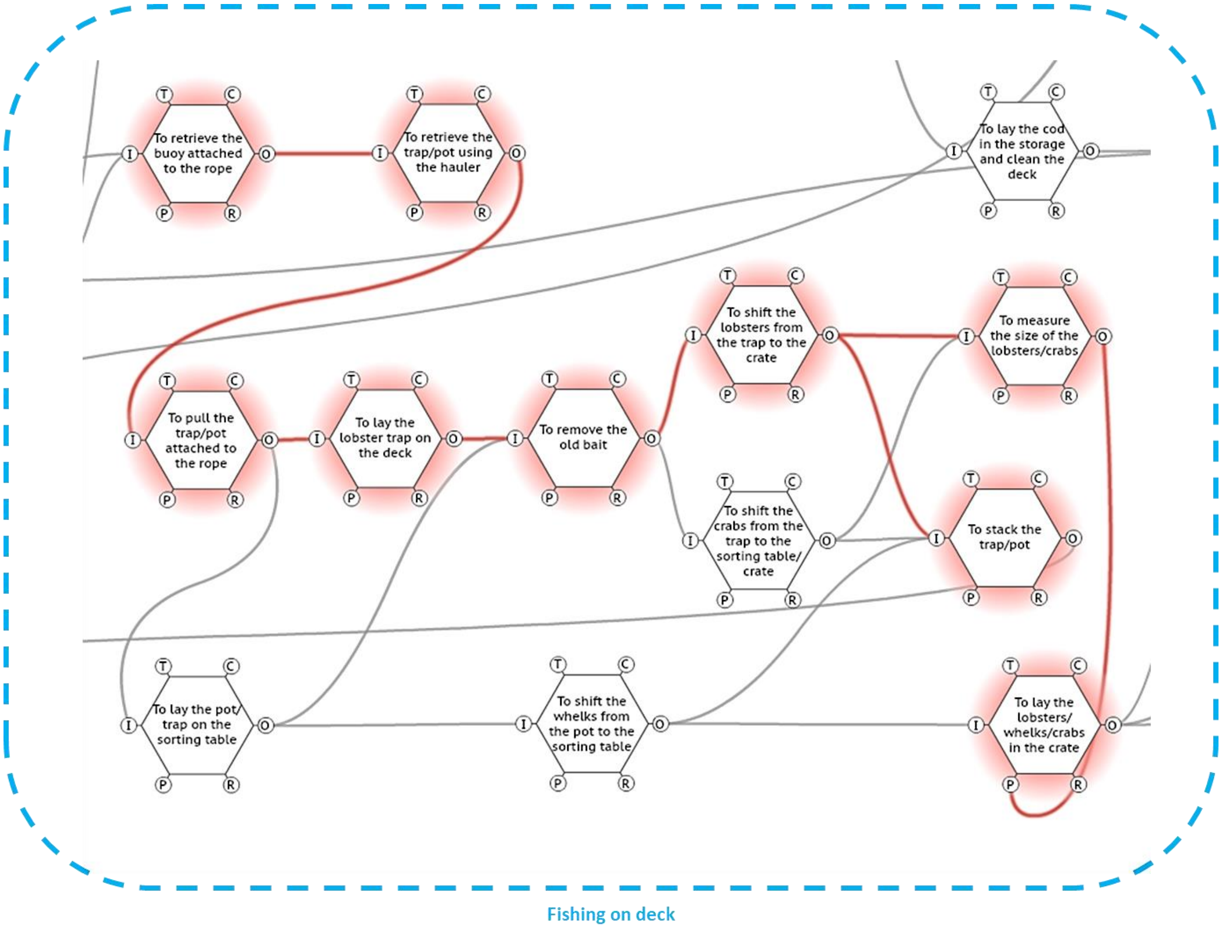

Figure 5.4: Functions Involved during Lobster Fishing Task

The difference between lobster, crab and whelk fishing is that a sorting table is used for whelk and crab fishing. High-level impact noise is generated when whelk pots and crab traps make contact with the sorting table. The high-level impact noise from the gear impacts contributes to the A-weighted equivalent sound pressure level of the whelk and crab fishing task. The contribution of impact noise increases the overall noise level during the whelk and crab fishing task. The measured noise levels during the crab fishing task without gear impacts were 73 dB(A), as indicated in Table 5.2. The range of impact noise levels due to crab trap impacts with the sorting table was 99 – 103 dB(A) (Burella et al., 2021). The impact of the lobster trap with the rail and deck during lobster fishing was low compared to the crab trap impact with the sorting table. The peak sound pressure level $L_{C,peak}$ measured during lobster and whelk fishing was 131 dB(C) and 130 dB(C), respectively, which is under the 140 dB(C) limit, while for crab fishing, it was 142.1 dB(C) which is beyond the 140 dB(C) limit, as indicated in Table 5.1. The impact of the whelk pot with catch hold and deck also generates high-level impact noise during the whelk fishing task.

Table 5.2: Noise Levels during Crab Fishing on Deck Task without Gear Impacts (Burella et al., 2021)

Fishery	Noise Sources	$L_{A,eq}$ dB(A)
Crab	1. Engine 2. Trap hauler 3. Muffler	73

Table 5.3 shows the parameters of impact noise in whelk fishing. In the vessel survey where whelk fishing was performed, it was observed that the number of impacts for each pot retrieval was three due to: (a) pot impact with the sorting table while pulling it from the fishing ground, (b) flipping the pot on a sorting table, and (c) pot impact with catch hold. Noise regulations in several jurisdictions in Canada, such as Quebec, Northwest Territories and Yukon Territories, treat impact noise and continuous noise separately. A standard approach is to limit the number of impacts at a given peak pressure over a workday. The maximum permitted exposure time for 91 dB(A) based on a 5 dB exchange rate for a whelk fishing task is 6 hours and 57 min, as shown in Table 5.3. According to the regulation respecting occupational health and safety by Publications du Québec, the permitted number of impacts (per 8 hours) based on peak sound pressure levels of 130 dB(C) is 1,000, as shown in Table 5.4. In the surveyed fishing vessel where whelk fishing was performed,

it was noted that the number of impacts for 16 lines of pots was 2,880. Based on the peak sound pressure level of 130 dB(C) measured during whelk fishing, the number of impacts of 2,880 is beyond the limit.

Table 5.3: Impact Noise Parameters

Parameters of Impact Noise in Whelk fishing	
Number of pots in each line	60
Number of impacts for each retrieval of a pot	3
Number of impacts for each line of pots	180
Number of impacts for 16 lines of pots	2,880
C-weighted peak sound pressure level dB(C)	130
Permitted number of impacts (per 8 hours) at a peak pressure level of 131 dB(C)	1,000
Time duration to retrieve and stack a pot (sec)	9 – 15
Time duration to retrieve each line of pots (min)	9 – 15
Time duration to retrieve 16 lines of pots (h)	2.4 – 4
Maximum permitted exposure for 91 dB(A) based on a 5 dB exchange rate for fishing on deck task	6 h 57 m

Table 5.4: Permitted Number of Impacts (Per 8 hours) Based on Peak Sound Pressure Levels (Publications du Québec, 2022)

Sound level in dB linear as a peak value	Permitted number of impacts (per 8 hours)

120	10,000
121	7,943
122	6,310
123	5,012
124	3,981
125	3,162
126	2,512
127	1,995
128	1,585
129	1,259
130	1,000
131	794
132	631
133	501
134	398
135	316
136	251
137	200
138	158
139	126
140	100
>140	0

5.1 Solutions to Reduce Impact Noise during Whelk Fishing

High-level impact noise is generated when the functions 'to lay the pot on the sorting table' and 'to stack the pot' inside the red circles becomes active during the whelk fishing task, as shown in Figure 5.5. In the surveyed fishing vessel, it was observed that the fish harvesters laid the pots on the sorting table and catch hold because they were unaware that pot impacts could cause severe hearing loss. These human factors are responsible for high-level impact noise during whelk fishing task. The Newfoundland and Labrador Fish Harvesting Safety Association (NL-FHSA) developed a noise exposure video where fish harvesters can be seen laying the whelk pots on the sorting table and catch hold during whelk fishing (NL-FHSA, 2021, 0:33). In another online video, it was observed that in a fishing vessel where whelk fishing was performed, the sorting table was placed at some distance from the hauler (Belinskis, 2015, 0:42). The skippers of the fishing vessels should ensure that there must be enough gap between the hauler and the sorting table so that the pots while pulling, cannot make contact with the sorting table. In an online video, it was also noticed that while shifting the whelks from the pot to the sorting table, fish harvesters were not laying the pots on the sorting table (Belinskis, 2015, 1:57). It was also observed that fish harvesters were laying the pots above the shock-absorbing material while stacking them (Belinskis, 2015, 2:00). Whelk pots are lightweight and small in size as compared to crab traps. While shifting the whelks from the pot to the sorting table, it is possible to hold the whelk pot. Fish harvesters should lay the pots above the shock-absorbing material rather than laying them on the catch hold after shifting the whelks from the pots to the sorting table. Following these work patterns can significantly reduce the impulsive component of noise exposure during the whelk fishing task, which would ultimately help in reducing hearing loss among fish harvesters involved in whelk fishing.

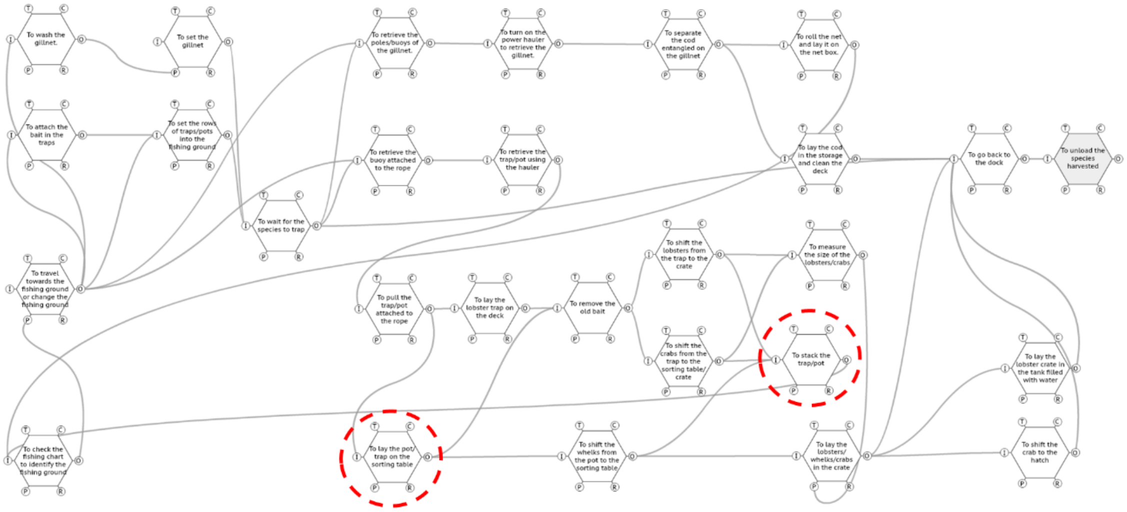

Figure 5.5: Functions which Cause Impact Noise during Whelk Fishing

5.2 Solutions to Reduce Impact Noise during Crab Fishing

In the surveyed fishing vessels, it was observed that high-level impact noise was generated when the fish harvesters laid the crab traps on the sorting table after pulling them using the hauler installed on the rail side of the fishing vessel (Burella et al., 2021). Forty traps were retrieved during the fishing trip, and the total number of impacts noted during crab fishing was 40 due to trap impact with the sorting table. Based on the peak sound pressure level of 142.1 dB(C) measured during crab fishing, the permitted number of impacts (per 8 hours) is zero, as shown in Table 5.4. Peak sound pressure levels beyond 140 dB(C) can cause severe hearing loss among fish harvesters. In online videos, it was observed that fish harvesters used a crab trap puller to retrieve the trap from the fishing ground (Isaac, 2019, 0:35; Rzrjay, 2015, 3:10). Figure 5.6 shows the crab trap puller, which comprises a hauler that pulls the crab trap from the fishing ground. In an online video, it was noticed that when the crab trap comes closer to the open block crab pulley, the hydraulic system allows the boom of the puller to lift the crab trap so that fish harvesters can open the trap at the bottom (Rzrjay, 2015, 3:54). The crab trap puller allows the fish harvesters to shift the crabs from the trap to the sorting table without the trap making contact with the sorting table. The advantage of using the crab trap puller is that it not only lifts the heavy crab traps but also reduces the chances of the trap impact with the sorting table. Fishing vessels should be equipped with a crab trap puller.

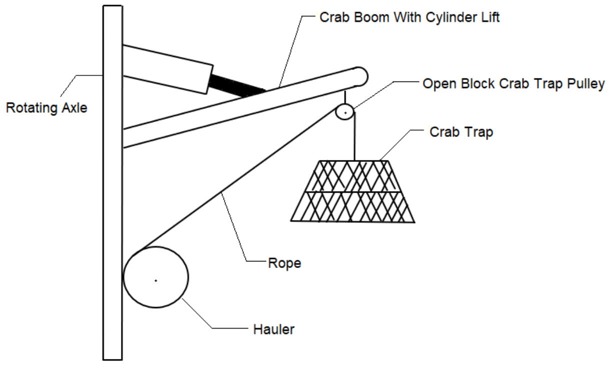

Figure 5.6: Crab Trap Puller

5.3 Use of Hearing Protection Devices to Reduce Noise Exposure

The range of impact noise levels due to catch impacts with the sorting table was 75 – 89 dB(A) during the crab fishing task (Burella et al., 2021). It is difficult to reduce the impact noise generated due to catch impacts with a sorting table that can go beyond the 85 dB(A) limit. It is recommended to wear hearing protection when noise levels exceed the limits at the workplace. The attenuation ratings of hearing protection were selected based on noise levels of fishing on deck tasks for whelk and crab fisheries using the Single Number Rating (SNR) method and the High, Medium, Low (HML) method. The aim of selecting the attenuation ratings shown in Table 5.5 was to reduce the noise levels at the ears of fish harvesters below 80 dB(A). According to the Health and Safety Executive of the United Kingdom, the noise levels at the ear under the protector should be between

80 and 75 dB(A). The predicted sound levels effective at the ear under the protector were estimated according to the International Organization for Standardization (ISO) Standard 4869-1:2018, as shown in Table 5.6.

Table 5.5: Attenuation Rating Calculated Based on Sound Pressure Levels

Fishery	Without hearing protection		Attenuation rating	
	A-weighted equivalent sound pressure level	C-weighted equivalent sound pressure level		
	$L_{A,eq}$ dB(A)	$L_{C,eq}$ dB(C)	SNR	HML
Whelk	91	100	20 – 30	H=28, M=21, L=13
Crab	90	99	19 – 29	H=28, M=21, L=13

Table 5.6: Predicted A-weighted Level Effective at the Ear under the Protector

Fishery	Without hearing protection		With hearing protection
	A-weighted equivalent sound pressure level	C-weighted equivalent sound pressure level	Predicted A-weighted level effective at the ear under the protector having attenuation rating SNR = 22

	$L_{A,eq}$ dB(A)	$L_{C,eq}$ dB(C)	L'A dB(A)
Whelk	91	100	78
Crab	90	99	77

6 Conclusions

This study presents a methodology to assess the feasibility of administrative control to reduce noise exposure of crew members and to identify human factors which cause high noise levels on board the vessels. Previous studies show a lack of information on the feasibility of administrative controls on the vessels. The purpose of using the functional resonance analysis method (FRAM) in this study was to gain insight into fishing operations and to examine whether the solutions that can be taken to reduce the noise exposure of fish harvesters are practicable. The feasibility of administrative controls in a workplace cannot be judged without understanding the functionality of an operation. Fish harvesters spend more time fishing on deck than the maximum permitted exposure time to achieve their target of catching the minimum amount of whelks. The FRAM analysis shows that the whelk fishing task cannot be completed within the permitted exposure time calculated based on noise levels due to the financial aspects involved in the fishing operations. In the surveyed fishing vessels, it was observed that the skipper of the vessel does not provide breaks between work periods because they are unaware that noise can cause fatigue among the crew members. The skipper can give a 15 to 30 min break during their shift so that the crew members spend some time in crew space to gain relief from the noise.

The FRAM helps to learn from a work pattern of a worker performing a task in such a manner that produces low noise levels instead of another worker carrying out the same task in such a way that causes high noise levels. The FRAM can be useful for noise exposure management because suggestions can be made using this method for workers who are exposed to high noise levels due to their work patterns to follow the work patterns in which the noise exposure is low.

The FRAM model built in this study reflects human factor interactions necessary to complete tasks involved during fishing operations. The FRAM can identify human factors that can contribute to overall noise in the workplace. This study identified human factors that generate high-level impact noise during the whelk and crab fishing task. Impact noise can cause more severe hearing loss than continuous noise. Impact noise can be reduced during whelk fishing if the fish harvesters do not lay the whelk pot on the sorting table and catch hold. This work pattern modification can be useful in reducing impact noise during the whelk fishing task. The possibility of impact noise exposure is low on the crab fishing vessels where the crab trap puller is installed. The benefit of using a crab trap puller is that it helps in lifting heavy crab traps, so it becomes easier for the fish harvesters to shift the crabs from the trap to the sorting table without the trap making contact with the table. A crab trap puller was not installed on the surveyed fishing vessels, which forced fish harvesters to lay the crab trap on the sorting table. Noise measurement results show that high-level impact noise was also generated due to catch impacts with a sorting table during crab fishing. The measured noise levels due to catch impacts were beyond the 85 dB(A) limit. The impact of whelks on the sorting table is also noisy. Fish harvesters should use hearing protection to prevent themselves from high-level noise reaching their ears during fishing.

6.1 Limitations

A limitation of this study was that the FRAM analysis performed was based on the data Burella et al. (2021) collected during fishing trips. The current study focused on whelk, crab and lobster fishing operations. Pelagic and shrimp fishing tasks are related to high noise levels. Human factors which cause high noise levels during pelagic and shrimp fishing tasks were not investigated due lack of information. Ethics clearance was obtained in this study to conduct interviews with the crew members to gain information about their jobs and tasks and perform personal noise exposure measurements on board vessels. The data was not collected in this study due to a lack of response or interest in participation from the companies. The owners and crew members of the fishing vessels were not asked about the feasibility of the proposed solutions to reduce noise levels during fishing operations. Access to vessels was limited due to the COVID-19 pandemic, which delayed the research. Marine transportation companies were not allowing us to collect data on their vessels because Transport Canada enforced restrictions due to the coronavirus for vessels while operating in Canadian waters to minimize the risk of exposure to COVID-19 in Canada. Future research should include more noise measurements on board vessels, interviewing the crew members and observing their job tasks, and performing vessel surveys to enhance the validity of the FRAM model for noise exposure management.

6.2 Recommendations and Future Work

In Newfoundland and Labrador, there were 160 hearing loss-related claims among workers in 2021, which cost around $3.3 million (WorkplaceNL, 2022). Construction, wholesale trade and retail trade, transportation and storage, manufacturing, mining, quarrying, and oil and gas extraction were the industries where hearing loss-related claims were reported (WorkplaceNL, 2022). This shows that noise in the workplace is a big concern for industries. Implementing both engineering and administrative controls can help reduce workers' noise exposure. The studies often ignore identifying the human factors in a workplace that can cause high noise levels. The procedure presented in this study can be applied in other industries to examine the feasibility of administrative controls to reduce the noise exposure of workers, identify human factors in an operation which cause high noise levels, and manage the noise exposure of workers by changing their work patterns. The current research used the FRAM to identify human factors contributing to the overall noise of the task. Further work should be performed to use other techniques, such as Human Factors

Analysis Classification System (HFACS), Hierarchical Task Analysis (HTA) and Task Decomposition Methodology (TDM), to identify human factors in an operation that can cause high noise levels.

Future work should be done on measuring the impact noise on board the fishing vessels and performing audiometry tests of fish harvesters. The results could help in identifying the correlation between hearing loss and impact noise parameters among fish harvesters. The data of the suggested work can verify the current study in which impact noise is found to be the cause of hearing loss among fish harvesters. There is a need to categorize hearing loss among fish harvesters based on the fishery in which they are involved.

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8 Appendix A

ICEHR – Application for Ethics Review (Secondary Use of Data)

Project Info.

File No: 20230590
Project Title: Investigating Work Processes to Manage Worker's Noise Exposure in the Workplace
Principal Investigator: Mr. Muhammad Sabah Ud Din Ersum (Faculty of Engineering and Applied Science\Department of Ocean and Naval Architectural Engineering)
Start Date: 2022/08/12
End Date:
Keywords: Health, Vessels and Related Equipment, Engineering, FRAM, Occupational Health and Safety, Aquaculture

Related Awards:

Award File No	Principal Investigator	Project Title	Funding Snapshot	Notes
20200928	Lorenzo Moro	Future Ocean and Coastal Infrastructures (FOCI): Designing safe, sustainable and inclusive coastal communities and industries for Atlantic Canada	**OFI** Program: OFI Phase 2 Type: Grant Account#: 214145 59000 2000 Requested: CAD 747,956.00 Awarded: CAD 747,956.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214146 59000 2000 Requested: CAD 110,567.00 Awarded: CAD 110,567.00	N/A

			OFI Program: OFI Phase 2 Type: Grant Account#: 214147 59000 2000 Requested:CAD 62,500.00 Awarded: CAD 62,500.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214148 59000 2000 Requested:CAD 371,058.00 Awarded: CAD 371,058.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214149 59000 2000 Requested:CAD 180,883.00 Awarded: CAD 180,883.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214150 59000 2000 Requested:CAD 111,375.00 Awarded: CAD 111,375.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214151 59000 2000 Requested:CAD 499,997.00 Awarded: CAD 499,997.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214152 59000 2000 Requested:CAD 141,500.00	

			Awarded: CAD 141,500.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214153 59000 2000 Requested: CAD 81,000.00 Awarded: CAD 81,000.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214154 59000 2000 Requested: CAD 300,000.00 Awarded: CAD 300,000.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214173 59000 2000 Requested: CAD 170,525.00 Awarded: CAD 170,525.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214174 59000 2000 Requested: CAD 374,100.00 Awarded: CAD 374,100.00 **OFI** Program: OFI Phase 2 Type: Grant Account#: 214183 59000 2000 Requested: CAD 246,777.00 Awarded: CAD 246,777.00 **OFI** Program: OFI Phase 2 Type: Grant	

			Account#: 214184 59000 2000 Requested: CAD 335,706.00 Awarded: CAD 335,706.00 **PROJECT TOTALS:** Requested: CAD 3,733,943.33 Awarded : CAD 3,733,942.98	
20201360	Doug Smith	Start up grant - Human factors in safety management	**MUN** Program: Faculty of Engineering Start-Up Funds Type: Grant Account#: 213875 41000 2000 Requested: CAD 20,540.00 Awarded: CAD 20,540.00 **MUN** Program: Vice-President Research Start-up Support Type: Grant Account#: 213875 41000 2000 Requested: CAD 19,460.00 Awarded: CAD 19,460.00 **PROJECT TOTALS:** Requested: CAD 40,000.00 Awarded : CAD 40,000.00	N/A
20222284	Paul Foley	PUBLICITY CLEARANCE PENDING Future Ocean and Coastal Infrastructures (FOCI): Designs for Diversity in	**Gov NL, Department of Industry, Energy and Technol** Program: Leverage R&D Program Type: Contract-Agreement	N/A

		Newfoundland and Labrador's Blue Economy	Requested: CAD 590,000.00 Awarded: CAD 590,000.00 **PROJECT TOTALS:** Requested:CAD 590,000.00 Awarded :CAD 590,000.00	

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Common Questions

1. Degree Program

#	Question	Answer
1.1	Please indicate the project program related to the application.	Master's Thesis
1.2	If OTHER, please specify.	N/A

2. Purpose of Study and Research Questions

#	Question	Answer
2.1	Explain the purpose, objectives, and hypotheses of the project in non-technical, plain language. (Maximum 500 words)	Continuous noise exposure in the workplace can negatively impact workers and cause noise-induced hearing loss (NIHL). High noise levels affect workers' performance and may lead to human error, which can contribute to accidents. High noise levels in the workplace can lead to fatigue, which is one of the major health problems among workers. Noise exposure during the jobs and tasks of workers has not been systematically investigated. Extensive literature has reported the impacts of noise such as hearing impairment, poorer sleep quality and stress level, etc. on workers and recommended many design solutions to mitigate high noise levels in the workplace such as enclosing the engine and generator in the insulating cabin, use of resilient mounting systems to decouple the engine and generator, soundproofing of engine room,

		and use of hearing protection devices during the operation. This research activity will help (i) analyze noise levels in the workplace; (ii) identify the jobs and tasks in which workers are exposed to hazardous noise levels; (iii) understand the noise exposure perception of workers; (iv) assess noise-induced fatigue in the workplace (v) reduce noise exposure by effectively planning the exposure time of the workers to create a safe working condition. The purpose of this research are i) analyze occupational noise exposures on vessels and aquaculture facilities, and ii) investigate whether work processes and/or locations can be re-designed to limit noise exposure and mitigate the risks of hearing loss for workers during their shift hours. The Functional Resonance Analysis Method (FRAM) will be used to model the worker's activities during their work shifts. The FRAM will help to understand the inner workings of the operation and to manage the tasks of the work, so noise exposure can be lowered. The ideal source to obtain information on the workers' activities is to interview them and observe their tasks and work patterns in the workplace. However, we have had trouble recruiting companies which can provide access to their workplace so that we can start employee recruitment. Another opportunity to demonstrate the utility of FRAM is to investigate the work patterns of the employees using the activity logs filled out by the participants during their work shifts. The participants used the activity logs to note their tasks, the locations where they carried out their tasks and the duration of each task when their personal noise exposure measurements were carried out by Giorgio Burella and Jonathan Stone et al. during their work shifts in the workplace. The noise data associated with each task was assessed using the information in the activity log to identify the activities associated with hazardous noise levels. This data would help to build a FRAM model so that the desired safe exposure level can be achieved by adjusting the working

		shifts of the workers to decrease the exposure times of workers in high noise locations of the workplace or possibly increasing the manning level in high noise locations to be able to make them work in shifts.

3. Data Characteristics and Background

#	Question	Answer
3.1	Select the relevant data type(s):	Coded data – Key IS NOT accessible to the researcher
3.2	Provide a summary description of the source data to be used in the proposed project. Indicate the nature / type of data, how and why it was originally collected and by whom, and how you will obtain access to the dataset(s).	1. Source data to be used in the proposed project: Giorgio Burella and Jonathan Stone worked under Dr. Lorenzo Moro's supervision to measure participants' occupational noise exposure during their shift hours. Giorgio Burella documented noise levels on fishing vessels, while Jonathan Stone documented noise levels at aquaculture facilities. 2. Nature / type of data: The personal noise exposure of participants was measured using dosimeters during their work shifts. During the personal noise exposure measurement, the participants used the activity logs to note their tasks, the locations where they carried out their tasks and the duration of each task. This information was used to identify the tasks of the participants associated with hazardous noise levels. 3. Why data was originally collected? Prolonged noise exposure on fishing vessels and aquaculture facilities is responsible for noise-induced hearing loss of the workers. The research of Jonathan Stone and Giorgio Burella et al. aimed to document noise exposures and hazardous noise sources at aquaculture facilities and fishing vessels, respectively. The noise levels measured at various measurement locations of the fishing vessels and aquaculture facilities were compared with the recommended levels to check whether noise levels were beyond the limits or not. 4. How you will obtain access to the dataset(s)? I am doing my research work under the supervision of Dr. Lorenzo Moro and Dr. Doug Smith. Dr. Moro was the principal investigator of the project titled

		"Noise Exposure of Workers in the Aquaculture Industry of Newfoundland" file No: 20192681, and "Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels" file No:20180105. Dr. Moro will provide me access to the dataset(s) once the Interdisciplinary Committee on Ethics in Human Research (ICEHR) approves our application for ethics review (Secondary Use of Data).
3.3	Describe the size of the dataset(s) and/or number of original participants in the data collection.	There were 36 participants working on 12 small fishing vessels in the "Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels" project while 10 participants working on 4 aquaculture facilities in the "Noise Exposure of Workers in the Aquaculture Industry of Newfoundland project". In the Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels project, 20 personal noise exposure measurements were taken. In the Noise Exposure of Workers in the Aquaculture Industry of Newfoundland project, all the employees participated in the personal noise exposure measurement.
3.4	Explain any criteria that will be used to identify / select relevant data such as specific participant attributes, periods of time, or geographical location.	No specific criteria would be used to identify the attributes of participants. The activity logs and the noise exposure data of the participants during their work shift would be used for the data analysis in our research.
3.5	Was any of the source data originally collected for research purposes?	Yes
3.6	If YES, specify the REB that approved the original data collection. If the original REB was ICEHR, provide the ICEHR file number. If the original data collection did NOT have REB approval, explain why not.	1- The source data is "Noise Exposure of Workers in the Aquaculture Industry of Newfoundland." PI: Dr. Lorenzo Moro and File No: 20192681. 2- The source data is "Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels." PI: Dr. Lorenzo Moro and File No:20180105.

3.7	If the source data was NOT originally collected for research purposes, indicate the purpose(s) of the original data collection.	
3.8	If OTHER, please specify.	N/A
3.9	Was the data collected with consent from participants?	Yes
3.10	If YES, describe the elements of consent regarding data sharing and future use that participants agreed to. If available, upload a BLANK or REDACTED copy of the consent form used for the original data collection in the Attachments tab.	1- See informed consent form from: "Noise Exposure of Workers in the Aquaculture Industry of Newfoundland." PI: Dr. Lorenzo Moro and File No: 20192681. 2- See informed consent form from: "Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels." PI: Dr. Lorenzo Moro and File No: 20180105.

4. Access to Data, Privacy, and Confidentiality

#	Question	Answer
4.1	Identify the source(s) of the data (e.g. government agency / department, other public body, or private company / individual)	1- The source data is from "Noise Exposure of Workers in the Aquaculture Industry of Newfoundland." PI: Dr. Lorenzo Moro and File No:20192681. 2- The source data is from "Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels." PI: Dr. Lorenzo Moro and File No:20180105.
4.2	Is the data available in the public domain? (See description above)	Yes
4.3	Identify the data custodian / holder for each data source identified in 4.1 and upload a copy of the correspondence communicating approval and/or granting access to the data in the Attachments tab.	Dr. Lorenzo Moro. All communication regarding this secondary use of this data was verbal.
4.4	Describe how data will be securely obtained / transferred and stored for use in this project.	Each participant was assigned an alpha/numeric identifier with only Giorgio Burella and Jonathan Stone et al. having access to the master list of participants as well as original data recordings, activity logs and additional notes. The principal investigator (Dr. Lorenzo Moro) of the projects i.e. "Noise Exposure of Workers in the Aquaculture Industry of Newfoundland"

		(File No:20192681) and "Short-term and Long-term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels" (File No:20180105) would provide activity logs and personal noise exposure files in which only the employee ID (alpha/numeric identifier) and role of the participants would be mentioned, not their names.
4.5	Are there specific retention and/or destruction parameters placed on the data by the data holder / custodian? If YES, discuss.	No
4.6	As per Memorial University's policy on Integrity in Scholarly Research, all primary data resulting from scholarly activity must be retained for a MINIMUM of 5 years. Please provide details regarding your anticipated plans for retention and/or disposal of the data.	The data will be stored for an indefinite period of time, and a minimum of five years as required by Memorial University's policy on Integrity in Scholarly Research.
4.7	Will data be shared with or accessed by anyone other than the principal investigator?	Yes
4.8	If YES, describe how data will be shared and in what format.	The data files will not be shared, but the results from the FRAM analysis will be presented in a journal publication.
4.9	Will data from this study be contributed to a larger study?	No
4.10	If YES, identify any other institutions and/or external team members involved in the larger study.	N/A

5. Data Linkage

#	Question	Answer
5.1	Will the proposed project require data linkage?	No
5.2	If YES, describe how confidentiality of the data will be protected, who will perform the data linkage, and how the merged files will be safeguarded?	N/A
5.3	If YES, is this linkage likely to result in re-identification of participants or the production of identifiable information? If so, how?	N/A

5.4	IF YES to 5.3, how will the identity or potentially identifying information relating to original participants be safeguarded?	N/A

6. Sharing / Disseminating Results

#	Question	Answer
6.1	Describe if / how the results of this project will be shared with the research community and/or the general public.	The results of the FRAM analysis on this data will be presented in a journal publication. These results will not have potential identifiers
6.2	If applicable, describe if / how the results of this project will be shared with participants from whom the data was originally collected, relevant agencies, or communities.	N/A

7. Funding, Contracts, and Agreements

#	Question	Answer
7.1	Please select the appropriate funding status for this project:	Funded
7.2	If funded, or funding is being sought, please indicate the funding agency/sponsor. If there are multiple sources of funding please enter each on a new line.	This research is funded through the Faculty of Engineering & Applied Science at Memorial University of Newfoundland; and the OFI project Future Ocean and Coastal Infrastructures (FOCI).
7.3	If you indicated in 7.1 that funding is being sought, specify whether or not this project will proceed if funding is not obtained.	Project will proceed regardless of funding status
7.4	Will funds be administered through Memorial's Research Initiatives & Services (RIS) office?	Yes
7.5	If you answered NO or OTHER to 7.4, explain.	N/A
7.6	If YES to 7.4, specify the principal investigator for the associated funding AND provide the RIS Awards file number(s):	Dr. Doug Smith Awards file number: 20201360 and Dr. Lorenzo Moro Awards file number: 20200928 (Omnibus Ethics application: 20210630)
7.7	Is there a funded or non-funded contract or research / partnership agreement associated with this research?	No
7.8	If YES to 7.7, specify the parties to the contract / agreement, and discuss the contract / agreement provisions relating to intellectual property, data access, and data	N/A

	ownership. Upload a copy of the agreement / contract in the Attachments tab.	

8. Conflict of Interest

#	Question	Answer
8.1	Is there any aspect of a contract/agreement that could put any member of the research team in a potential conflict of interest?	No
8.2	If YES, identify the conflict(s) and discuss how they will be mitigated.	N/A

9. Pre-Submission Checklist

#	Question	Answer
9.1	All questions have been answered in the space allowed (Including "N/A" where appropriate).	Yes
9.2	A copy of the Principal Investigator's TCPS2 Tutorial Certificate of Completion is included in the Attachments tab.	Yes
9.3	A copy of any funded or non-funded contract or research / partnership agreement is included in the Attachments tab.	Not Applicable
9.4	A copy of the correspondence regarding data access from the data holder / custodian has been attached in the Attachments tab.	Not Applicable
9.5	If this study primarily involves data from an Aboriginal population, a copy of the research agreement or letter of support from the relevant community groups and boards is included.	No
9.6	The supervisor signature form is included. (Students Only)	Yes
9.7	(Faculty / Staff) If funded, the project funding has been linked under 'Related Awards' on the Project Info tab.	No
9.8	(Student / Postdoc) If funded, the 'Funded Projects' section has been completed on the attached Supervisor signature page.	Yes

10. Declaration

#	Question	Answer

10.1	I have read, and understand that I must comply with, Memorial University's Policy on Ethics of Research Involving Human Participants and the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (TCPS2 - 2014).	Agree
10.2	I will ensure that all procedures performed under the project will be conducted in accordance with the TCPS2 (2014) and all relevant university, provincial, national, and international policies and regulations that govern the collection and use of personally identifiable information and/or any other data in research involving human participants.	Agree
10.3	I agree to conduct the research subject to Section 3 (Guiding Ethical Principles) and accept the responsibilities as outlined in Section 18 (Responsibilities of Researchers) of Memorial University's Policy on Ethics of Research Involving Human Participants.	Agree
10.4	I understand that if I misrepresent and/or fail to accurately and fully disclose any aspects of the research, my ethics clearance may be suspended.	Agree
10.5	I understand that Article 6.16 of the TCPS2 (2014) requires that I submit an amendment request to ICEHR before making any changes to my approved protocol that may affect participants including, but not limited to, changes in recruitment, informed consent, test instruments, and/or tasks or interventions involved in the research. I understand that changes implemented without approval constitute a violation of the TCPS2 (2014) and Memorial University policy.	Agree
10.6	I understand that Article 6.14 (Continuing Research Ethics Review) of the TCPS2 (2014) requires that I submit an annual update for each year my project is active, and a final report after my project is completed.	Agree
10.7	If there is any occurrence of an adverse event(s), I will report it to ICEHR immediately by submitting an Adverse Event Report.	Agree

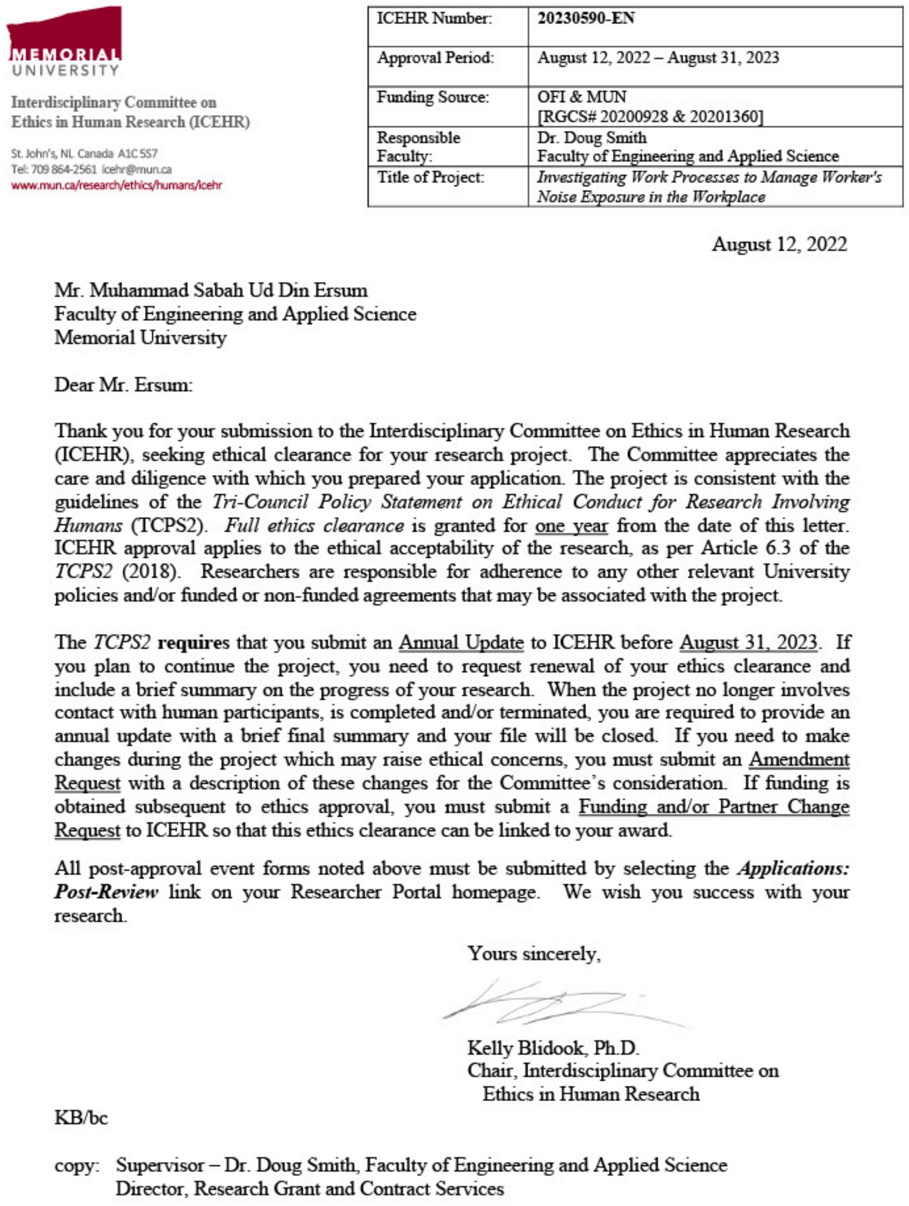
Attachments

Doc / Agreement	Version Date	File Name	Description
Informed Consent Form	2022/07/29	009_Crew Consent Form_07_June_2017.pdf	Original crew informed consent form (File No:20180105)
Informed Consent Form	2022/07/29	010_Owner-operator_Consent Form_07_June_2017.pdf	Original owner/operator informed consent form (File No:20180105)
Informed Consent Form	2022/07/29	009_REVISED_Employee_Consent_Form_February_26_2019.pdf	Original employee informed consent form (File No:20192681)
Informed Consent Form	2022/07/29	010_REVISED_Company_Consent_Form_February_26_2019.pdf	Original company informed consent form (File No:20192681)
Letter (Approval)	2022/08/12	4 - 0590 Approval Letter.pdf	N/A

Secondary Use of Data Approval Letter	2022/07/29	Secondary_use_data_20220728.pdf	N/A
Signature Form	2022/07/29	Supervisor Signature Page (v0218SUD)_signed.pdf	N/A
TCPS2 Certificate	2022/07/29	tcps2_core_certificate_L_Moro.pdf	Co-supervisor-Lorenzo TCPS2 certificate
TCPS2 Certificate	2022/07/29	tcps2_core_certificate_D_Smith.pdf	Supervisor-Doug TCPS2 certificate
TCPS2 Certificate	2022/07/29	tcps2_core_certificate_M_Ersum.pdf	Principal Investigator-Muhammad TCPS2 certificate
TCPS2 Certificate	2022/07/29	tcps2_core_certificate_G_Burella.pdf	Giorgio TCPS2 certificate
TCPS2 Certificate	2022/07/29	tcps2_core_certificate_J_Stone.pdf	Jonathan TCPS2 certificate
TCPS2 Certificate	2022/07/29	tcps2_core_certificate_B_Neis.pdf	Barbara TCPS2 certificate

9 Appendix B

ICEHR Ethics Approval



MEMORIAL
UNIVERSITY

Interdisciplinary Committee on
Ethics in Human Research (ICEHR)

St. John's, NL Canada A1C 5S7
Tel: 709 864-2561 icehr@mun.ca
www.mun.ca/research/ethics/humans/icehr

ICEHR Number:	**20230590-EN**
Approval Period:	August 12, 2022 – August 31, 2023
Funding Source:	OFI & MUN [RGCS# 20200928 & 20201360]
Responsible Faculty:	Dr. Doug Smith Faculty of Engineering and Applied Science
Title of Project:	*Investigating Work Processes to Manage Worker's Noise Exposure in the Workplace*

August 12, 2022

Mr. Muhammad Sabah Ud Din Ersum
Faculty of Engineering and Applied Science
Memorial University

Dear Mr. Ersum:

Thank you for your submission to the Interdisciplinary Committee on Ethics in Human Research (ICEHR), seeking ethical clearance for your research project. The Committee appreciates the care and diligence with which you prepared your application. The project is consistent with the guidelines of the *Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans* (TCPS2). *Full ethics clearance* is granted for one year from the date of this letter. ICEHR approval applies to the ethical acceptability of the research, as per Article 6.3 of the *TCPS2* (2018). Researchers are responsible for adherence to any other relevant University policies and/or funded or non-funded agreements that may be associated with the project.

The *TCPS2* **requires** that you submit an Annual Update to ICEHR before August 31, 2023. If you plan to continue the project, you need to request renewal of your ethics clearance and include a brief summary on the progress of your research. When the project no longer involves contact with human participants, is completed and/or terminated, you are required to provide an annual update with a brief final summary and your file will be closed. If you need to make changes during the project which may raise ethical concerns, you must submit an Amendment Request with a description of these changes for the Committee's consideration. If funding is obtained subsequent to ethics approval, you must submit a Funding and/or Partner Change Request to ICEHR so that this ethics clearance can be linked to your award.

All post-approval event forms noted above must be submitted by selecting the ***Applications: Post-Review*** link on your Researcher Portal homepage. We wish you success with your research.

Yours sincerely,

Kelly Blidook, Ph.D.
Chair, Interdisciplinary Committee on
Ethics in Human Research

KB/bc

copy: Supervisor – Dr. Doug Smith, Faculty of Engineering and Applied Science
Director, Research Grant and Contract Services

10 Appendix C

Description of FRAM Functions and Aspects of Fishing Operations

Name of function	**To wash the gillnet**
Description	The net should be cleaned before setting the gillnet
Aspect	Description of Aspect
Input	Prepare the net for catching target species
Output	Shoot the net while steaming
Precondition	
Resource	
Control	
Time	
Name of function	**To set the gillnet**
Description	After reaching the fishing ground, fish harvesters set the gillnet in order to trapthe cod fish.
Aspect	Description of Aspect
Input	
Output	Soak times range from 6 hours to 72 hours
Precondition	Shoot the net while steaming
Resource	
Control	
Time	
Name of function	**To retrieve the poles/buoys of the gillnet**

Description	Poles and buoys are used in fishing operations for marking fishing grounds and finding gillnet. The skipper of the vessel turns off the propulsive engine while cod fishing. Genset provides electric power to electric equipment such as haulers.
Aspect	Description of Aspect
Input	Go towards the other fishing ground to retrieve the net
	Pick the poles/buoys of the net
Output	Turn on the hauler
Precondition	
Resource	
Control	
Time	
Name of function	**To turn on the power hauler to retrieve the gillnet**
Description	The hauler pulls the gillnet aboard the fishing vessels where fish are entangled.
Aspect	Description of Aspect
Input	Turn on the hauler
Output	Pick out the cod from the net
Precondition	
Resource	
Control	
Time	
Name of function	**To separate the cod entangled on the gillnet**

Description	After retrieving the gillnet, fish harvesters separate the fish entangled in the net.
Aspect	Description of Aspect
Input	Pick out the cod from the net
Output	Store the fishes
Precondition	Lay the net on the net box
Resource	
Control	
Time	
Name of function	**To roll the net and lay it on the net box**
Description	After separating the fish from the gillnet, fish harvesters roll the gillnet and lay it inthe box.
Aspect	Description of Aspect
Input	Lay the net on the net box
Output	Check other fishing grounds
Precondition	
Resource	
Control	
Time	
Name of function	**To check the fishing chart to identify the fishing ground**
Description	Fishing charts help fish harvesters to identify the fishing grounds where the possibility of harvesting large amounts of fish is high.
Aspect	Description of Aspect
Input	Check other fishing grounds
Output	Approach the fishing ground

Precondition	
Resource	
Control	
Time	
Name of function	To travel towards the fishing ground or change the fishing ground
Description	The fishing trip starts by travelling toward the fishing grounds to harvest target species. Fish harvesters change the fishing ground after completing fishing in one fishing area. Fish harvesters find fishing grounds using fishing charts.
Aspect	Description of Aspect
Input	
Output	Prepare the traps for catching target species
	Prepare the net for catching target species
	Pick the buoys attached to the rope
	Pick the poles/buoys of the net
Precondition	Approach the fishing ground
Resource	
Control	
Time	
Name of function	**To lay the cod in the storage and clean the deck**
Description	Fish harvesters shift all the cod in the storage space. They clean the deck after completing fishing.
Aspect	Description of Aspect

Input	Store the fishes
Output	Go back to the dock
Precondition	
Resource	
Control	
Time	
Name of function	**To go back to the dock**
Description	Fish harvesters return to the dock after catching the targeted amount of cod, lobster, crab or whelk.
Aspect	Description of Aspect
Input	Go back to the dock
Output	Sell the species
Precondition	
Resource	
Control	
Time	
Name of function	**To retrieve the buoy attached to the rope**
Description	Buoys are used in fishing operations for marking fishing grounds and finding traps and pots. Fish harvesters follow the rows of the trap/pot by identifying the buoys. For lobster fishing, the skipper operates the fishing vessel at low speed (Slow down mode of the engine). The skipper of the vessel turns off the propulsive engine while crab and whelk fishing. Genset provides electric power to electrical equipment such as haulers.

Aspect	Description of Aspect
Input	Go towards the other fishing ground to retrieve the traps/pots
	Pick the buoys attached to the rope
Output	Turn on the hauler-trap/pot
Precondition	
Resource	
Control	
Time	
Name of function	**To retrieve the trap/pot using the hauler**
Description	The hauler pulls the line of whelk pots aboard the fishing vessels in which whelks are trapped. Fish harvesters retrieve each lobster and crab trap one by one, which are set at different spots of fishing ground.
Aspect	Description of Aspect
Input	Turn on the hauler-trap/pot
Output	Pull the trap
Precondition	
Resource	
Control	
Time	
Name of function	**To pull the trap/pot attached to the rope**
Description	Although the hauler help to bring the fishing gear aboard the vessel, the fish harvesters pull the pots or traps when they come closer to the vessel while thehauler is running.

Aspect	Description of Aspect
Input	Pull the trap
Output	Lay the trap/pot
Precondition	
Resource	
Control	
Time	
Name of function	**To remove the old bait**
Description	After retrieving the traps, the fish harvester removes the bait from them.
Aspect	Description of Aspect
Input	Remove the bait
Output	Shift the lobster
	Shift the crab
Precondition	
Resource	
Control	
Time	
Name of function	**To measure the size of the lobsters/crabs**
Description	Fish harvesters measure the size of lobsters and crabs using gauges. Undersized lobsters and crabs are shot back to the fishing ground. The length ofthe lobster should be at least 3.25 inches long, while the minimum size limit for male crabs is set at 4.52 inches carapace width.
Aspect	Description of Aspect
Input	Measure lobster size

	Measure crab size
Output	The minimum size of lobsters and crabs that can be caught is 3.24 inches and 4.52 inches, respectively
Precondition	
Resource	
Control	
Time	
Name of function	**To lay the lobsters/whelks/crabs in the crate**
Description	Fish harvesters put rubber bands on the lobsters' claws whose size is equal to or above the legal limit. Fish harvesters lay the whelks, crabs andlobsters on the crates.
Aspect	Description of Aspect
Input	Lay the whelk in the crate
Output	Lay the crate in the hatch
	Go back to the dock
	Shift the crab to the hatch
Precondition	The minimum size of lobsters and crabs that can be caught is 3.24 inches and 4.52 inches, respectively
Resource	
Control	
Time	
Name of function	**To lay the lobster crate in the tank filled with water**
Description	Fish harvesters lay the crate in the water tank to keep lobsters alive

Aspect	Description of Aspect
Input	Lay the crate in the hatch
Output	Go back to the dock
Precondition	
Resource	
Control	
Time	
Name of function	**To unload the species harvested**
Description	Fish harvesters unload the cod, lobster, crab or whelk in the harbour, where theysell them.
Aspect	Description of Aspect
Input	Sell the species
Output	
Precondition	
Resource	
Control	
Time	
Name of function	**To stack the trap/pot**
Description	Fish harvesters stack the empty pots and traps on the deck.
Aspect	Description of Aspect
Input	Stack the trap
	Stack the pot
Output	Check other fishing grounds
Precondition	
Resource	
Control	

Time	
Name of function	**To attach the bait in the traps**
Description	Bait is used in fishing operations to attract lobsters and crabs when fishing
Aspect	Description of Aspect
Input	Prepare the traps for catching target species
Output	Drop the traps/pot
Precondition	
Resource	
Control	
Time	
Name of function	**To wait for the species to trap**
Description	During this function, the fish harvesters can either wait for the target species to trap, go back to the dock or go to the other fishing ground for fishing. The soak times of fishing gear range from 6 hours to 72 hours.
Aspect	Description of Aspect
Input	Soak times range from 6 hours to 72 hours
Output	Go towards the other fishing ground to retrieve the net
	Go towards the other fishing ground to retrieve the traps/pots
	Go back to the dock
Precondition	
Resource	
Control	
Time	

Name of function	**To set the rows of traps/pots into the fishing ground**
Description	After reaching the fishing ground, fish harvesters set the gear (Traps orpots) to trap the lobster, whelk or crab.
Aspect	Description of Aspect
Input	Drop the traps/pot
	Prepare the traps for catching target species
Output	Soak times range from 6 hours to 72 hours
Precondition	
Resource	
Control	
Time	
Name of function	**To shift the crabs from the trap to the sorting table/crate**
Description	After laying the crab traps on the sorting table, fish harvesters open the trap andshift the crabs from the trap to the table.
Aspect	Description of Aspect
Input	Shift the crab
Output	Measure crab size
	Stack the trap
Precondition	
Resource	
Control	
Time	
Name of function	**To shift the whelks from the pot to the sorting table**

Description	After laying the whelk pots on the sorting table, fish harvesters open the whelk pot and shift the whelks from the pot to the table.
Aspect	Description of Aspect
Input	Shift the whelk
Output	Stack the pot
	Lay the whelk in the crate
Precondition	
Resource	
Control	
Time	
Name of function	**To shift the lobsters from the trap to the crate**
Description	After removing the bait, fish harvesters shift the lobster into the crate.
Aspect	Description of Aspect
Input	Shift the lobster
Output	Measure lobster size
	Stack the trap
Precondition	
Resource	
Control	
Time	
Name of function	**To shift the crab to the hatch**
Description	Fish harvesters shift the crab on the crate after measuring their size. After completing the crab fishing, fish harvesters shift the

	crabs from the crate to thecatch hold.
Aspect	Description of Aspect
Input	Shift the crab to the hatch
Output	Go back to the dock
Precondition	
Resource	
Control	
Time	
Name of function	**To lay the pot/trap on the sorting table**
Description	In the surveyed fishing vessel, it was observed that the fish harvesters lay the whelk pots and crab traps on the sorting table after retrieving them.
Aspect	Description of Aspect
Input	Lay the trap/pot
Output	Shift the whelk
	Remove the bait
Precondition	
Resource	
Control	
Time	
Name of function	**To lay the lobster trap on the deck**
Description	Fish harvesters lay the lobster traps on the deck after retrieving them.
Aspect	Description of Aspect
Input	Lay the trap/pot
Output	Remove the bait
Precondition	

Resource	
Control	
Time	