A Critical Analysis of the International and Canadian Regulations and Strategies for Managing Seafarers' Fatigue and its Associated Risks in the International Maritime Sector

by

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ABSTRACT

This evidence-based study aims to ascertain the adequacies of the existing regulations and strategies, including the Standards of Training, Certification and Watchkeeping for Seafarers and Maritime Labour Convention 2006, for managing and preventing seafarers' fatigue in the international maritime sector, including Canada. Maritime accidents having seafarers' fatigue as a causal factor often result in huge capital loss, insurance and property damages issues, health consequences, environmental pollution and property damages, and risks and liabilities to the global supply chain. These issues justify the value of this current project.

This study used four different review approaches as sources of evidence to achieve its aim. The first is a systematic review of literature identifying the prevalence of seafarers' fatigue as a causal factor of maritime accidents. Second, a systematic review of over 2000 maritime accident investigation reports from the maritime accident investigation bureaus of Canada, the United States, the United Kingdom, Australia, and Denmark, to identify the prevalence of seafarers' fatigue as a causal factor of maritime accidents. The third approach critically analyses the adequacy of the existing international regulations and strategies for managing and preventing seafarers' fatigue. Fourth, a comparative review of the international regulations and the Marine Personnel Regulations for managing and preventing seafarers' fatigue in international and Canadian maritime sectors.

The recommendations from this study's findings are to guide the Canadian and International maritime regulatory bodies, including the International Maritime Organization and International Labour Organization, among others, on amending the existing Canadian and international regulations relevant to managing and preventing seafarers' fatigue to ensure their adequacy.

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INTRODUCTION

A. Review Background and Justifications

Global seafarers are the heart and driving engine of the maritime industry, and maritime transportation drives international trade and the global economy (United Nations Conference on Trade and Development (UNCTAD), 2020). However, an issue that significantly plagues seafarers in the worldwide maritime sector is fatigue. Fatigue was identified as the causal factor of the Exxon Valdez oil spill accident, one of the worst maritime disasters of the last century (International Maritime Organization (IMO), 2001). The detrimental role of seafarers' fatigue in the execution of work is that it is a causal factor in various seafarers' fatigue-associated disasters at sea, including fire, explosions, significant health and safety consequences among international seafarers, vessel collisions, vessel sinking, cargo disputes, and oil spillage, fatalities, costly environmental clean-up operations, and groundings, among others (Acejo et al., 2018; Xhelilaj & Lapa, 1996).

Seafarers' fatigue is a significant causal factor of maritime accidents, despite the crucial fact that global seafarers are the heart and driving engine of the maritime industry. Moreover, maritime transportation drives international trade and economy; therefore, the well-being of international seafarers, including ensuring a work environment that is devoid of fatigue, is crucial (Li et al., 2022; United Nations Conference on Trade and Development (UNCTAD), 2020). Hence, this validates the imperative importance of conducting this current project to ensure the adequacy of the various existing regulations and strategies for managing and preventing seafarers' fatigue, and to achieve seafarers' fatigue-free maritime work environment by informing maritime regulatory bodies with its recommendations for necessary amendment.

Moreover, maritime accidents having seafarers' fatigue as a causal factor often result in huge capital loss, insurance issues and damages claims, the subsequent investigation,

environmental pollution and properties damages, risks and liabilities to the global supply chain, legal impacts, and seafarers' replacement, training, and familiarization of new seafarers, with significant economic consequences (Reza & Rajapakse, 2021; Shan & Neis, 2019; Wang et al., 2021; Zhao et al., 2020). A notable example of the worst maritime accident having seafarers' fatigue as a causal factor, with most of the listed maritime accident's impacts, was the Exxon Valdez oil spill accident (International Maritime Organization (IMO), 2001; Skinner & Reilly, 1989). All the above seafarers' fatigue issues justify conducting this project to ascertain the adequacy of the various existing regulations and strategies for managing and preventing seafarers' fatigue. Conducting this project is crucial for enhancing global maritime safety, preventing marine environmental pollution and property damage, and sustaining the international and Canadian maritime industry, trade, and economy (Li et al., 2022; United Nations Conference on Trade and Development (UNCTAD), 2020).

Seafarers' fatigue is a disease (illness), and this distinguishes it from all other causal factors of maritime accidents. Hence, assessing the causal effects of seafarers' fatigue on board a ship is an epidemiological study. An adequate understanding of its effects requires a detailed review of insight into updated epidemiological principles. This is done in this study to ascertain valid and precise determination of the adequacy of the various existing regulations and strategies for managing and preventing seafarers' fatigue (Aschengrau & Seage, 2020)

This fact-finding evidence-based study aims to confirm whether seafarers' fatigue is genuinely a severe issue in the international maritime sector. This confirmation requires assessing seafarers' fatigue to prove that it is a causal factor of maritime accidents, but it cannot be measured. Hence, it's being a causal factor of maritime accidents cannot be proven. The reasons for the inability to measure seafarers' fatigue are due to the absence of a maritime industry gold standard

measure of seafarers' fatigue; the presence of interrelated measurement errors hindering precise and valid seafarers' fatigue assessment, including confounders, biases, and random errors; and the absence of a multi-factor seafarers' fatigue auditing tool to precisely and accurately measure the various factors with the interrelated seafarers' fatigue causal factors (Aschengrau & Seage, 2020; Smith et al., 2006). However, the violations of the IMO's fatigue guidelines, the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)* (International Convention and Code on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 2011) and *Maritime Labour Convention (MLC), 2006* regulations (International Labour Organization (ILO), 2006) for managing and preventing seafarers' fatigue can be proven. Therefore, this study uses the violations of these existing international regulations and strategies as yardsticks for ascertaining their sufficiency for managing and preventing seafarers' fatigue. The assumption is that if these existing regulations and strategies for managing and preventing seafarers' fatigue are violated, then the existing regulations and strategies are inadequate. However, if these existing regulations for managing and preventing seafarers' fatigue are not violated, then the existing regulations for managing and preventing seafarers' fatigue are viewed as adequate.

Many past studies indicated the percentage (prevalence) of seafarers' fatigue as a causal factor of maritime accidents. For instance, an authoritative study conducted by Smith's (2006) Cardiff University Research Program indicated that the percentage of seafarers' fatigue as a causal factor of maritime accidents occurring among 1,856 British seafarers is 53% (Smith et al., 2006). Akhtar & Utne's (2014) study findings indicated that 41% of vessel groundings and collisions have seafarers' fatigue as a causal factor, while the Marine Accidents Investigation Branch's (MAIB) study findings indicated that 82% of vessel groundings have seafarers' fatigue as a causal

factor (Akhtar & Bouwer Utne, 2015). These statistics on seafarers' fatigue issues underscore their problematic nature in the international maritime industry, necessitating this fact-finding exploratory study.

Numerous past studies have pointed out that there is still a wide gap between seafarers' fatigue management regulatory frameworks and their actual practical implementations (Shan & Neis, 2020a; Zhang et al., 2020). Although practical regulatory implementations have to do with enforcement, it is crucial to ensure the sufficiency of the various regulations and strategies for managing and preventing seafarers' fatigue before those implementations are done. This is done by subjecting those existing regulations and strategies to critical analytical review, to gather more evidence to ascertain their adequacy, and to assess their sufficiency in managing and preventing seafarers' fatigue in the international and Canadian sectors. This is the task done in this study.

The various seafarers' fatigue causal factors referred to in this study may be either immediate causes or contributory causes of a maritime accident (Acejo et al., 2018). Immediate causes imply those that directly result in maritime accidents at the end of error chains, while contributory causes, which could be multiple, either result in the immediate cause or create circumstances for contributory/immediate causes to occur (Acejo et al., 2018). The immediate cause is the same as the direct cause, while the contributory cause may be a root cause or an underlying cause.

This study aims to show evidence confirming the existence of regulatory and strategic inadequacies in the existing regulations and strategies for managing and preventing seafarers' fatigue to provide evidence for advocating regulatory policy upgrades through necessary amendments. This study's findings and recommendations serve as an evidenced-based regulatory amendment toolkit that will guide the Canadian and international regulatory bodies, including the

International Maritime Organization (IMO) and International Labour Organization (ILO), among others, on amending and advancing the existing Canadian and international regulations and strategies for managing and preventing seafarers' fatigue, to ensure their sufficiency.

B. Literature Review

The International Maritime Organization (IMO) Marine Safety Committee circular *MSc.1/Circ1598 Annex* on guidelines on fatigue defined fatigue as:

> A state of physical and mental impairment resulting from factors such as inadequate sleep, extended wakefulness, work/rest requirements out of sync with circadian rhythms and physical, mental or emotional exertion that can impair alertness and the ability to safely operate a ship or perform safety-related duties (International Maritime Organization (IMO), 2019, p.1).

The IMO's guidelines on fatigue emphasize that fatigue is an issue in the maritime sector that affects everyone regardless of skill, training, and knowledge. Fatigue may hinder seafarers' ability to do their job safely and effectively. Furthermore, the IMO's guidelines on fatigue stress that an effective seafarers' fatigue management plan starts with determining operational workload requirements and matching onboard staffing levels and onshore support resources, combined with well-organized management of workload and hours of work and rest on board the ship (International Maritime Organization (IMO), 2019). Analyzing violations or compliances with these above IMO guidelines on fatigue on board the ship is one of the key analytical tools used in this study.

According to the IMO's fatigue guidelines, the five categories of fatigue's causal factors are seafarer-specific factors, management factors (ashore and aboard ship), ship-specific factors, environmental factors, and operational factors (International Maritime Organization (IMO), 2019).

The seafarer-specific factors include sleep and rest (quantity, quality, and continuity of sleep, sleep disorders/disturbances, and recovery rest/breaks), body clock/Circadian rhythms, psychological and emotional factors (fear, monotony and boredom, and loneliness), health and well-being (diet/nutrition/hydration, exercise and fitness, and illness and the onset of illness), stress (skill, knowledge, and training related to the job, personal issues of concern and interpersonal relationships at work or home), medication and substance use (alcohol, drugs (prescription and non-prescription), supplements, caffeine and other stimulants), age, shift work and work schedules, workload (mental/physical), and jet lag (International Maritime Organization (IMO), 2019).

The various management causal factors (ashore and aboard ship) that can cause fatigue include organizational factors (manning policies, levels, and retention; the role of riders and shore personnel; administrative work/reporting/inspection requirements; economics; duty schedule-shift, overtime, breaks; company procedures, culture, and management style; shore-based support; rules and regulations; other resources; maintenance and repair of the ship; and drill schedules and training of crew), and voyage and scheduling factors (frequency and duration of port calls, the time between ports routing, weather and sea conditions on the route, traffic density on the route, nature of duties/workload while in port and at sea, and availability of shore leave) (International Maritime Organization (IMO), 2019).

The various ship-specific causal factors that can cause fatigue include ship design, level and complexity of automation, level of redundancy, equipment design and reliability, inspection and maintenance, condition of the ship, physical comfort in workspaces, location of quarters, ship motion, and physical comfort of accommodation spaces. Environmental-specific factors that can cause fatigue include noise, vibration, light, ship motion, temperature and humidity, and

ventilation or air exchange. Operation-specific factors that can cause fatigue include inspections, surveys, reporting, audits, visits, security measures, and other extra tasks on board (International Maritime Organization (IMO), 2019). This study will confirm and ascertain the existence of these causal factors in the maritime sector and use that as a measure of the adequacy of the existing regulations and strategies for managing and preventing seafarers' fatigue in the international and Canadian maritime sectors.

Acejo et al. (2018) pointed out that part of the approach to advancing maritime safety on board ships at sea is to learn from previous shipping accident reports by accumulating them to study their patterns and trends (Acejo et al., 2018). These patterns and trends offer a complete account of what occurred and are used to find all the relevant causal factors. They often provide insight, useful information, and thorough analysis that explain the general patterns or trends when such documents are analyzed en masse and aggregate their findings systematically to develop safety at sea (Acejo et al., 2018; Tang et al., 2013). These are the reasons for this current project. Smith (2007) also supported this by indicating that existing seafarers' fatigue management by legislation and guidance has failed due to little or no attempt to systematically review them to assess their sufficiency (Smith, 2007), hence, necessitating the current study.

Moreover, numerous studies reported that seafarers' fatigue is a significant causal factor of maritime accidents (Acejo et al., 2018; Akhtar & Utne, 2015; Marine Accident Investigation Branch (MAIB), 2004; Smith et al., 2006; Tang et al., 2013). The absence of a multi-factor auditing tool and a maritime industry's gold standard measure of seafarers' fatigue are significant issues in the maritime sector. These hinder the precise and accurate measurement of seafarers' fatigue. Moreover, the lack or falsification of Hours of Rest (HOR) records worsens the situation. All these are currently common issues on board ships (Barnett et al., 2017; Smith et al., 2006; Xhelilaj &

Lapa, 1996). Crew members adjust the records on work and rest hours due to the fear of facing external or internal pressures, retribution, discrimination or blame during investigations (Baumler et al., 2021; Darbra et al., 2007; Shan & Neis, 2020). These seafarers' dilemmas caused by fear of these factors are common in the maritime industry (Shan & Neis, 2020; Zhao et al., 2020b). Also, the lack of implementation of fatigue risk management systems onboard ship, the practice of 6 on and 6 off watches, and noncompliance with the relevant hours of rest regulations, are widespread current practices in the shipping industry (Acejo et al., 2018; Akhtar & Utne, 2015; Barnett et al., 2017; Marine Accident Investigation Branch (MAIB), 2004; Smith et al., 2006; Tang L. et al., 2013).

The MARTHA project introduced the Fatigue Risk Management System (FRMS), which provides fatigue awareness, enlightenment training, and fatigue prediction models, and advises on various corrective actions to be utilized for minimizing and preventing seafarers' fatigue and its associated maritime incidents (Barnett et al., 2017). Project MARTHA was the first research to differentiate between fatigue and sleepiness. One of the important distinctions of the MARTHA project's accomplishments was the explanation that the effects of fatigue could result in sleepiness (Barnett et al., 2017). Project MARTHA indicated that fatigue is a subjective feeling of tiredness, distinct from weakness, and has a gradual onset, while sleepiness is a state of being sleepy. Therefore, sleepiness and fatigue are closely associated and are crucial issues for global seafarers. Both have consequences for safety and long-term mental and physical health (Barnett et al., 2017).

Also, Project MARTHA indicated that long tours of duty of over 6 months might result in loss of sleep quality, increased sleepiness, and reduced motivation. Moreover, these outcomes could result in 'near-misses' and maritime accidents onboard (Barnett et al., 2017). It also showed that night watch keepers are most at risk of falling asleep on duty and that captains feel stressed

and fatigued at the end of their tours of duty more than the rest of the crew and therefore need more recovery time than the rest of the crew (Barnett et al., 2017). This ground-breaking project introduced easy operational solutions for ensuring that sleep is easier for seafarers onboard by implementing fatigue risk management. This involves presenting an integrated systems approach to managing fatigue risk and changing the fatigue safety culture (Barnett et al., 2017). This study will ascertain all these MARTHA projects' claims regarding seafarers' fatigue as a key issue in the maritime sector.

Also, inadequate manning, short-sea service and frequent port calls, long contract lengths that may result in fatigue, insufficient rest hours, and worldwide variations in compliance with the international regulations for managing seafarers' fatigue are common concerns onboard ships in different nations (Marine Accident Investigation Branch (MAIB), 2004; Smith et al., 2006; Shan & Neis, 2019; Zhao et al., 2020).

Therefore, all the various seafarers' fatigue issues stated above call for this project to ascertain the adequacy of the present Canadian and international regulatory framework and strategies for preventing and managing seafarers' fatigue in the Canadian and global maritime sectors.

C. Overall Review Questions

The main overall review question is: *"What are the various pieces of evidence in the existing public domain that show the adequacy or inadequacy of the present regulations and strategies for managing and preventing seafarers' fatigue and its associated maritime accident risks in the Canadian and international maritime sectors?".* The current project is a fact-finding critical analysis review seeking various lines of evidence for answering this overall question.

D. Review Objectives

This review objective is to critically analyze the adequacy of the present regulations and strategies for managing and preventing seafarers' fatigue in the Canadian and international maritime sectors using various sources of evidence to answer the review's overall and specific questions. The various specific objectives used to execute each source of evidence in this review to answer the above-stated overall review question are clearly stated in each respective chapter.

E. Review Methodologies

Each methodology used to analyze each source of evidence explored in this review is clearly stated in various chapters. This study employed several review methodologies to accumulate evidence from numerous sources that proved or disproved the adequacy or inadequacy of these regulations and strategies. The review approaches utilized in this study are the four sources of evidence explored that form each successive chapter to determine the adequacy of these seafarers' fatigue management regulations and strategies. These include conducting a systematic review of what the existing literature has indicated regarding the percentage (prevalence) of maritime accidents identifying seafarers' fatigue as a causal factor; conducting a systematic review comprising over 2000 maritime accident investigation reports from the maritime accident investigation bureau of five leading maritime countries, Canada, United States, United Kingdom, Australia, and Denmark, to determine the percentage (prevalence) of seafarers' fatigue as a causal factor of maritime accidents from these reports; conducting a critical analytical review of the international regulations, including Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and Maritime Labour Convention (MLC), 2006, for managing and preventing seafarers' fatigue in the international maritime sector to ascertain their adequacy; and conducting a critical analytical review of the international regulations, STCW and MLC 2006, and the various Canadian regulations, including the seafarers' hours of rest requirements, for managing and

preventing seafarers' fatigue in the international and Canadian maritime sectors (International Maritime Organization (IMO), 2011; International Labour Organization (ILO), 2006).

F. Review Scope

This project's scope involves many review approaches. The scope of the first review approach involves a systematic review of existing primary and secondary literature studies to identify what they have indicated regarding the percentage (prevalence) of seafarers' fatigue as a causal factor of maritime accidents. The scope of this review also includes a second systematic review involving a critical review of existing maritime accident investigation reports from the accident investigation agencies of the United States of America (USA), Australia, Canada, United Kingdom (UK), and Denmark, to determine the percentage (prevalence) of seafarers' fatigue as a causal factor of maritime accidents from these investigation reports, from all these countries. The third review involves a critical analysis of the existing international regulations and strategies, including seafarers' hours of rest regulations, for managing seafarers' fatigue. The fourth review involves a critical analytical review of the Canadian and international regulations for managing seafarers' fatigue, including seafarers' hours of rest regulations for another source of evidence. All these reviews' targets are to provide sources of evidence for confirming the adequacy of existing international and Canadian regulations and strategies for managing seafarers' fatigue to be able to answer the overall and specific review questions.

CHAPTER ONE

A SYSTEMATIC LITERATURE REVIEW IDENTIFYING THE PREVALENCE OF SEAFARERS' FATIGUE AS A CAUSAL FACTOR OF MARITIME ACCIDENTS

1.1 Review Introduction

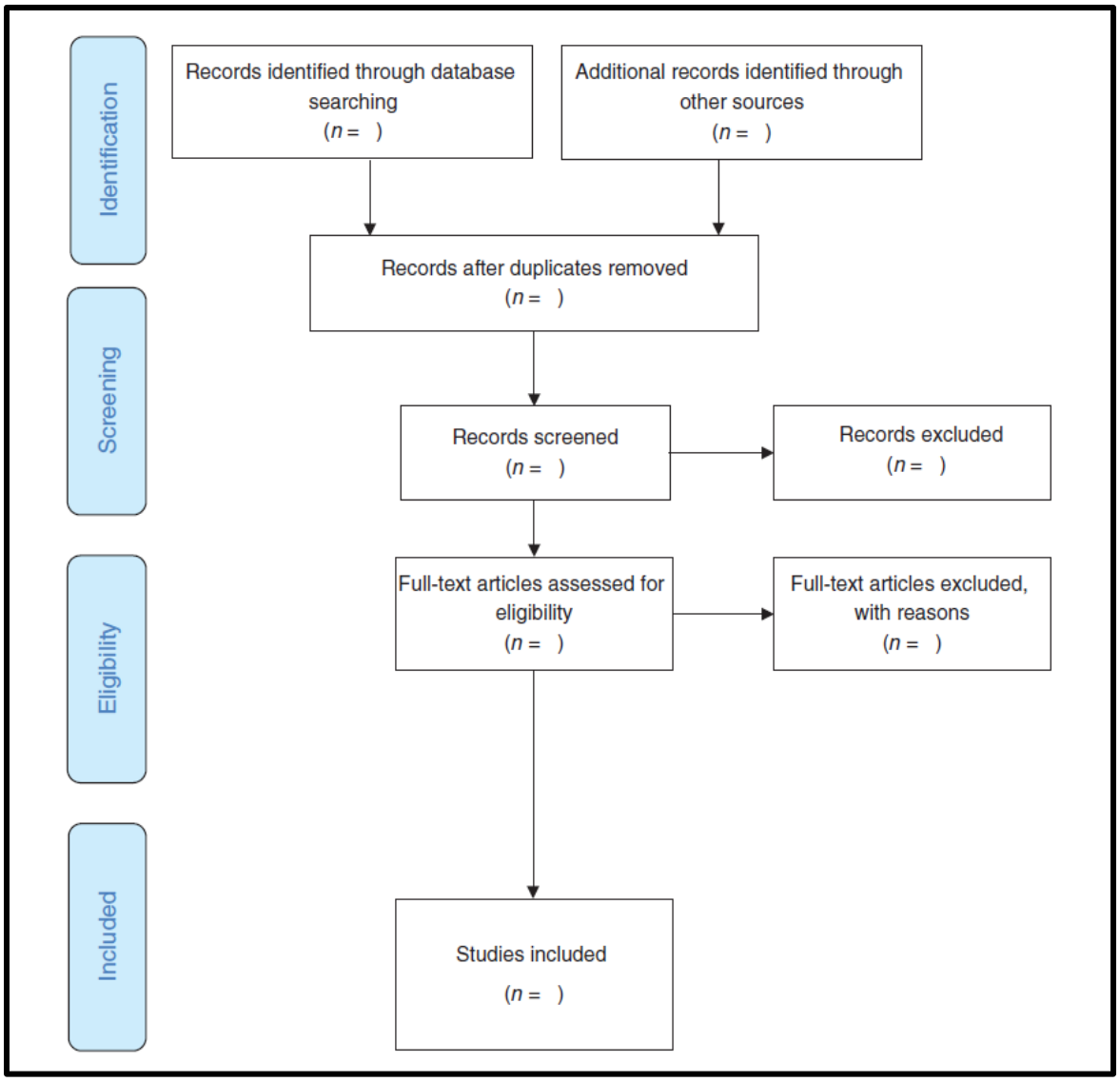
This chapter reviews the existing literature to summarize what has been identified as the prevalence of seafarers' fatigue as a causal factor of maritime accidents. The purpose of this review is to provide evidence for answering the overall review question and the overall review objective. The specific objective of this systematic review is to review the existing primary and secondary literature studies indicating the prevalence of seafarers' fatigue as the causal factor of maritime accidents, critically and systematically determine if those prevalence values are significant, and use the various quantitative and qualitative findings from this review as yardsticks of evidence to answer the overall review question. This is with the intention that those findings will shed more light on general trends and the nature of those maritime accidents to elucidate what occurred and to provide evidence for determining the adequacy of existing international and Canadian regulations and strategies for managing and preventing seafarers' fatigue.

1.2 Systematic Review Methodology

The methodology adopted for this systematic literature review is the Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA). The statistical aspect of the PRISMA concept, meta-analysis, is excluded in this review. See Figure 1.1 (Peters et al., 2015). This systematic review adopts a standard cut-off statistical significance value of 5%. Any prevalence value of or greater than 5% is significant, while any prevalence value lower than 5% is insignificant. The quantitative prevalence value and the qualitative findings from this review are used as a gauge of evidence for ascertaining the adequacy of the existing national and international regulations and strategies for managing seafarers' fatigue. Also, the findings from this review are critically analyzed and compared with other review findings from other sources of evidence in this overall study to ascertain the validity and precision of their evidence for answering the overall review question.

Figure 1.1

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (Source: Peters et al., 2015).



1.3 Systematic Review Structured Summary

1.3.1 Identification of Systematic Review Questions

The research question below guides the building of the search strategies, provides the road map for subsequent stages and gives adequate clarity on the scope of the systematic review enquiry since this review question is specific to finding evidence for answering the overall review question.

Therefore, this specific review question was redefined in an explicated statement of questions being addressed regarding Participants "P", Exposures "E", Comparisons "C", Outcomes or Disease "O" and Study types "S" – PECOS (Moher et al., 2009). This systematic review's objective was aligned with the definition of this systematic review's question, which stated: *What have the existing primary and secondary literature (Study types "S") indicated about the prevalence of seafarers' fatigue as a causal factor (Exposures "E") of maritime accidents (Outcomes "O"), using applicable significant statistical reference limits of 5 per cent (%) and above (Comparisons "C"), in the Canadian and international maritime sectors (Participants "P")?* Therefore, the specific systematic review question is restated as follows: *What has the existing primary and secondary literature indicated about the prevalence of seafarers' fatigue as a causal factor of maritime accidents, using applicable significant statistical reference limits of 5 per cent (%) and above, in the Canadian and international maritime sectors?*

1.3.2 Identification of Relevant Studies

(a) Selection of Search Terms and Building Search Terms Strategy: The combination of various search terms (keywords) from this above-stated systematic review question was first selected and searched on a few electronic databases, but none was effective enough to return relevant articles. The search term used for this systematic review is *seafarer* fatigue,* and it was chosen after trying many combinations without success. This search term captured a few key articles relevant to the specific review question stated above, and those not captured were found in the reference listing of these key articles.

(b) Sources of Relevant Studies: The identification of relevant studies is made by mapping the following electronic databases, including Google Scholar, Cochrane Library, Pubmed, and Memorial University of Newfoundland's one-search database for articles pertinent

to the systematic review topic, question, and objectives. No limits on the date, language, subject or type are placed on these databases searched. Also, the search terms have been tailored to the specific requirement of each database search. The first 100 articles from the google scholar search and the first 50 articles from Memorial University of Newfoundland library's one-search online database were identified for screening, while 55 articles from PubMed and two articles from the Cochrane Library were identified for screening using the search term *seafarer* fatigue.* A total of 207 articles and conference papers were identified through a systematic search of all these databases. All these articles were screened in this review using the PRISMA concept. The first search of relevant databases is followed by analysing the title, abstract text words, and index terms used to describe the article. A reference listing of relevant articles is manually searched to identify all pertinent literature not captured in the databases search that is relevant to the systematic review topic and question. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) explain this systematic review decision process. Figure 2.2 indicates the PRISMA flow diagram (Peters et al., 2015). The directory of publications was created using Mendeley.

1.3.3 Relevant Studies Selection:

The various definitions of exclusion and inclusion criteria relevant to this systematic review topic and question are made to select relevant studies finally included in the current systematic review. This stage is an iterative process of searching the literature, refining the search strategy, assessing the eligibility criteria, pre-screening and reviewing the title, abstract, and full text for inclusion, and retaining only articles relevant to the specific systematic review question and objectives. Studies are considered eligible for screening if (1) study participants were seafarers

engaged in occupational sailing, (2) one or more pertinent review questions about seafarers' fatigue were included, and (3) quantitative and qualitative data were provided. The *final inclusion criterion* used was that the article assessed and indicated the percentage of seafarers' fatigue as being a causal factor of maritime accidents, while the *final exclusion criterion* used was that the study did not assess and indicate the percentage of seafarers' fatigue as being a causal factor of maritime accidents. The PRISMA flow format documents the systematic review progression flow chart step-by-step, including the number of articles identified and screened for full-text article eligibility, and those finally selected for inclusion in this systematic review are reported on the PRISMA diagram flow chart in Figure 2.2.

The extraction stage includes quality assessment and data extraction. The Joanna Briggs Institute (JBI) critical appraisal checklist for analytical cross-sectional studies is used as the quality assessment tool to ascertain the quality of the finally included articles (Joanna Briggs Institute, 2017). The extracted data are used to prepare a table of characteristics of the seven included studies' indicated percentages of maritime accidents having seafarers' fatigue as a causal factor, using applicable significant statistical reference limits of 5 per cent (%) in the Canadian and international maritime sector.

1.4 Charting and Collating the Data/Review Findings

1.4.1 Charting and Collating the Data:

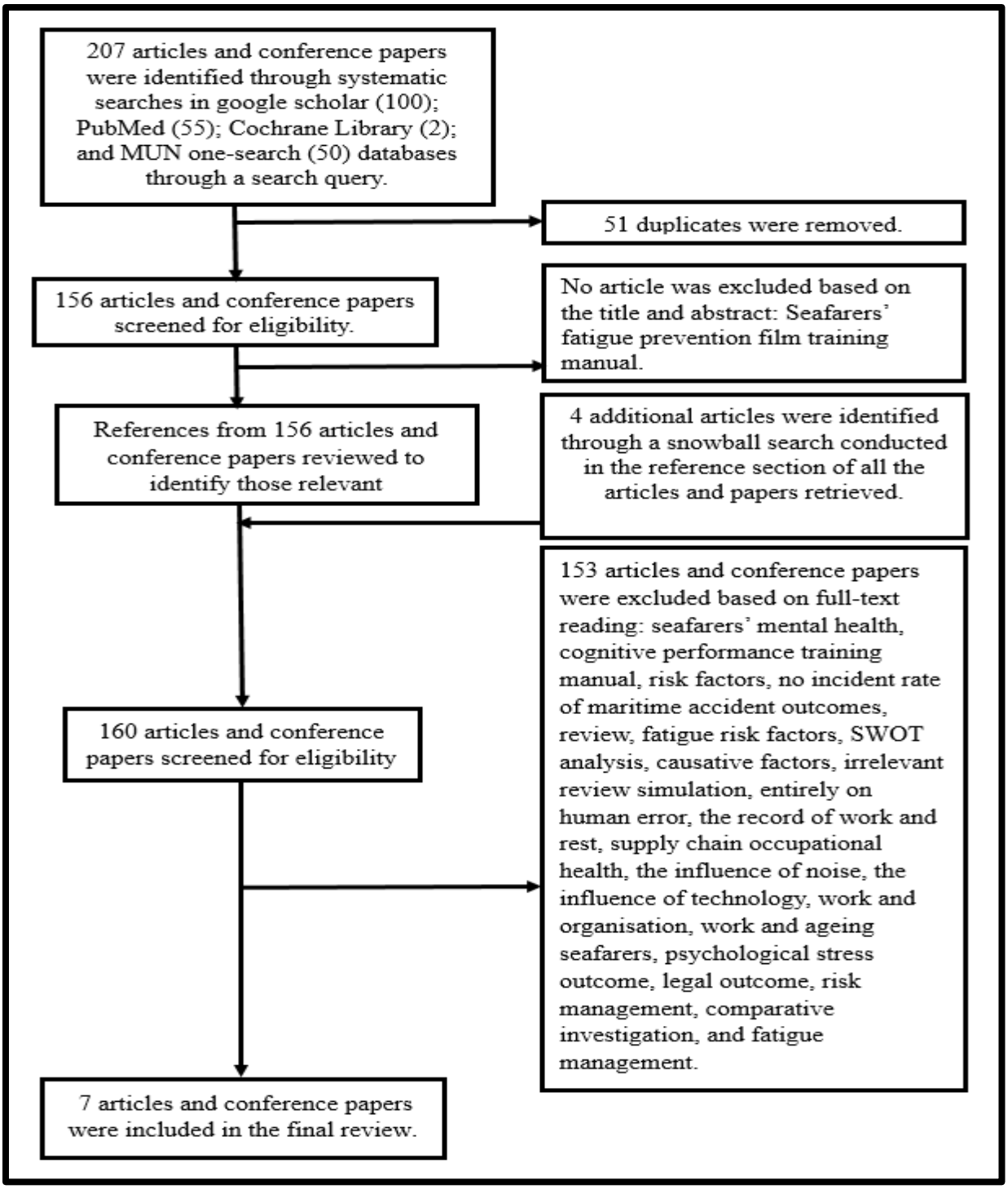
This stage involves data extraction to record the characteristics relevant to the review question in the included studies, as shown in Table 1.1. It consists of developing a data charting form to extract data from each study. All variables relevant to the review question and objectives are extracted. Charting is also an iterative process, with continual data extraction and updating of the data charting form. The approach of the data charting form is consistent with the review

question and purpose. Since this systematic review's findings are meant to serve as evidence for determining the adequacy of the existing regulations and strategies for managing seafarers' fatigue after subjecting them to critical analysis and deductive interpretations, therefore, to ascertain the quality of our findings, a quality assessment of the literature is done using the Joanna Briggs Institute Critical Appraisal tools for use in JBI systematic reviews for analytical cross-sectional studies, by classifying them into poor, fair, and good (Joanna Briggs Institute, 2017). See Appendix 1A for the summary of the qualitative assessment done for each article included in Appendix 1B for explanations.

This review findings' significant percentage values are evaluated and cross-referenced with each other and other sources of evidence in this overall study for critical interpretations to ascertain the adequacy of existing international and Canadian regulations and strategies for managing and preventing seafarers' fatigue. A narrative explanation of the review process for identifying relevant studies, studies' selection and inclusion and exclusion approaches using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is shown in Figure 1.2 (Peters et al., 2015).

Figure 1.2

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for the Current Systematic Review Process (Source: Peters et al., 2015).



The summary of the quantitative characteristics of the finally included articles is indicated in Table 1.1. All the findings outcomes indicated in Table 1.1 have more than 5% significant

reference value. This indicates that seafarers' fatigue as a causal factor of maritime accidents issues is significant in the international and Canadian maritime sectors. Hence, it is a significant causal factor of maritime accidents in the international and Canadian maritime sectors. Therefore, the regulations and strategies for managing them are **inadequate**.

1.5 Summarizing and Reporting the Findings

1.5.1 Qualitative and Quantitative Review Findings From Included Articles

(a) Quantitative Review Findings From Included Articles: This aspect summarizes all the included articles' quantitative findings below in the chronologically sequential order shown in Table 1.1.

Table 1.1 Quantitative Characteristics of Included Studies Identifying the Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents

S/N	Author and Publication Year	Study Location, Duration, Study Population	Study Aim(s)	Quality Score	Reference Value for Prevalence Significance	Prevalence (%) of Seafarers' Fatigue as a Causal Factor of Maritime Accidents
1	Raby & Lee (2001)	United States Coast Guard (USCG) United States Mariners Conducted over 6 months period	To examine some general contributors to fatigue in the shipping industry through an accident analysis to define the role of fatigue in shipping safety and field studies to describe sleep patterns and workload fluctuations that may contribute to fatigue	Fair	5%	23%
2	Marine Accident Investigation Branch (MAIB) (2004)	United Kingdom. 1994 to 2003 inclusive. 652 collisions and groundings (merchant vessels of over 500gt) & 995 near collisions (342 involve fishing vessels and merchant vessels of over 500gt).	To establish the principal causal factors that cause maritime accidents' collisions and groundings.	Good	5%	30 % immediate causal factors and 82% contributing causal factors of the grounding and collisions that occurred between 00:00 and 06:00 hours.
3	Houtman et al. (2005).	Netherlands by the Shipping Council in the Netherlands. Dutch Seafarers' Population. From 1997 until August 2005.	To determine the prevalence of maritime accidents, seafarers' fatigue is a causal factor of the collision or grounding.	Fair	5%	The range between 11% to 22.4%
4	Smith et al. (2006)	The Cardiff Research Programme, Cardiff University's Centre for Occupational and Health Psychology (COHP, 2006), United Kingdom. 1856 British Seafarers	To determine the prevalence of cases having seafarers' fatigue as a causal factor of the maritime accident	Good	5%	53%

Table 1.1 Characteristics of Included Studies Identifying the Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents (Continuation)

S/N	Author and Publication Year	Study Location, Duration, Study Population	Study Aim(s)	Quality Score	Reference Value for Prevalence Significance	Prevalence (%) of Seafarers' Fatigue as a Causal Factor of Maritime Accidents
5	Akhtar & Utne (2014)	Norway and the United Kingdom (Mixed locations) 98 collision/contact accidents and 56 groundings from the MAIB in the UK and 22 maritime accident reports from the Accident Investigation Board Norway. From these 33 fatigue-related maritime accidents were analyzed with the CREAM method. 1999 to 2011.	To use accident charts derived from in-depth studies of human fatigue-related accidents to analyse common patterns of interconnected fatigue factors, using the Cognitive Reliability and Error Analysis Method (CREAM) modified for maritime accidents.	Good	5%	41% averaging both groundings and collisions in each case.
6	Tang et al. (2013	Seafarers International Research Centre (SIRC). 319 maritime accident reports. 10 years period	To identify the prevalence of cases having seafarers' fatigue as a causal factor of maritime accidents	Fair	5%	13.8 %
7	Acejo et al. (2018)	Seafarers International Research Centre (SIRC). The total number of accident reports analyzed is 693. The total number of cases is 71. Period: 2002-2016 inclusive.	To identify the prevalence of cases having seafarers' fatigue as a causal factor of maritime accidents in the period 2002-2016	Fair	5%	10.2 %

(b) Qualitative Review Findings From Included Articles: This aspect summarizes all the included articles' qualitative findings below in the chronologically sequential order.

(1) Raby & Lee (2001): This study examined some general causal factors of fatigue in the shipping industry through an accident analysis to define the role of fatigue in shipping safety and

field studies to describe sleep patterns and workload fluctuations that may be causal factors of fatigue (Raby & Lee, 2001). Four Maritime Safety Offices (MSOs) and 42 investigating officers were involved in this project. The data collection period was 6 months, including data from ships and seafarers' maritime accidents. The data analysis targeted identifying and characterising accidents with causal fatigue factors. Fatigue information gathered during the investigation includes seafarers' experience and job position, seafarers' schedule and activities on the casualty day, a 72-hour work and rest schedule, number of days off in the last 30 days, symptoms of fatigue and contributing factors to fatigue, seafarers' decisions or action, and seafarers' opinions on the contribution of fatigue to the casualty (Raby & Lee, 2001).

This study used two approaches to identify maritime accidents having seafarers' fatigue as a causal factor. The first approach involves using the investigating officers' and seafarers' judgement to identify fatigue causal factors in each case. The advantage of this approach is the intimate experience of the investigating officers and seafarers regarding the specific condition of the casualty. In contrast, its disadvantage is the lack of expertise among the investigating officers and seafarers about the diagnosis of fatigue and the possible biases regarding reporting fatigue cases (Raby & Lee, 2001). The second approach used an externally developed and validated fatigue criterion involving fatigue causal factors identified in the literature and gathered during the investigation (Raby & Lee, 2001).

The accident analysis suggested that fatigue is a crucial causal factor in 16% of ship accidents and 33% of personnel injury cases, making 23% when all are combined. The field study indicated that scenarios that result in fatigue-related accidents are not isolated incidents in the shipping sector, and this hinders their measurement. This six months' study indicated that chronically low levels of alertness and disrupted sleep are common issues in the shipping industry

that require meticulous consideration by the maritime regulatory agencies, the operating companies, and the seafarers that work on the ship (Raby & Lee, 2001).

(2) Marine Accident Investigation Branch (MAIB) (2004): This study involves analysing 652 maritime accidents including collisions and groundings and 995 near collisions. All are merchant vessels of over 500gt. Although the statistical base of MAIB's Bridge Watchkeeping Safety Study is relatively small, the data quality is good. This is because it utilized the restriction method to control for confounders by restricting its analytical focus to determining the causal factors of groundings and collisions that occurred during the 00:00 and 06:00 hours period. Humans naturally have a high propensity to fall asleep during this period, hence, it focuses on areas where high confidence can be put in its accuracy. This study was initiated to establish the key causal factors of maritime accidents. Therefore, this study's findings, though not surprising, are crucial (Marine Accident Investigation Branch (MAIB), 2004).

This study's findings indicated that fatigue contributed to 82% of the groundings, which occurred between 00:00 and 06:00 hours and was a 25% cause of all collisions. It established that minimal manning, comprising a master and a chief officer as the only two watchkeeping officers on vessels, results in watchkeeper fatigue and the inability of the master to accomplish his duties, which often leads to maritime accidents (Marine Accident Investigation Branch (MAIB), 2004). Therefore, this study has verified that fatigue, a master's incapability to execute his duties, and watchkeeper manning levels are major causal factors for collisions and groundings, while inadequate lookout is a major causal factor in collisions. This study disclosed that the hours of work and lookout provisions stipulated in STCW 95 are inadequate and ineffective in their relevant areas (Marine Accident Investigation Branch (MAIB), 2004).

This study stressed that various recommendations to address inadequate manning, causal factors of fatigue, and poor lookout are therefore justified. It emphasized that for such recommendations to be effective, actions to improve the following are crucial, including improving the master's capability to execute his duties, lowering fatigue levels, and improving the standard of the lookout, which must be done on an international basis and must be made mandatory (Marine Accident Investigation Branch (MAIB), 2004). This study emphasized that this can only be accomplished by the International Maritime Organization (IMO) by executing relevant amendments to address these inadequacies in the existing regulations or by initiating new actions (Marine Accident Investigation Branch (MAIB), 2004).

This study's conclusions and recommendations regarding combating fatigue among bridge watchkeepers operating in the short-sea trade and improving the standard of the lookout on all merchant vessels submitted to the Maritime and Coastguard Agency to be forwarded to the IMO with the aim of the amendment are stated as below:

> *The guidelines on safe manning, to ensure that all merchant vessels over 500gt have a minimum of a master plus two bridge watchkeeping officers unless specifically exempted for limited local operations as approved by the Administration.*
>
> *The requirements of STCW 95 to change the emphasis with respect to the provision of a designated lookout to ensure that a lookout is provided on the bridge at all times unless a positive decision is taken that, in view of daylight and good visibility, low traffic density and the vessel being well clear of navigational dangers, a sole watchkeeper would be able to fulfil the task.*

> *The requirements of STCW 95 so that a bridge lookout can be more effectively utilised as an integral part of the bridge team (Marine Accident Investigation Branch* (MAIB), 2004, p.28).

(3) Houtman et al. (2005): This study analyzed the relations among fatigue, collisions and groundings, and the shift system. It indicated that a decline in performance and reported clear incapacitating effects, including declining vigilance, alertness, and perception, are results caused by fatigue (Houtman et al., 2005). This study indicated that fatigue was a causal factor in 11 to 22.4 per cent of collisions and groundings, and it stressed that fatigue as a causal factor of accidents like collisions and groundings is being underreported. It pointed out that changing the shift system into 4 hours on to 8 hours off or 8 hours on 4 hours off s an option which accommodates the advice to have at least 8 hours of rest and preserves the regularity in shifts over a 24 hour period (Houtman et al., 2005). This study indicated the important of establishing a Fatigue Management Program as part of the ISM-Code because it is a holistic efficient way of managing and preventing seafarers' fatigue (Houtman et al., 2005). It recommended the most crucial effective ways of reducing fatigue in the Netherlands, including proper implementation of the ISM-Code, optimising the organisation of work on board vessels, lengthening the rest period, and reducing administrative tasks on board vessels (Houtman et al., 2005). In summary, Houtman et al (2005) identified the following areas to advance fatigue management: lengthening the resting period; optimising the organisation of work; reducing administrative tasks; fewer visitors, inspectors in the harbour, and better coordination of inspections; reducing overtime; proper Human Resource Management; education and training; development of a management tool for fatigue; proper implementation of the ISM-code; healthy design of the ship; health promotion at work; and expanding monitoring of fatigue causes, behaviours or consequences, including near misses (Houtman et al., 2005).

(4) Smith et al. (2006): This groundbreaking study was executed and supported by the Seafarers' International Research Centre (SIRC) at Cardiff University, the Maritime and Coastguard Agency, the Health and Safety Executive, and Nautilus UK. There was very little evidence-based research regarding fatigue at sea before this study (Smith et al., 2006). It indicated that the possibility of fatigue at sea is high because of a range of factors unique to the marine environment. Therefore, this study highlighted that negative causal factors must be considered in combination rather than alone in order to have adequate insight into fatigue at sea. Moreover, this shows the reality of the seafarers' working experience (Smith et al., 2006).

Smith et al. (2006) concluded that fatigue rises most substantially during the first week of the contract, possibly reflecting a ceiling effect, adaptation, or a combination of these options. They further indicated that recovery from fatigue after a tour of duty, on average, does not occur until the second week of leave (Smith et al., 2006). This study concluded that the existing reporting systems are ineffectively designed to record fatigue-related factors. Moreover, it indicated that excessive working hours are an issue in the seafaring industry and that a substantial number of crew falsified records. This was proved because those who at least occasionally under-recorded their working hours reported higher fatigue (Smith et al., 2006). In addition, this study indicated that fatigue was always associated with poor quality sleep, negative environmental factors, high job demands, and high stress. Other key factors included physical work hazards, frequent port turnarounds, working more than 12 hours a day, low job support, and finding the switch to port work fatiguing (Smith et al., 2006).

This study indicated that more frequent port calls were associated with increased fatigue among those on shorter contract, while those with less fatigue were among those on longer tours. This difference would appear to reflect ship type (Smith et al., 2006). The authours indicated that

mini-bulkers possibly represent a worst-case scenario in terms of a ship environment conducive to fatigue, as evidenced by objective testing done in this study. The negative factors on this ship type include changing cargos, short port stays, frequent port turnarounds, only two watchkeepers (in many cases), and long periods of pilotage. This study pointed out that the consequences (outcomes) of fatigue have been shown not only in terms of maritime accidents' contribution but also for self-reported physical and mental health outcomes (Smith et al., 2006).

Smith et al. (2006) stressed that fatigue can be addressed at three levels, namely regulation, company policy, and personal awareness/management. They stated that success can only be achieved if all these three levels are cooperatively involved. Therefore, the various recommendations for addressing seafarers' fatigue made by this study include effectively changing how working hours are recorded, fatigue awareness, fatigue management training and information campaigns, establishing an industry-standard measure of fatigue, and developing a multi-factor auditing tool (Smith et al., 2006).

(5) Akhtar & Utne (2014): This study used accident charts derived from in-depth studies of human fatigue-related accidents to analyse common patterns of interconnected fatigue causal factors, using the Cognitive Reliability and Error Analysis Method (CREAM) modified for maritime accidents (Akhtar & Utne, 2015). The major fatigue causal factors identified include irregular working hours and shiftwork, inadequate task allocation, and excessive demands. The article shows many variations between ship grounding and collision accidents and their associated fatigue causal factors. Human fatigue-related collision damages are associated with misconceptions, wrong decision-making, and poor communication between the ships (Akhtar & Utne, 2015). The crew frequently panics, and mistakes are certainly made right before the collision occurs; while human fatigue-related groundings are associated with when conditions are often

monotonous, and the piloting officer has either overlooked the upcoming seabed or simply fallen asleep. The study recognised climate safety issues as critical contributors to human fatigue (Akhtar & Utne, 2015).

(6) Tang et al. (2013): This paper indicated that despite the positive advancements in maritime safety over the years, the safety of shipping is still an area of increasing concern. This was the first paper of its type done by the Seafarers International Research Centre (SIRC) at Cardiff University (Tang et al., 2013). This article offers insight into past accidents by analysing and aggregating the findings of 319 maritime accident investigation reports published over a ten-year period by four maritime authorities, including 148 investigated by the United Kingdom's Maritime Accident Investigation Branch (MAIB), 110 by the Australian Transportation Safety Board (ATSB), 43 by Maritime New Zealand, and 18 by the United States National Transportation Safety Board (NTSB) (Tang et al., 2013). Although such reports' constructions and production are vulnerable to bias influences, they offer useful information regarding the types of causal factors the accident investigators have previously identified for causing accidents at sea (Tang et al., 2013). This study highlighted that the immediate and contributory causal factors of the maritime accidents indicated in respective reports were used to generate an idea of the key causal factors of maritime accidents over a decade, including seafarers' fatigue. The intention for doing this was to use these findings to determine the trend and pattern of various causal factors of maritime accidents and use the results to make the appropriate recommendations to enhance maritime safety (Tang et al., 2013).

The number of maritime accident cases having seafarers' fatigue as an immediate causal factor was 12, representing a prevalence of 3.8%, while the number of maritime accident cases having seafarers' fatigue as a contributory causal factor was 32, representing a prevalence of 10%,

making an overall prevalence of seafarers' fatigue-causal factor of maritime accidents 13.8% (Tang et al., 2013). Notable among many other contributory causes was inadequate risk management, because the number of maritime accidents having inadequate risk management as a contributory causal factor was 117, representing a percentage of 36.7%; moreover, a crucial aspect of risk management is fatigue risk management (Tang et al., 2013). Therefore, the key causal factor of the maritime accident indicated by the investigators was inadequate risk management, despite the implementation of the International Safety Management (ISM) Code. This article recognized the complexities of determining accident causal factors and the harms of oversimplification in assigning them (Tang et al., 2013).

(7) Acejo et al. (2018): This was the second paper of its type done by the Seafarers International Research Centre (SIRC) at Cardiff University. It was built upon an earlier study by Tang et al. (2013), which was published as part of the SIRC symposium proceedings in 2013 (Acejo et al., 2018; Tang et al., 2013)**.** The report involves an analysis of accident investigation reports that have been published online by the Australian Transport Safety Bureau (ATSB), the United States National Transportation Safety Board (NTSB), the United Kingdom's Marine Accident Investigation Branch (MAIB), the Federal Bureau of Maritime Casualty Investigation in Germany, and the Danish Maritime Accident Investigation Board (DMAIB) in the period 2002-2016 inclusive (Acejo et al., 2018). Accident investigation reports from Maritime New Zealand only included the period from 2002 to 2004 because their publication was discontinued in 2004. A total of 693 accident reports were analyzed in this study.

Like Tang et al. (2013), this study also analyzed the immediate and contributory causal factors of maritime accidents indicated in the various maritime accident reports analyzed, and used their patterns and trends of findings for insight regarding the key numerous causal factors of

maritime accidents indicated over a decade, among which is seafarers' fatigue. The immediate causal factors' prevalence of seafarers' fatigue as a causal factor of maritime accidents was 2.7%, while the contributory causal factors prevalence due to seafarers' fatigue as a causal factors of maritime accidents was 7.5% (Acejo et al., 2018). The combined total number of all types of maritime accidents having seafarers' fatigue as their causal factors was 71, representing a prevalence of 10.2%. Like Tang et al. (2013), inadequate risk management was largely identified as both an immediate and a contributory causal factor of accidents when all types were combined. Insufficient risk management was identified as the immediate causal factor of 17% of maritime accidents having seafaers' fatigue as a causal factor, and was acontributing causal factor of 27.1% of all accidents. The combined total number of maritime accidents having inadequate risk management as their causal factor of maritime accidents was 306, representing a percentage of 44.2% (Acejo et al., 2018). Therefore, since inadequate risk management, which includes seafarers' fatigue risk management, is identified as the significant causal factor in the overall picture, this emphasized the importance of implementing efficient seafarers' fatigue risk management in the maritime sector to address how accidents might be avoided in the future (Acejo et al., 2018).

1.5.2 Analytical Interpretation of Quantitative Findings and Comparison of the Prevalences of Seafarers' Fatigue as a Causal Factor of Maritime Accidents Obtained:

The respective prevalence of seafarers' fatigue as the causal factor of maritime accidents indicated by each of the finally included articles is indicated below in chronological order of their publication date, including Raby & Lee (2001) which indicated 23%. The Marine Accident Investigation Branch (MAIB) (2004) indicated 30% direct causal factor and 82% contributing causal factor for all groundings and collisions that occurred between 00:00 and 06:00 hours.

Houtman et al. (2005) indicated a range of 11% to 20%, Smith et al. (2006) indicated 53%, and Akhtar & Utne (2014) indicated 41% of vessels groundings and collisions. Tang et al. (2013) indicated 13.8 %, and Acejo et al. (2018) indicated 10.2%, respectively (Acejo et al., 2018; Akhtar & Utne, 2014; Houtman et al., 2005; Marine Accident Investigation Branch (MAIB), 2004; Raby & Lee, 2001; Smith et al., 2006; Tang et al., 2013).

Despite the variations in the values of the prevalence of seafarers' fatigue as a causal factor of maritime accidents obtained from these seven finally included articles, all of them have greater than the 5% referenced significant value. This indicates that seafarers' fatigue is a serious issue in the maritime sector; hence, the existing international regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector are **inadequate**. This is because all these prevalences' values are significant. Each of them passed disparate messages for improving maritime safety via how each of them was conducted in design and analysis. Similarly, when all included studies were compared, their disparities showed some findings, as explained below in this section.

Seafarers' fatigue is a disease and this uniqueness differentiates it from all other causal factors of maritime accidents. Therefore, a study to find a seafarers' fatigue measure of effects, that is, the prevalence of seafarers' fatigue as a causal factor of maritime accidents, is a typical epidemiological study. An adequate understanding of its measure of effects requires in-depth insight into updated epidemiological principles, including an understanding of the various systematic and unsystematic errors that occur during the analysis and design of epidemiological-related studies, as in this review (Aschengrau & Seage, 2020). Both bias and confounding are known as systematic errors because they occur due to a discernible process in the design and analysis of a study, while random errors are known as unsystematic errors because they occur due

to an undiscernible natural process, by chance, in the design and analysis of a study (Aschengrau & Seage, 2020).

A bias is a systematic error committed by an investigator in the design or analysis of an epidemiological study that results in an incorrect (false) estimate of the measure of association between an exposure (seafarers' fatigue causal factor) and outcome (seafarer fatigue and its associated maritime accident). Examples of biases in an epidemiological-related study are selection bias and information bias. Selection bias emerges from systematic variations in selecting and following the study groups while information bias is an error that arises from systematic variations in the way that information on exposure and disease is obtained from the study groups. For instance, a maritime accident investigator's reluctance to report seafarers' fatigue as a causal factor of maritime accidents is a type of information bias. Selection bias can be prevented by the following approaches: using similar measures to obtain high participation, select cases and controls, using effective approaches to retain and trace study subjects, eliminating self-referrals from a study, and acknowledging referral and diagnostic practices when designing the study (Aschengrau & Seage, 2020).

A confounder is a systematic error in the design or analysis of an epidemiological study known as the third extraneous variable, that stems from the natural mixing of effects, exposure (seafarers' fatigue causal factor), outcomes (seafarer fatigue and its associated maritime accident) and this extraneous variable. The amount of a confounder may be small, moderate, or large, and the confounder's distortive effects can either exaggerate or minimize the true association between an exposure and outcomes; the former effect is known as positive confounding, while the latter effect is known as negative confounding. Confounding in a study can be prevented in the design, the analysis, or a combination of the two. The three approaches to control for confounding in the

design stage of a study are matching, restriction, and randomization, while approaches to control for confounding in the analysis stage of a study are standardization, stratified analysis, matched analysis, and multivariable analysis (Aschengrau & Seage, 2020).

In contrast, a random error is an unsystematic error in the design or analysis of an epidemiological study that leads to a false association between an exposure (seafarers' fatigue causal factor) and outcome (seafarers' fatigue and its associated maritime accident), that arises from an unforeseeable and unpredictable process known as chance, which is an uncontrollable natural force that seems to have no assignable cause. Precision is used as a term for the lack of random error. There are two sources of random error. They are measurement error and sampling variability. Measurement error emerges from incorrectness in evaluating the exposure and outcomes, while sampling variability emerges from the selection of particular study subjects. An epidemiologist uses hypothesis testing and confidence intervals to assess and quantify the role of random error in a study, respectively. Hypothesis testing, such as the P-value, is used to make statistical inferences, including generalizations from a study sample to the parent population, while the confidence interval is usually calculated around a point estimate, which is usually a measure of disease (outcome) frequency or association. An epidemiologist uses experience, power curves, sample size calculations, adequate sample size, and intuition to project the appropriate sample size for a study (Aschengrau & Seage, 2020). Therefore, epidemiologists or maritime accident investigators assessing the measure of effects of seafarers' fatigue as a causal factor of maritime accidents should evaluate whether their study's results are valid by evaluating the presence of these three alternative explanations: bias, confounding, and random error (Aschengrau & Seage, 2020).

The prevalence value of seafarers' fatigue as a causal factor in maritime accidents obtained from Raby & Lee (2001) was 23%, a range of 11% to 20% was obtained by Houtman et al. (2005),

13.8 % was obtained from Tang et al. (2013), and 10.2% was obtained from Acejo et al. (2018). All these prevalence values are lower compared to other studies with higher prevalence values of maritime accidents having seafarers' fatigue as a causal factor, obtained from the Marine Accident Investigation Branch (MAIB) (2004), which indicated 30% direct causal factors and 82% contributing causal factors of fatigue for all groundings and collisions that occurred between 00:00 and 06:00 hours, Smith et al. (2006) indicated 53%, and Akhtar & Utne (2014) indicated fatigue as a causal factor for 41% of vessels groundings and collisons. The reasons for the disparity in the prevalence values between the former and the latter group of studies may be the various types of biases, confounders, and random errors that may be inherent and not controlled for in the design and analysis of those former group's studies, including those of Raby & Lee (2001), Houtman et al. (2005), Tang et al. (2013), and Acejo et al. (2018). Hence, this resulted in the lower percentage values of those former group's studies, because of the lower quality of study design and analysis methodology used for conducting each of them, which may not have identified and controlled for likely biases, confounders, and random errors (Acejo et al., 2018; Aschengrau & Seage, 2020; Houtman et al., 2005; Marine Accident Investigation Branch (MAIB), 2004; Raby & Lee, 2001; Smith et al., 2006; Tang et al., 2013).

In contrast, the presence of biases, confounders, and random errors was minimized in the latter group's studies, including MAIB (2004), Smith et al. (2006), and Akhtar & Utne (2014) (Aschengrau & Seage, 2020). The latter group's studies may have used more caution in avoiding these various types of biases, confounders, and random errors in their methodology for conducting their respective studies design, and analysis. These resulted in their comparative higher percentage values due to seafarers' fatigue as a causal factor of maritime accidents in the latter group compared to the former group. Hence, this significantly increases the validity, precision, reliability,

and confidence in the latter group's studies than for the former ones (Acejo et al., 2018; Aschengrau & Seage, 2020; Houtman et al., 2005; Marine Accident Investigation Branch (MAIB), 2004; Raby & Lee, 2001; Smith et al., 2006; Tang et al., 2013). This was confirmed by Appendixes 1A and 1B which indicated the methodological quality assessment summary of all the included studies and their interpretation, respectively (Joanna Briggs Institute, 2017).

An example of this bias was pointed out by Tang et al. (2013), who acknowledged biases inherent in assigning maritime accident causal factors by investigators, including the issues of oversimplification in assigning causal factors in the various reports used by Tang et al. (2013) and Acejo et al. (2018). This issue led to underreporting of fatigue as a causal factor of maritime accidents; the investigators were reluctant to report seafarers' fatigue as a causal factor because it cannot be proven. This bias issue was also pointed out by Houtman et al. (2005) (Acejo et al., 2018; Aschengrau & Seage, 2020; Houtman et al., 2005; Tang et al., 2013).

Apart from these factors, another reason why the prevalence values indicated by Tang et al. (2013) and Acejo et al. (2018) are low is that both studies treated some fatigue-related causal factors separately, following what was indicated by the investigators in each report, including undermanning, inadequate lookout (poor attention), poor judgment and inadequate risk management. However, the IMO's (2019) *Marine Safety Committee circular MSc.1/Circ1598 Annex on guidelines on fatigue* elaborated that each of these factors may be causal factors of seafarers' fatigue (International Maritime Organization (IMO), 2019). All these substantially lowered the percentage values due to seafarers' fatigue as a causal factor of maritime accidents in the former studies' group.

The high confidence placed in the MAIB (2004) study is due to the quality of methodology adopted for conducting its design and analysis, called restriction and stratification, respectively,

that controls for the various confounders, despite the fact that its power is low. A restriction is a potent approach for controlling for confounders in the design stage of a study, while stratification is used to control for confounders in the design stage of a study. The restriction was done by focussing on areas where high confidence is placed in its findings, by determining the causal factors of groundings and collisions that occurred during the 00:00 and 06:00 hours period, during which humans naturally have a high tendency to fall asleep. This explains the high confidence put into the accuracy of its findings. Stratification was done by categorizing the various causal factors in its analysis (Aschengrau & Seage, 2020; Marine Accident Investigation Branch (MAIB), 2004).

Also, Smith et al. (2006) and Akhtar and Utne (2014) controlled for various confounders in their analysis by grouping the causal factor into subgroups, which is an effective method called stratification. Stratification is the act of sorting samples, data, or participants into numerous subsamples or distinct groups or layers according to stated criteria such as age and causal factor's subgrouping. Akhtar and Utne (2014) used a specialized type of stratification approach called the Cognitive Reliability and Error Analysis Method (CREAM). Also, Smith et al. (2006) used odd ratios (OR), confidence interval (CI), and P- values to assess precision and control for errors in their findings on seafarers' fatigue causal factors and its associated maritime accident risks (Akhtar & Utne, 2014; Aschengrau & Seage, 2020; Smith et al., 2006). These various controls used by the latter group studies resulted in higher quality studies and higher significant prevalences values when compared with those from the former group studies with lower quality studies and lower percentages.

1.6 Summary of Included Studies' Quantitative and Qualitative Review Findings

Table 1.2 shows the summary of included studies' quantitative and qualitative findings to ascertain the adequacy of existing regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector, including Canada.

1.7 Implications for Research, Policy, and Practice

The analysis of bias, confounder, and random error in the assessment of causal factors of seafarers' fatigue is a future research area that requires more maritime research, and this involves adequate application of updated epidemiological principles into maritime research (Aschengrau & Seage, 2020). The aim of all reviews done in this overall study is to use their findings to make recommendations for regulatory amendment of the existing regulations and strategies for managing and preventing seafarers' fatigue to advance their adequacy. Therefore, ensuring the validity, precision, and reliability of these review findings is crucial to ensure their authenticity and effectiveness as amendment guiding tools to ensure the adequacy of the existing seafarers' fatigue management regulations. Ascertaining the authenticity of this review's findings usage for the above-stated aim of this overall study necessitates comparing them with other sources of evidence. This forms the basis for conducting the next chapter for a comparative analysis of the two findings to ascertain their precision, validity, and reliability. The next chapter's topic is the systematic review of maritime accident investigation reports to identify the prevalence of seafarers' fatigue as a causal factor of maritime accidents.

CHAPTER TWO

SYSTEMATIC REVIEW OF MARITIME ACCIDENT INVESTIGATION REPORTS TO IDENTIFY THE PREVALENCE OF SEAFARERS' FATIGUE AS A CAUSAL FACTOR OF MARITIME ACCIDENTS

2.1 Review Introduction

This second chapter utilized Acejo et al.'s (2018) and Smith's (2007) suggestions that maritime safety at sea can be enhanced by systematically reviewing past maritime accident investigation reports identifying seafarers' fatigue as a causal factor of maritime accidents. This enables using the trends and patterns from these reports' review findings to evaluate the adequacy of regulations and strategies for managing and preventing seafarers' fatigue in the Canadian and international maritime sector (Acejo et al., 2018; Smith et al., 2018). The findings from this second systematic review are used to evaluate the adequacy of the existing national and international regulations and strategies for managing and preventing seafarers' fatigue and its associated maritime accident risks, to answer the overall review question and objective.

This second systematic review analyzed 2,010 maritime accident investigation reports. All were accumulated from the publicly available databases of 5 national maritime accident investigation agencies of the leading maritime nations, including the United States of America (USA), United Kingdom (UK), Canada, Australia, and Denmark. The initial investigation report's database used for this review was compiled in one database by Fadal Al-Ajdaa and Captain Philip Bulman. The authors further worked on this database to update it to 2021 and sorted all its reports to comprise only maritime accident reports involving ships of 500 gross tons and above. This chapter reviews evidence from these accident investigations reports published over three decades,

from 1990 to 2021 (32 years), to determine the prevalence of seafarers' fatigue as a causal factor of maritime accidents.

2.2 Review Methodology

Various investigation reports' eligibility criteria established for this review include greater than 500 gross tons, commercial ships, fully completed maritime accident reports, the report's completion date being between 1990 to 2021 inclusive, and the report drawn from the websites of the maritime accident investigation bodies of these five countries, namely the United States of America (USA), United Kingdom (UK), Canada, Australia, and Denmark.

Smith (2007) pointed out that past attempts to prevent or manage seafarers' fatigue by legislation and guidance have failed because there has been little attempt to assess their adequacy. This is the gap in knowledge that this review intends to bridge. Many previous reviews on seafarers' fatigue issues and legislation are based on relatively small sample sizes, which made the 'power' of these studies low. This is the reason for this review, comprising of over 2010 maritime accident investigation reports. Out of the 2,010 investigation reports pooled from these five countries' maritime accident investigation agencies, only 1,346 of them met the eligibility criteria. The respective report's completion years' range and the name of the respective maritime accident investigation agencies of each country are as follows: the United Kingdom's (UK) Marine Accident Investigation Branch (MAIB) (1990 to 2021), the United States of America's (USA) National Transportation Safety Board (NTSB) (1990 to 2021), Canada's Transport Safety Board of Canada (TSBC) (1990 to 2021), Australia's Australian Transportation Safety Bureau (ATSB) (1990 to 2021), and Denmark's Danish Maritime Investigation Board (DMIB) (2010 to 2021). The maritime accident investigation reports gathered cover three decades, ranging from 1990 to 2021 (32 years). However, only maritime accident reports covering over a decade, from 2010 to 2021,

could be obtained from Denmark's DMIB. The search start dates on these five maritime accident investigation agencies' databases for reports extraction were the 1st of December 2022 and they ended on the 31st of December 2022.

The commercial vessels of greater than 500 gross tons involved in this review are of various types, including container ships, bulk carriers, tankers, roll-on roll-off, oil tankers, passenger ships, platform supply vessels, reefer ships, fishing vessels, barges, chemical tankers, gas carriers, cruise ships, heavy lift ships, livestock carriers, and sailing ships. Unlike the first review in chapter one, which used PRISMA, this review used *pdf search* to identify and accumulate all the finally included reports. The final inclusion criterion for all the included reports was that they must identify seafarers' fatigue as the causal factor of their respective maritime accidents and vice versa for the exclusion criterion. All included reports were analyzed to address the overall objective and question. This second review determines the percentage of maritime accident reports identifying seafarers' fatigue as the causal factor of their respective maritime accidents. This second review will provide further analytical inferences and deductions when analyzed together with the first one done in chapter one.

Similar to Chapter One's review, the standard cut-off value for the prevalence of seafarers' fatigue as the causal factor of maritime accidents adopted in this review for its statistical significance is 5% and above. Any prevalence value of 5% and above is significant, while a prevalence value of less than 5% is insignificant. Any prevalence value less than 5% implies the adequacy of existing regulations and strategies for managing seafarers' fatigue and its associated maritime accident risks, while any prevalence value greater than 5% and above implies the inadequacy of existing regulations and strategies for managing seafarers' fatigue and its associated maritime accident risks.

Also, this review's findings are critically compared with the review in chapter one and with other available various sources of evidence from disparate sources to ascertain the adequacy of the existing regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector, including Canada. The various search terms pertinent to *"fatigue"* were developed to enable easy identification of finally included investigation reports during the *pdf search*. These included reports are exclusively those reports of which conclusive findings indicated that the significant causal factor of their respective maritime accident was seafarers' fatigue. The search terms sequentially selected for the pdf search were *fatigue, exhaust, rest, stress, workload,* and *sleep*. During each pdf search, all sentences containing the respective search term in each country or pooled folder searched are returned. All sentences in each search returned are meticulously read to keep and use those included accident reports with conclusive findings indicating that the contributory or immediate causal factor of their respective maritime accident is seafarers' fatigue.

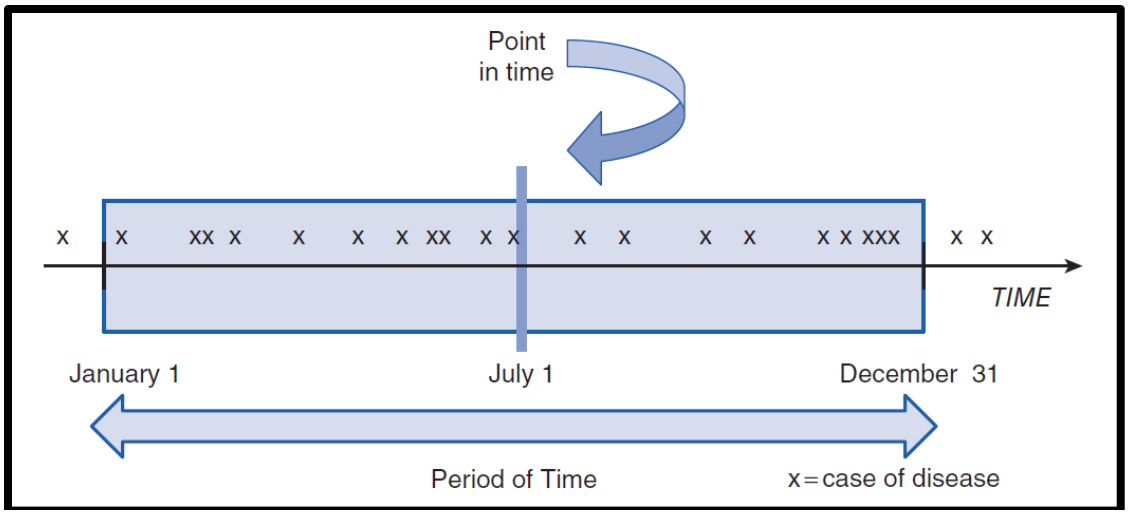
The final inclusion criterion to include the maritime accident investigation report is the identification of seafarers' fatigue as a causal factor of their respective maritime accidents. 63 reports out of the 500 eligible reports gathered from the UK's MAIB are finally included, while 28 reports out of the 293 eligible reports gathered from Australia's ATSB are finally included. Similarly, 29 reports out of the 287 eligible reports gathered from Canada's TSBC are finally included, while 9 reports out of the 217 eligible reports gathered from the USA's NTSB are finally included. 1 report out of 49 eligible reports gathered from Denmark's DMIB is included. Extra caution is taken to differentiate between metallic or material fatigue and human fatigue. All search terms were searched for each country to enable subsequent analytical interpretations and data gathering for each country.

2.3 Review Findings and Their Interpretations

2.3.1 Explanatory Analyses and Interpretations of this Review Quantitative Findings, Including Prevalence Obtained:

Prevalence measures the frequency of existing disease, and it is defined as the proportion of the total population that is diseased. There are two types of prevalence measures, namely period prevalence and point prevalence. Point prevalence refers to the proportion of the population that is diseased at a single point in time, such as yearly point prevalence as in this review instance, and can be thought of as a single snapshot of the population, while period prevalence refers to the proportion of the population that is diseased during a specified duration of time, such as the 32 years period in this review (Aschengrau & Seage, 2020). Mathematically, point prevalence is expressed as the number of existing cases of disease divided by the number in the total population at that point in time, while period prevalence can be expressed as the number of existing cases of disease divided by the number in the total population during that period in time (Aschengrau & Seage, 2020). For illustrative purposes to show the disparity between these two prevalence measures, Figure 2.1 shows the time frame for point prevalence in July 1, while the time frame for period prevalence is from January 1 to December 31.

Figure 2.1
The Time frame for point and period prevalence (Source: Aschengrau & Seage, 2020).

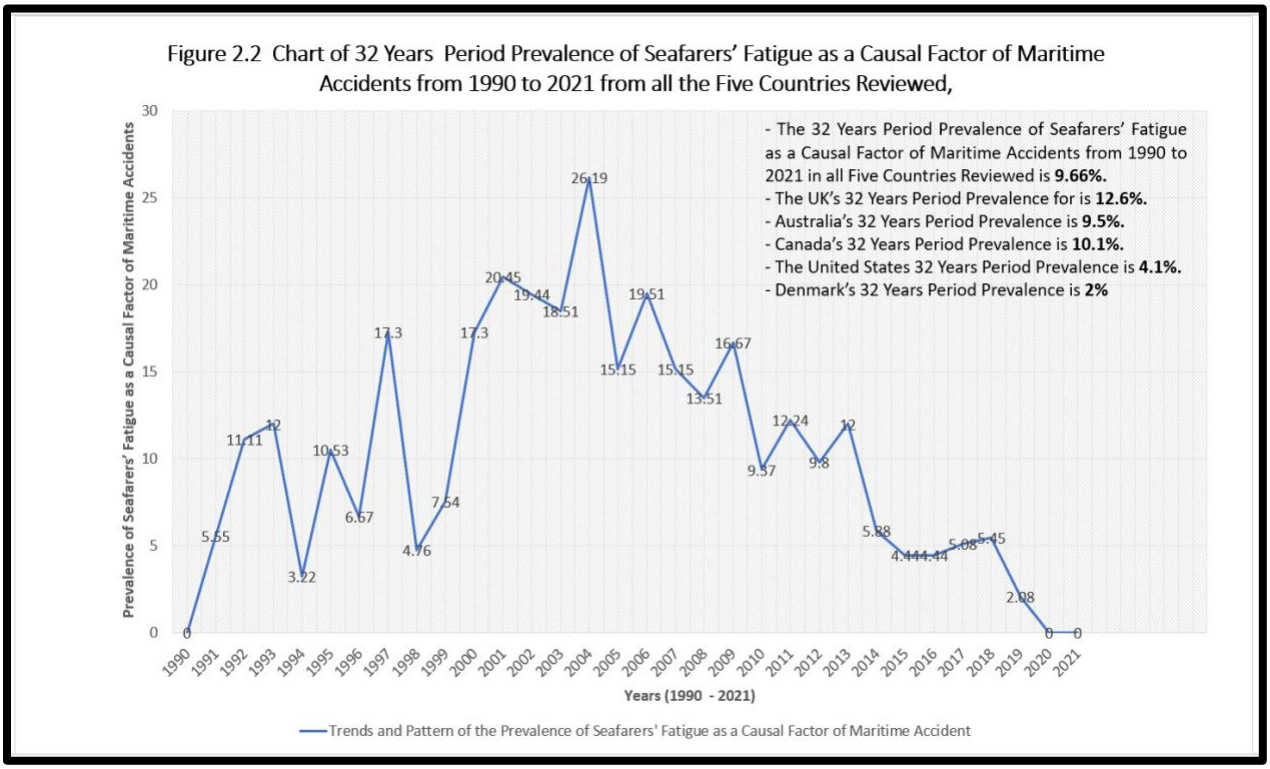


Likewise, in this review, the yearly point prevalence of seafarers' fatigue as a causal factor of maritime accidents for each respective year is calculated as the number of existing maritime accidents having seafarers' fatigue as one of their causal factors within that year, divided by the total number of vessels navigating within that year at that yearly point in time. In contrast, the 32 year period prevalence of seafarers' fatigue as a causal factor of maritime accidents from 1990 to 2021 is calculated as the number of existing maritime accidents having seafarers' fatigue as their causal factor within that 32 year period divided by the total number of vessels population navigating within that 32 years period during that period in time. The 32 year **period prevalence** of seafarers' fatigue as a causal factors of maritime accidents for the overall countries and each respective country reviewed are indicated in Figure 2.2. The overall 32 year period prevalence from 1990 to 2021 inclusive is **9.66%**. Figure 2.3 indicates the respective **yearly point prevalence** of seafarers' fatigue as a causal factor of maritime accidents from 1990 to 2021 inclusive. It should be noted that the date used for calculating and charting 36 years period prevalence measures from 1990 to 2021 inclusive shown in Figure 2.2 and the respective yearly point prevalence shown in Figure 2.3 is the year of occurrence of the respective maritime accident indicated in their various

respective included reports; it is not the year of publication of the respective included maritime accident investigation reports.

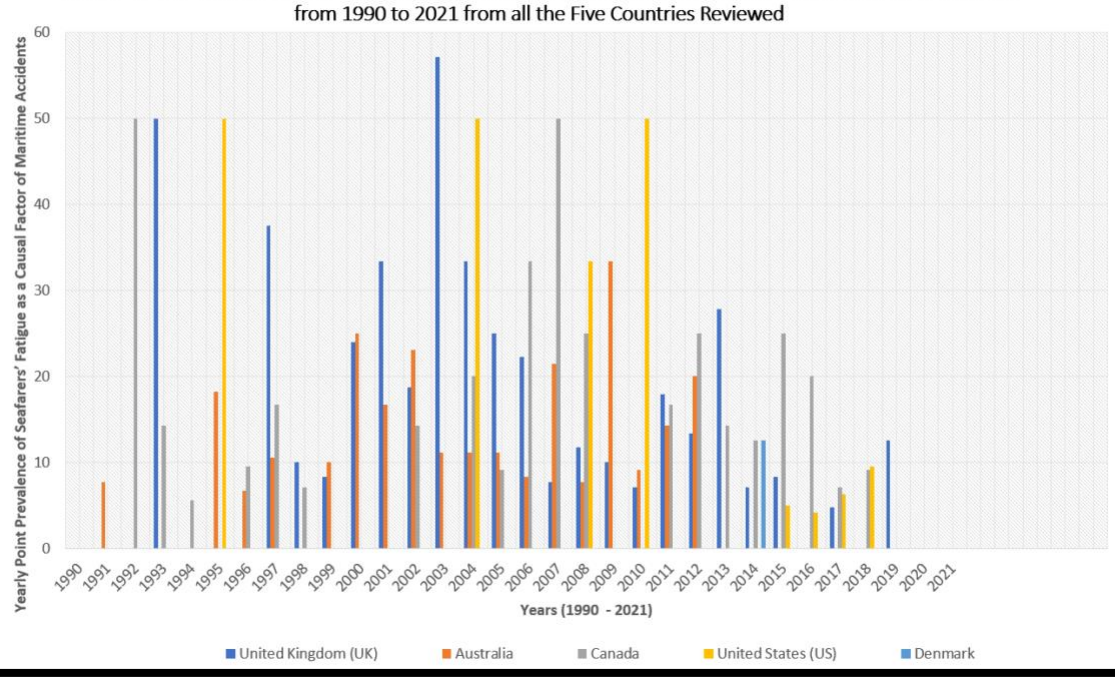
The total number of maritime accident reports gathered from five countries reviewed was 2,010, out of which 1,346 were eligible. 130 reports, out of these 1,346 eligible reports, are finally included maritime accident reports that identified seafarers' fatigue as a causal factor of their respective maritime accidents. Therefore, according to this chapter's review, the **32 year period prevalence** of seafarers' fatigue as a causal factor of maritime accidents from 1990 to 2021 inclusive is **9.66%**, as indicated in Figure 2.2. The overall review quantitative summary table of yearly point prevalence is shown in Appendix 2A. The yearly point prevalence summary tables for the United Kingdom (UK), Canada, Australia, United States of America (USA), and Denmark are shown in Appendixes 2B, 2C, 2D, 2E, and 2F, respectively.

Figure 2.2 Chart of 32 Years Period Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents from 1990 to 2021 from all the Five Countries Reviewed,



The 32 year period prevalence of seafarers' fatigue as a causal factor of maritime accidents for each of the five countries reviewed from the highest to the lowest is 12.6% for the United Kingdom (UK), 10.1% for Canada, 9.5% for Australia, 4.1% for the United States of America (USA), and 2% for Denmark, respectively, as indicated in Figure 2.2. Figure 2.3 shows a bar chart illustrating various yearly points prevalence of seafarers' fatigue as a causal factor of maritime accidents among the five countries reviewed. In visual observation of Figure 2.3, it should be noted that the value numerator and denominator that comprise each yearly point prevalence varies. The 32 years period prevalence of seafarers' fatigue as a causal factor of maritime accidents for all of the five countries reviewed is 9.66%. This is greater than 5%, therefore, this means that the 32 years period prevalence indicates that the existing regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector, including Canada, are **inadequate**.

Figure 2.3 Bar Chart of Yearly Point Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents from 1990 to 2021 from all the Five Countries Reviewed



The investigators' reluctance to report seafarers' fatigue as a causal factor of maritime accidents is observed in all the five countries reviewed. Also, the 32-year period prevalence of seafarers' fatigue as a causal factor of maritime accidents analyzed from reports pooled from the United Kingdom's (UK) MAIB, Canada's TSBC, and Australia's ATSB are 12.6%, 10.1%, and 9.5%, respectively. These values are more than the 5% reference value. Therefore, these three countries' 32-year period of seafarers' fatigue-related maritime accident prevalence indicates that the repective existing national regulations and strategies for managing and preventing seafarers' fatigue in these three countries' maritime sectors are **inadequate**. The 32-year period prevalence of seafarers' fatigue as a causal factor of maritime accidents for the United States of America's (USA) NTSB and Denmark's DMIB, having 4.1% and 2%, respectively. Although these values are less than 5% reference value, they seem to indicate that the existing national regulations and strategies for managing and preventing seafarers' fatigue in the USA and Denmark maritime sectors are adequate, they are **inadequate** because all these five countries used the same existing international regulations and strategies for managing and preventing seafarers' fatigue. The explanation for the significantly lowered 32-year period prevalence of the United States of America's (USA) NTSB and Denmark's DMIB having 4.1% and 2%, respectively, may be due to the presence of information bias, noticed generally in all the reports from all five countries reviewed. This information bias was caused by the investigators' reluctance to report seafarers' fatigue as a causal factor of maritime accidents because seafarers' fatigue cannot be measured. Because of this, there is no evidence to show its presence, and therefore, it cannot be proven.

Moreover, regarding the described information biases, it was noted that all the 32-year period prevalence of seafarers' fatigue as a causal factor of maritime accidents may be lowest for all the reports gathered from Denmark's DMIB because of this information reporting bias, as it

was observed that all the reports eligible from Denmark's DMIB did not have a section for analyzing and discussing seafarers' fatigue like the United Kingdom's (UK) MAIB, Australia's ATSB, Canada's TSBC, and the USA's NTSB. All the reports pooled from United Kingdom's (UK) MAIB, Australia's ATSB, Canada's TSBC, and the USA's NTSB adopted the reporting format of the Marine Accident Investigators' International Forum (MAIIF), which is the reporting format recommended by the International Maritime Organization (IMO). However, all reports gathered from Denmark's DMIB did not follow the MAIIF reporting format (MAIIF, n.d.). The reason for the information bias noticed in all reports from Denmark's DMIB may be that the Denmark's DMIB does not want to indicate seafarers' fatigue as a causal factor of maritime accident because seafarers' fatigue cannot be measured, and hence the evidence of its presence cannot be proven.

Table 2.1 shows the characteristic of this review's quantitative findings, from all the pooled included reports, indicating the overall and each country's 32-year period prevalence of seafarers' fatigue as a causal factor of maritime accidents and their respective interpretation for answering the overall review question and objective. Appendixes 2G, 2H, and 2I tabulate the qualitative characteristics of all included reports having seafarers' fatigue as a causal factor of maritime accidents from 1990 to 2021 from all the countries analyzed, including the name of the ship, the year of the maritime accidents' disaster occurrence, maritime accident investigative report's number, the type of maritime accidents that occurred, and the seafarers' fatigue causal factor type, respectively.

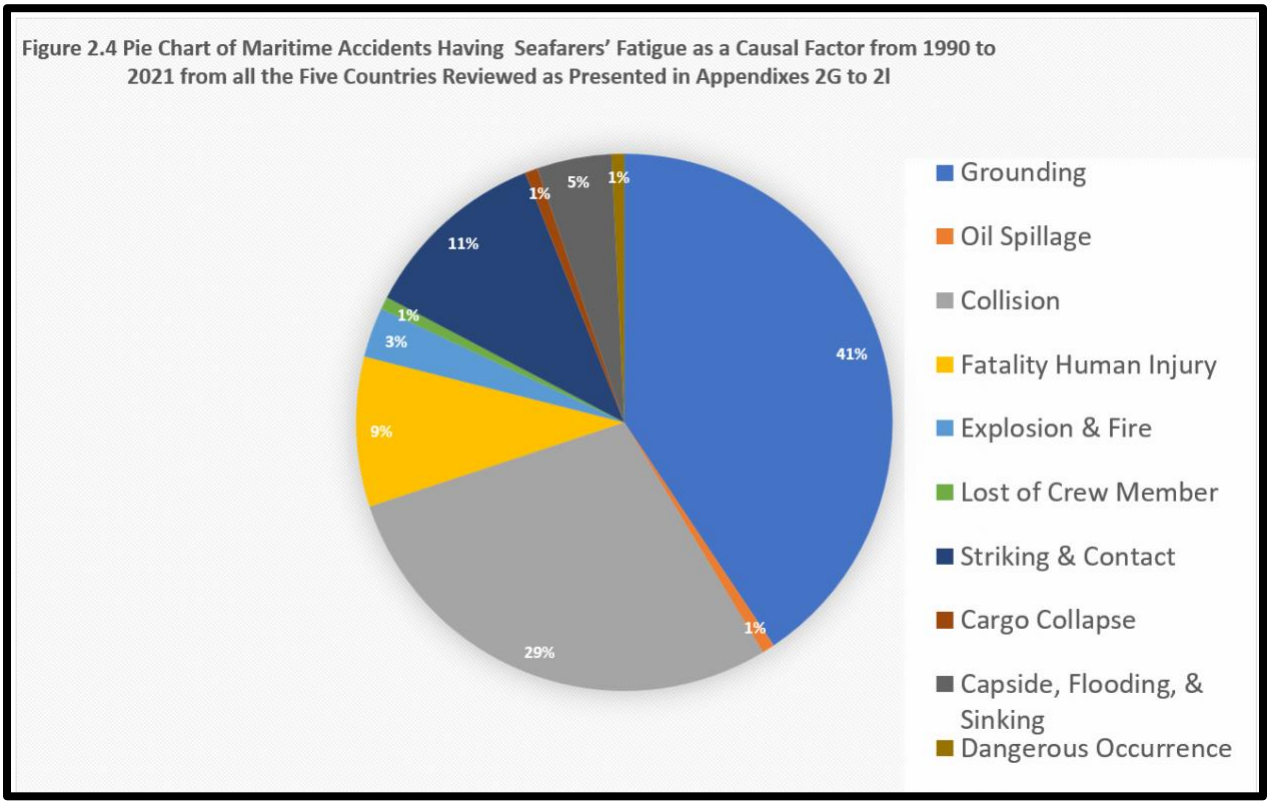
Table 2.1 Summary of Characteristics of Quantitative Findings Indicating Both the Overall and Each Country's 32 years Period Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents and their Respective Interpretation for Answering the Overall Review Question And Objective

Source of 32 Years Period Prevalence Data	32 Years Period Prevalence Obtained (%)	Prevalence Reference Value (%)	Answer to the Overall Review Question and Objective Regarding Ascertaining the Adequacy of the Existing Regulations and Strategies for Managing Seafarers' Fatigue in the International Maritime Sector, Including Canada
Overall 32 Years Period Prevalence for all the Five Countries Reviewed	9.66%	5%	**Inadequate*** This value means that the existing regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector, including Canada, are inadequate.
United Kingdom's (UK) MAIB	12.6%	5%	**Inadequate*** This value means that the existing national regulations and strategies for managing and preventing seafarers' fatigue in the UK's maritime sector are inadequate.
Australia's ATSB	9.5%	5%	**Inadequate*** This value means that the existing national regulations and strategies for managing and preventing seafarers' fatigue in Australia's maritime sector are inadequate.
Canada's TSBC	10.1%	5%	**Inadequate*** This value means that the existing national regulations and strategies for managing and preventing seafarers' fatigue in Canada's maritime sector are inadequate.
United States of America's (USA) NTSB	4.1%	5%	**Inadequate*** The period prevalence value seems to indicate regulatory adequacy, but this significantly lowered period prevalence value may be due to information bias, noticed generally in all the reports from all five countries reviewed caused by the investigators reluctance to report seafarers' fatigue as a causal factor of a maritime accident because seafarers' fatigue cannot be measured, and therefore, it cannot be proven. Therefore, the existing national regulations and strategies for managing and preventing seafarers' fatigue in USA's maritime sector are inadequate.
Denmark's DMAIB	2%	5%	**Inadequate*** The period prevalence value seems to indicate regulatory adequacy, but this significantly lowered period prevalence value may be due to information bias, noticed generally in all the reports from all five countries reviewed, caused by the investigators' reluctance to report seafarers' fatigue as a causal factor of maritime accidents because seafarers' fatigue cannot be measured, and therefore, it cannot be proven. Therefore, the existing national regulations and strategies for managing and preventing seafarers' fatigue in Denmark's maritime sector are inadequate.

*This value is substantially reduced by information bias due to the investigators' reluctance to report seafarers' fatigue as a causal factor of maritime accidents because seafarers' fatigue can not be proven.

Figure 2.4 shows a pie chart illustrating the frequency percentages of the various types of maritime accidents occurrence having seafarers' fatigue as a causal factor from all included reports from 1990 to 2021 inclusive in all the five countries reviewed, as presented in Appendixes 2G, 2H, and 2I. The frequency percentages of various maritime accidents due to seafarers' fatigue as a causal factor in all included reports from 1990 to 2021 inclusive are as follows in decreasing order: groundings are 41%; collisions are 29%; strikings and contacts are 11%; fatalities and human injuries are 9%; capsizes, floodings, and sinkings are 5%; explosions and fires are 3%; oil

spillage is 1%; loss of a crew member is 1%; dangerous occurrence is 1%; and cargo collapse is 1%.



These findings indicate that in decreasing order, groundings, collisions, strikings and contacts, and fatalities and injuries are the dominant maritime accident occurrences having seafarers' fatigue as a causal factor in all included reports from 1990 to 2021. Therefore, all these findings show that seafarers' fatigue issue is a severe issue in the international maritime sector, including Canada. Hence, the existing international and national regulations and strategies for managing and preventing seafarers' fatigue in each of these five countries reviewed, including Canada, are **inadequate**.

(a) Explanatory Reasons for the Peak High Yearly Point Prevalence Obtained in 2004:

Figure 2.2 describes the trend pattern of the overall included reports' 32-year period prevalence covering the whole 32 years reviewed, from 1990 to 2021, and Figure 2.3 describes the

trend pattern of yearly point prevalence of each respective year covering the whole 32 years reviewed from 1990 to 2021. Figure 2.2 shows that the incidence percentage rose steeply in a sharp up-and-down pattern from 1990 up to its peak incidence percentage in 2004 and gradually fell steeply from one year to the next after 2004 till it reached zero in 2020 and 2021. Many reports on maritime accidents that occurred in 2020 and 2021 may still be in the preliminary stages and were not yet published by 2022 December, when the reports' database for this review was updated and gathered. This may be the reason for the yearly point prevalence of 0% in 2020 and 2021, as shown in Figure 2.2.

There are many reasons for the high peak yearly point prevalence obtained in 2004. Figures 2.2 and 2.3 illustrate the reason for this high yearly point prevalence of seafarers' fatigue as a causal factor of maritime accidents in 2004. Figure 2.3 shows that no other year, apart from 2004, in all the 32 years evaluated, has such a high yearly point prevalence from all five countries, with finally included reports. Similarly, Figure 2.2 shows the high peak yearly point prevalence of 26% in 2004, which is the highest yearly point prevalence in all 32 years reviewed, supporting what Figure 2.3 has indicated. Another explanatory reason for the highest yearly point prevalence of 26%, obtained in 2004 was because the period prevalence of seafarers' fatigue as a causal factor of maritime accidents between 1990 to 2004 inclusive is 13.2%, which is more than the 8.5% obtained for the period prevalence between 2005 to 2021 inclusive. This proved that the period prevalence from 1990 to 2004 inclusive is more than that of between 2005 to 2021 inclusive; hence this means that there were more period prevalent occurrences of seafarers' fatigue as a causal factor maritime accidents before 2004 inclusive than after 2004.

Another explanation of this high peak yearly point prevalence of 26% in 2004 is that all the reports of maritime accidents that occurred before 2004 and in 2004 may have been published

in 2004 as part of the many safety security preparedness activities to get the maritime sector ready in anticipation of July 1st 2004, when the maritime sector commenced worldwide enforcement of the International Ship and Port Facility Security (ISPS) Code (Huda et al., 2012; Yilmazel & Asyali, 2005). This worldwide enforcement of the ISPS Code on 1st July 2004 was enacted to enhance maritime security by delineating minimum security standards for ships and port facilities (Huda et al., 2012; Yilmazel & Asyali, 2005). The ISPS code created an international framework for cooperation in effective gathering and sharing of information to detect and prevent security threats, such as terrorism or looming maritime accidents, by taking adequate preventive actions to avert such adverse occurrences (Huda et al., 2012; Yilmazel & Asyali, 2005).

(b) Explanatory Reasons for the Yearly Gradual Steeply Falling in the Yearly Point Prevalence Obtained after 2004, Between 2005 to 2021 Inclusive:

There are many other reasons for the gradual reduction in the yearly point prevalence of seafarers' fatigue as a causal factor of maritime accidents obtained after 2004, between 2005 to 2021 inclusive, as reflected in the 8.5% period prevalence of seafarers' fatigue as a causal factor maritime accidents obtained, compared with 13.2% period prevalence obtained before 2004, between 1990 to 2004 inclusive. This gradual fall in the yearly point prevalence may have been due to the manifestation of the efficacy of the prior ISPC's enforcement efforts, which started on 1st July 2004. This may have caused a subsequent gradual steep decline in the yearly point prevalence of seafarers' fatigue as a causal factor of maritime accidents after 2004, between 2005 to 2021, as shown in Figure 2.2. All these were reasons that caused the sharp gradual reduction in the yearly point prevalence of seafarers' fatigue as a causal factor maritime accidents after 2004, between 2005 to 2021, as shown in Figure 2.2.

2.3.2 Explanations for Substantial Reduction in this Review's Yearly Point Prevalence and Period Prevalence:

The explanation for the substantial reduction in this review's yearly point prevalence and period prevalence is the information bias, which was caused by the investigators' reluctance to report seafarers' fatigue as a causal factor of maritime accidents. This resulted in many eligible reports not being included in this review, thereby causing a substantial lowering of these two prevalence measures. The investigators felt reluctant to report seafarers' fatigue as a causal factor of maritime accidents because it cannot be measured, and hence its presence cannot be proven. This significantly reduced the overall period prevalence and the period prevalence obtained from each of these five countries where the included accident investigation reports were obtained, as shown in Table 2.1 and Figure 2.2.

2.3.3 Qualitative Findings for Ascertaining the Adequacy of the Existing Regulations and Strategies for Managing and Preventing Seafarers' Fatigue in Canadian and International Sectors

This review section uses the violations of the existing international regulations and strategies related to seafarers' fatigue as a gauge to ascertain the adequacy of the existing regulations and strategies for managing and preventing seafarers' fatigue in Canadian and international sectors. These are the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978 Convention's Standards Regarding Watchkeeping, Section A-VIII/1 Fitness for Duty, items 1 to 10,* as amended (International Maritime Organisation (IMO), 2011, p.251-252), and the International Labour Organization's (ILO) *Maritime Labour Convention (MLC) (2006) Convention's regulation, standard A.2.3 hours*

of work and hours of rest, items 1 to 14, as amended (International Labour Organization (ILO), 2006, p.30-31), among other existing regulations and strategies for managing seafarers fatigue.

This section used the included maritime accident investigation reports, tabulated in Appendixes 2G, 2H, and 2I, with accident scenarios that violated these existing international regulations and strategies related to seafarers' fatigue to account for the inadequacy of these existing regulations and guidelines. Also, to further prove the inadequacy of these two regulations, some extracts from these included maritime accident investigation reports in Appendixes 2G, 2H, and 2I with circumstances that complied with these two regulations, are used to confirm their inadequacy, because compliance with them still instigated seafarers' fatigue.

Various explanations of regulatory violation and regulatory insufficiency are decribed analytically under each respective group to prove or disprove the adequacy of these two regulations related to seafarers' fatigue. These include hours of rest regulations, 6 hours on and 6 hours off watchkeeping, sufficient manning, development of an efficient implementation of company/shipboard fatigue management plans, short-sea services and frequent port calls, long-contract terms, industrial gold standards for measuring fatigue, developing a multi-factor auditing tool, and overwork due to additional duties. All these factors are interrelated. Each of them is discussed below:

(a) Violations of Hours of Rest Regulations: The violation of the hours of rest regulations is the most dominant issue that is very pervasive, directly and indirectly, in the majority of the included maritime accident investigation reports instances reviewed. 80% of all the scenarios described in the included reports listed in Appendixes 2G, 2H, and 2I, directly and indirectly, violated the hours of rest regulations. This violation of the hours of rest regulation issue initiated

the bulk of the seafarers' fatigue causal factor that resulted in maritime accidents in most of the reports reviewed.

The *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978 as amended* regulate seafarers' work and rest hours (International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). The *STCW Convention's Standards Regarding Watchkeeping, Section A-VIII/1 fitness for duty* specified that the limits on hours of work or rest shall be as follows:

"(a)……a rest period of not less than:

(i)- a minimum of 10 hours of rest in any 24-hours period; and

(ii)- 77 hours in any 7 days.

(b) The hours of rest may be divided into no more than two periods, one of which shall be at least 6 hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours" (International Maritime Organisation (IMO), 2011, p 251-252).

Similarly, The *MLC (2006) Convention's regulation 2.3 standard A.2.3 hours of work and hours of rest, items 1 to 14* stipulates that the limits on hours of work or rest shall be as follows:

"a- maximum hours of work shall not exceed:

(i) 14 hours in any 24-hour period; and

(ii) 72 hours in any seven-day period;

or

(b) minimum hours of rest shall not be less than:

(i) ten hours in any 24-hour period; and

(ii) 77 hours in any seven-day period.

(c) Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours" (International Labour Organization (ILO), 2006, p.30).

However, numerous pieces of evidence from the various investigation reports reviewed indicated multitudes of instances where these two international regulations' hours of rest are violated. The minimum rest hours of 10 hours per day and 77 hours per week allow a maximum of working hours of 14 and 91 respectively; however, this is commonly violated in the existing maritime industry, as indicated in the numerous reports reviewed. Some reports indicated that instances of working more than the 14 hours maximum permissible time between rest periods were observed in the reports reviewed. This contravened the existing hours of rest requirements stipulated in both the *Maritime Labour Convention 2006* and the *Manila amendments to the STCW Convention and Code* that stipulated that 14 hours is the maximum permissible time between rest periods. However, numerous data inside the included reports indicated work of more than the limit of 14 hours maximum permissible time between rest periods. This instigated significant seafarers' fatigue (International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). This indicated the violation of these two existing regulations, hence, this confirmed their inadequacy. Moreover, the numerous unclearly defined clauses in the hours of rest regulations further complicated the seafarers' fatigue issues by subjecting seafarers to chronic seafarers' fatigue and its associated maritime accidents risks, including fatality in some extreme cases reviewed. These instances came from excessive working hours and inadequate periods of rest, thereby resulting in those seafarers' fatigue, and are causal factors that triggered those maritime accident occurrences.

One of the many circumstances among the included maritime accidents reports tabulated in Appendixes 2G, 2H, and 2I involving working over 14 hours maximum permissible time between rest periods is the collision between the bulk carrier *Huayang Endeavour* and the *Seafrontier* approximately 5NM west of Sandettie Bank, English Channel on 1st July 2017, reported in MAIB report number 7/2018 (Marine Accident Investigation Branch (MAIB), 2018). Some extracts from this report are below:

> *Seafrontier's master had been present on the bridge for over 14 hours and was probably suffering from fatigue, which was likely to have had an adverse effect on his decision making (p.1).*
>
> *…….Seafrontier's master had been on the bridge almost continuously since departure from Antwerp. Inspection of his hours of work record showed that, at the time of the accident, he had recorded over 14 hours of work without a break (p.10).*
>
> *Seafrontier's master was present on the bridge from the Antwerp departure until the time of the accident, a period of slightly more than 14 hours. The Manila Labour Convention 2006, as amended, states that 14 hours is the maximum permissible time between rest periods……. Therefore, Seafrontier's master was operating at the limit of his permitted working hours at the time of the accident, with the prospect of spending further time on the bridge before his vessel was clear of congested waters (p.11).*
>
> *It is considered very likely that a combination of fatigue and high mental loading would have affected Seafrontier's master's decision making and reaction times at the time of the accident (p.14).*

This event, among many other instances in appendixes in Appendixes 2G, 2H, and 2I, violated the existing international regulations for hours of rest requirements because of involving more than the stipulated 14 hours maximum permissible time of work between rest periods.

Also, many maritime accident examples in the included investigation reports in Appendixes 2G, 2H, and 2I indicated that daily hours of rest are under-recorded, not recorded, or forged by either management or by individual seafarers who are cautious of risking their current or future employment if they bring their company under legislative scrutiny. They contravened the requirements of *MLC 2006 Convention's regulation, standard A.2.3 hours of work and hours of rest, item 12* and the *STCW Convention's Standards Regarding Watchkeping, Section A-VIII/1 fitness for duty, item 7* (International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). An example of such maritime accidents with regulatory violation with evidence of no record of daily hours of rest onboard is MAIB Report number 3/2010.

Also, apart from this instance of no record of hours of rest, another report indicating evidence of falsification of the record of hours of rest is in MAIB Report number 18/2020. This is a report on the investigation of the fatal crash accident on the general cargo vessel, *Karina C,* in Seville, Spain, on 24 May 2019. Extracts from this report showing evidence of falsification of the record of hours of rest are below:

> *The 2/O's hours of rest records indicated that he had the mandated minimum 10 hours of rest in the 24 hours before he died. However, he was woken 3 hours into a rest period. This, coupled with the effect of alcohol in his bloodstream, increased the likelihood that the 2/O was tired, if not fatigued, when he arrived on deck. Therefore, tiredness and/or fatigue might also have influenced the 2/O's judgment and actions.*

> *Although the C/O had recorded 10.5 hours of rest in the 24 hours before the incident, he only had 4.5 hours in the 16 hours before the accident. While within the mandated minimum, it is possible the C/O might have been fatigued at the time of the accident, and this might have affected his judgment and failure to apply the correct safety procedures for the operation of the gantry crane (p.34).*
>
> *The 2/O's and C/O's actions might also have been influenced by tiredness or fatigue (p.37).*

Moreover, the findings of Smith et al. (2006) supported and stressed this evidence with its conclusion that the existing reporting systems in the maritime industry are inefficiently designed to record fatigue-related factors, including hours of rest, and that excessive working, under-recording, not recording or forging record of hours of rest are severe issues in the seafaring industry (Smith et al., 2006). Smith et al. (2006) also pointed out that seafarers' fatigue may be caused by a number of factors, including excessive workload, cumulative sleep debt problems because of poor sleep during the day, long working hours, lack of or poor quality sleep, prolonged work, and insufficient rest between work periods (Smith et al., 2006). In addition, the exigency of adequate seafarers' rest is one of the findings of the MARTHA project. It emphasized that night watch keepers are more vulnerable to falling asleep on duty, and that captains feel stressed and fatigued at the end of their tours of duty more than the rest of the crew. Therefore, the captain needs more recovery time than the rest of the crew (Barnett et al., 2017). These pieces of evidence verified regulatory violations of hours of rest regulations, which justified the inadequacy of the current regulations and strategies for managing and preventing seafarers' fatigue, including hours of rest regulations.

(b) 6 hours on and 6 hours off Watchkeeping: Another significant issue emerging from the review of various included maritime accident investigation reports of maritime accidents

having seafarers' fatigue as a causal factor is the 6 hours on and 6 hours off watchkeeping regime. Although the 6 hours on and 6 hours off watchkeeping system may not violate the existing international regulations, the *STCW Convention* and the *MLC (2006) Convention*, relevant to seafarers' fatigue, numerous pieces of evidence from the included reports showed that this watch system causes significantly seafarers' fatigue. This propensity of 6 and 6 watches to initiate seafarers' fatigue is because this watch system does not allow for the recommended 7-9 hours of uninterrupted sleep (International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). It commonly causes seafarers' fatigue, a causal factor in those maritime accidents of ships that used this 6 hours on and 6 hours off watchkeeping system. This 6 hours on and 6 hours off watchkeeping regime is notoriously known to cause seafarers' fatigue, because sleep can only be restorative if it should occur at continuously night for a period of at least 7, and up to 9 continuous hours (Hirshkowitz et al., 2015). However, this watchkeeping regime does not allow enough for this type of adequate sleep.

Past research findings on shift-scheduling practices for Bridge Officers indicated that the 6-on-hours and 6-off-hours watchkeeping schedule, compared with other watchkeeping schedules, causes less daily sleep, more recurrent episodes of micro-sleeps (nodding), more propensity for poor-quality fragmented sleep, and excessive sleepiness. This commonly happens during the early morning hours (Härmä et al., 2008; Lützhöft et al., 2010). Also, Smith et al. (2006) stressed that the 6 hours on and 6 hours off watchkeeping system issue in the maritime sector is a potential problem reflecting organisational factors, by showing the shipping company's management insensitivity to adopting a watch system that ensure adequate restorative rest for its seafarers (Smith et al., 2006). Furthermore, the Marine Accident Investigation Branch (MAIB) (2004) supported this review's findings by indicating that a large number of maritime accidents occur

with only two watchkeepers on the 6-on and 6-off watch system in most cases (Marine Accident Investigation Branch (MAIB), 2004).

An example of included reports with this scenario having seafarers' fatigue as a causal factor is TSBC Marine Investigation Report number M16P0378, involving the grounding and subsequent sinking of an articulated tug-barge Tug *Nathan E. Stewart* and tank barge *DBL 55* in Seaforth channel, 10 NM west of Bella Bella, British Columbia, on 13th October 2016 (Transportation Safety Board of Canada (TSBC), 2018). Various extracts from this report are below:

> *Further, the daily hours of rest are to be divided into no more than 2 periods, one of which is at least 6 hours in length, and the interval between 2 consecutive rest periods must not exceed 14 hours. The shift-scheduling practices of the Nathan E. Stewart were in accordance with the applicable MPR provisions (p.19).*
>
> *The shift-scheduling practice on board the Nathan E. Stewart was to assign watch duties while the tug was at sea according to a shift schedule where an individual would work for 4 consecutive hours and would then be off duty for 8 hours (i.e., a 4-on, 8-off schedule). When the tug was in port (and for the 12-hour period before and after arriving in, and departing from, port), the shift schedule would change to a 6-on, 6-off schedule, to allow the crew to perform additional duties such as voyage planning and unloading cargo. Each crew member's shifts typically ended at the same time of day (p.20).*
>
> *In this occurrence, the grounding took place in the early morning hours of 13 October. The crew had been working a 6-on and 6-off shift schedule from 10 October until the morning of 12 October, while the tug was in port; it left port on 11 October at approximately 2230 (p.20).*

Part of this report's conclusion stated that:

The second mate, who was working alone on the bridge, was fatigued. The second mate fell asleep and did not make the planned course alteration, and the articulated tug-barge struck and grounded on a reef (p.53).

If a 6-on, 6-off shift schedule is used without fatigue-mitigating measures, there is a risk that crew members will be impaired by fatigue while on duty (p.53).

This extract indicated that the 6-on, 6-off shift-scheduling practices of the Nathan E. Stewart were in accordance with the applicable Marine Personnel Regulations (MPR) provisions. This shows the complicated inefficient nature of the Canadian MPR. This will be analyzed thoroughly in chapter four of this overall review.

Apart from the instance above, other maritime accident reports in Appendixes 2G, 2H, and 2I, showing evidence of the 6-on-hours and 6-off-hours regime's ineffectiveness in the international and Canadian maritime sectors are MAIB report number 14/2006, MAIB report number 23/2005, MAIB report number 16/2007, MAIB report number 8/2014, MAIB report number 8/2016, and ATSB MOI 265. All this evidence further demonstrates the inadequacy of the existing regulations and strategies for managing seafarers' fatigue in the international maritime sector, including Canada.

(c) Insufficient Manning: Another predominant issue emerging from the review of various included maritime accident investigation reports having seafarers' fatigue as a causal factor of their maritime accidents, is inadequate manning. The *MLC (2006) regulation 2.7 on manning levels* requirement stipulates adequate manning of seafarers working on board ship, to ensure the safe, effective, and secure operation of the ship (International Labour Organization (ILO), 2006). Similarly, the *IMO's assembly 27th session agenda item 9 in its resolution A.1047(27) on the*

Principles of Minimum Safe Manning, adopted on 30th November 2011 specified all requirements for adequate manning and also stressed compliance with all the SOLAS regulations regarding adequate manning (International Maritime Organization (IMO), 2011). However, there are many pieces of evidence in the various included reports regarding ineffective manning of officers' watchkeeping on board ships, thereby causing seafarers' fatigue which was a causal factor of those maritime accidents. Some maritime industries complicated this issue by reducing the required two officers' watchkeeping at the same time, and they did not equate the workload on board the ship with the manning level, or manned with officers with inadequate training. These acts compromised the safety, effectiveness, and secure operation of the ship as specified by the IMO's principle of safe manning. Those maritime industries practised these risky acts because they wanted to reduce manning costs at the expense of safety, thereby increasing the propensity level of seafarers to fatigue.

The IMO's principle of safe manning stipulates that the vessel must be adequately manned and manned with officers with adequate training. Insufficient manning is a pervasive issue currently plaguing seafarers in the maritime industry, as confirmed by the majority of the included maritime accident investigation reports in Appendixes 2G, 2H, and 2I. A few instances, among them, are described in this section.

One of these instances indicating evidence of undermanning issues in the international maritime sector, is TSBC Marine Investigation Report number M13L0123. This is a report on the collision between the bulk carrier *Heloise* and Tug *Ocean Georgie Bain* in the Port of Montreal, Quebec, on 3rd August 2013 (Transportation Safety Board of Canada (TSBC), 2014). Extracts from this report are below:

The safe manning document of the Ocean Georgie Bain authorized the tug to operate without a third person when the operating conditions are judged by the master and the authorized representative to be safe for the "vessel, crew and environment". To address the feasibility and safety of navigating with only 2 persons on board under different operating conditions, the company of the Ocean Georgie Bain completed a risk assessment in 2012 to identify the involved risks and some mitigating strategies to manage those risks. The risk assessment emphasizes the importance of maintaining visual and verbal (including through very high frequency [VHF] radio) contact with the second person on board under challenging navigating conditions in order to maintain awareness and ensure the overall safety of navigation.

Furthermore, although the company's assessment of the adequacy of manning acknowledged some deficiencies with regard to familiarization and training, the engineer in this occurrence was certified. Although the engineer had received familiarization for the vessel, he was not aware of his specific duties on board, such as that of acting as a lookout, when required to be part of the bridge watch. Thus, when he spotted the Heloise, he did not report this to the master.

In a 2-person operation, when a member of the bridge watch is required to leave the bridge for a certain reason, such as checking the engine room, the master is left alone. In that situation, the master assumes all of the responsibilities of the bridge watch and has an increased workload that may preclude him from identifying safety-critical situations in a timely manner.

Therefore, if companies and vessel masters do not accurately interpret and apply the requirements of a safe manning document, it is possible that a vessel will be inadequately manned and/or manned by crew with inadequate training (p.17).

Part of this report's conclusions indicated that:

The pilot on the Heloise was not monitoring the Ocean Georgie Bain at the time of the collision, and the bridge crew on the Heloise was not assisting the pilot by maintaining a lookout or using navigational equipment to advise the pilot of relevant traffic (p.18).

"If companies and vessel masters do not accurately interpret and apply the requirements of a safe manning document, it is possible that a vessel will be inadequately manned and/or manned by crew with inadequate training (p.18).

This instance above is a good undermanning scenario that vividly describes the inadequacy of the two officers' watchkeeping system. Other maritime accident reports in Appendixes 2G, 2H, and 2I with evidence of undermanning issues include MAIB report number 3/1998, MAIB report number 2/1999, MAIB report number 5/1999, MAIB report number 8/2001, MAIB report number 27/2003, MAIB report number 11/2004, MAIB report number 8/2014, TSBC report number M04L0099, and NTSB/MAB-17/14_ DCA16FM033. All of them provide practical evidence that confirms that the existing international manning regulatory requirements that stipulate two officers' watchkeeping system is inadequate in the international and Canadian maritime sectors. Safe manning level regulatory requirements are among the critical regulations and strategies for managing and preventing seafarers' fatigue in the maritime sector.

Moreover, Smith et al. (2006) emphasized that the insufficient manning issue in the maritime sector is a potential problem reflecting organisational factors (Smith et al., 2006). The MAIB (2004) reports findings confirmed this review's findings in its conclusion that stated that

watchkeeper's insufficient manning levels are one of the causal factors in collisions and groundings. It stressed that ships over 500gt should have a least a master and two bridge watchkeeping officers on board (Marine Accident Investigation Branch (MAIB), 2004).

These various pieces of evidence above have proved that the existing international regulations and strategies, including those for ensuring sufficient manning levels in the international and Canadian sectors, are inadequate.

(d) Ineffective or Lack of Implementation of Company/Shipboard Fatigue Management Plans (FMP):

Similarly, another significant issue emerging from the review of various included maritime accident investigation reports of maritime accidents having seafarers' fatigue as a causal factor is the inefficient implementation or lack of company/shipboard fatigue management plans. Numerous pieces of evidence for this are in many included reports in Appendixes 2G, 2H, and 2I.

An instance of lack of implementation of company/shipboard fatigue risk management plans is TSBC report number M16P0378 involving the grounding and subsequent sinking of an articulated tug-bargeTug *Nathan E. Stewart* and tank barge *DBL 55* in Seaforth channel, 10 NM west of Bella Bella, British Columbia, on 13th October 2016 (Transportation Safety Board of Canada (TSBC), 2018). Various extracts from this report regarding this issue are below:

> *There is currently no requirement for marine companies to develop or implement FMPs or provide fatigue awareness training. Kirby did not have an FMP at the time of the occurrence, nor was it required to by regulation. The master, first mate, and second mate had not undergone training on fatigue awareness, fatigue management, or alertness strategies, nor were they required to have done so by regulation (p.25).*

In this occurrence, the company that owned the Nathan E. Stewart did not provide training to the crew on fatigue awareness and/or management (including mitigation strategies), and none of the crew on board the Nathan E. Stewart had undergone fatigue awareness training prior to working for the owners of the tug. As a result, the symptoms of fatigue in the second mate were not identified, prevented, or mitigated, leading to the second mate's falling asleep while on bridge watch (p.48).

Although hours of work and rest requirements represent a layer of defence, they are not a guarantee that mariners will obtain adequate sleep. More is needed to effectively and reliably prevent fatigue among mariners. A fatigue management plan is a means of establishing more than minimum hours of rest and can address fatigue awareness training, the use of alertness strategies, and fatigue-reporting mechanisms to monitor actual levels of operational fatigue. Shared night shifts, longer and more frequent breaks, increased use of the 4-on, 8-off shift schedule, and a limit of 9 working hours a day have also been proposed.

The United States Coast Guard has developed, and promotes deployment of, the Crew Endurance Management System for managing the risk factors that can lead to human error and performance degradation in maritime work environments. In Canada, the development of fatigue management plans is required in the rail industry but not in the marine industry, nor is there any requirement for fatigue-related training (p.49).

Part of this report's conclusions is that:

If there is no requirement for crews to receive fatigue awareness or -management training, there is a continued risk that fatigue will not be identified, prevented, or mitigated (p.54).

This report shows evidence of no development of a Fatigue Management Plan (FMP) in the international and Canadian maritime sectors. The report went further described the critiality of implementing FMP in the international and Canadian maritime sectors, that it is a is a means of ensuring more than minimum hours of rest and can address the use of alertness strategies, fatigue awareness training, and fatigue-reporting mechanisms to monitor actual levels of operational fatigue.

Another piece of evidence of an ineffective implementation of FMP is in the TSBC Marine Investigation Report number M14C0219, involving the Bottom contact of Tanker Nanny on Deer Island, Chesterfield Inlet (Nunavut) on 14th October 2014 (Transportation Safety Board of Canada., 2016). Some extracts from this report regarding this ineffective FMP issue are below:

> *Preventing fatigue in the workplace requires that workers be provided with adequate rest periods between work shifts during which they are able to obtain sufficient sleep. Employers and employees must also be cognizant of the risks of fatigue to the extent that they manage their own sleep and rest effectively. This is of particular importance for those whose duties can have an impact on the personal safety of themselves or others. As a basis for ensuring that seafarers get sufficient sleep, international standards exist to establish minimum hours of rest (off-duty hours) for seafarers. This is the regulatory means by which the risks of fatigue are addressed in the marine industry.*
>
> *The Nanny did not have a separate fatigue management plan (FMP), apart from the measures addressing fatigue included in the safety management system (SMS). However, the investigation found the following shortcomings with these measures:*
>
> *• Although crew hours of rest and work were recorded, no one ashore or on the vessel was monitoring these records for compliance with the SMS and regulations; there were*

numerous instances where the crew had worked extra hours and had not received the minimum prescribed hours of rest. A further examination of the crew members' rest periods from the previous grounding of the Nanny in Chesterfield Inlet in 2012 indicated a similar situation where minimum hours of rest were not being respected at all times.

• An instructional safety video on fatigue was on board; it had been provided by the company, but at the time of the occurrence, the crew had not watched it (p.24).

Part of this report's conclusion is that:

Ineffective fatigue management on board the vessel contributed to the master and helmsman being fatigued while on duty (p.29)

Apart from these above two instances, other examples of no or inefficient FMP are documented in TSBC report number M12N0017, TSBC report number M07L0158, and ATSB MOI 274. Moreover, the MARTHA project stressed that the simple operational resolution which ensures sleep is easier for seafarers onboard is fatigue risk management, involving the seafarers and agencies ashore which affect shipboard operations (Barnett et al., 2017). Smith et al. (2006) recommended efficient fatigue awareness and fatigue management training and information campaigns (Smith et al., 2006).

This is another proof indicating the inadequacy of the existing regulation and strategies for managing and preventing seafarers' fatigue in the international and Canadian maritime sectors they lack provisions for FMP.

(e) Short-Sea Services and Frequent Port Calls: Another severe issue that plagues seafarers with a high workload and fatigue in the maritime industry by causing seafarers' fatigue are maritime operations is short-sea services and frequent port call operations. Many included investigation reports of maritime accidents having seafarers' fatigue as a causal factor contain

evidence of seafarers' fatigue emanating from maritime operations involving short-sea services and frequent port calls. This breached the *MLC (2006) regulation 2.3 standard A2.3 item 4,* which stipulated that:

> *In determining the national standards, each Member shall take account of the danger posed by the fatigue of seafarers, especially those whose duties involve navigational safety and the safe and secure operation of the ship (International Labour Organization (ILO), 2006, p.30).*

Evidence of such instances among the various included reports are TSBC Report number M07L0158; MAIB Report number 7/2009; MAIB Report number 24/2012.

The TSBC Report number M07L0158 involves the striking of the passenger vessel *Nordik Express* at Entrée Island, Harrington Harbour, Quebec, 16th August 2007 (Transportation Safety Board of Canada (TSBC), 2010). Extracts from this report are below:

> *However, split rest periods provide several challenges to obtaining restorative sleep. Should one of the periods occur during the crew members' normal "daytime" period, it would be less restorative. Moreover, breaking a rest period into a number of sections can result in increased sleepiness and decreased performance. A more general challenge to obtaining sleep across short rest periods is the risk that meals, personal chores, and unscheduled interruptions may prevent the crew member from obtaining the required amount of sleep in the time available. In addition, when schedules are changed, for instance from four/eight hours to six/six hours, there is an accommodation period in which an individual is likely to be fatigued until he or she adjusts to the new schedule (p.15).*
>
> *The 2/O and 3/O (the OOW at the time of the occurrence), for example, worked a four on/eight off schedule followed by a six/six schedule, whereas the 1/O and master followed*

a more irregular schedule that was determined by the vessel's arrivals and departures. Although both these schedules can allow sufficient opportunities for restorative sleep, this requires proper management: individuals require an acclimatization period to adjust to any new schedule and splitting rest periods into multiple periods throughout a day can reduce the quantity and quality of sleep (p.24).

The deck watch system aboard the Nordik Express, however, changed frequently, from a four/eight schedule for the first few days, to a six/six schedule and then back again. This constant changeover pattern would have made proper acclimatization more difficult. In the case of six/six schedules, studies have demonstrated that it is even harder to ensure enough restorative rest because there are fewer opportunities to compensate. Some operators, aware of the difficulties associated with this schedule, have modified the watch system on their vessels.

Moreover, rest periods would likely have been interrupted every time the vessel made port; for some sections of the voyage, stops would have been frequent. Changes in engine sounds, movements around the crew quarters, and changes to the movement of the vessel would likely have had an effect on the possibility of quality sleep, in addition to those duties required for loading and unloading. More specifically, both the master and the 1/O were required to be present at every stop and, during his familiarization week, the 3/O's rest was broken at every port.

The more generic challenges to obtaining sufficient sleep include the time required to hand over watches, time required for meals and personal hygiene, and time required for ad hoc duties in addition to the normal watch schedule. Additional factors such as stress, poor health, and a noisy environment also have an impact. Although all of these can be dealt

with under a proper fatigue management plan, no evidence of one was found on the Nordik Express.

The investigation identified indications of fatigue in crew members as well as behaviours likely to lead to fatigue. Moreover, the vessel's schedule was adapted to meet the company's business—frequent, rapid port turnarounds—but the effect on crew performance was not mitigated by a fatigue management plan. This increased the probability of fatigue and thus fatigue-induced errors by the bridge crew—thereby increasing the risk to vessel, crew, passengers, and the environment (p.25).

Part of this report's conclusions is that:

In the absence of a fatigue management plan, the probability of fatigue-induced errors increases, thereby increasing the risk to vessels, crew, passengers, and the environment In the absence of a fatigue management plan, the probability of fatigue-induced errors increases, thereby increasing the risk to vessels, crew, passengers, and the environment (p.29).

The absence of an effective safety management system increases the risk that unsafe conditions and practices will remain unidentified and unaddressed (p.30).

This instance is a vivid description of how short-sea services and frequent port calls can have severe fatigue consequences on the seafarers. Moreover, Smith et al. (2006) confirmed the evidence by indicating that more frequent port calls were associated with increased fatigue among those on shorter contracts, while there is less fatigue among those on longer tours. These disparities would appear to reflect ship type (Smith et al., 2006). Smith et al. (2006) indicated that mini bulkers on short-sea services and frequent port calls may be the worst-case scenario regarding a ship environment conducive to vulnerability to associated seafarers' fatigue. Mini bulkers are

small vessels with a capacity of under 10,000 DWT (Smith et al., 2006). The negative factors on this ship type that increase seafarers' workload include changing cargos, short port stays, frequent port turnarounds, only two watchkeepers (in many cases), and long periods of pilotage (Smith et al., 2006).

All the evidence shows how seafarers on ships operating on short-sea services and frequent port calls can have serious fatigue consequences when coupled with a high workload. All these proofs demonstrate the inadequacy of the existing international regulations and strategies for managing and preventing seafarers' fatigue in the international and Canadian maritime sectors.

(f) Absence of a Maritime Industry's Gold Standard Measure of Seafarers' Fatigue: The absence of a gold standard for measuring seafarers' fatigue biased the maritime accident investigators' assessment. This is because seafarers' fatigue is difficult to measure and it cannot be proven. Many of these assessments were observed in the various eligible but not included reports. An instance of a report with circumstances that described this issue is *Scot Explorer* and *Dorthe Dalsoe* reported in 2004 (Marine Accident Investigation Branch (MAIB), 2005). Part of this report's conclusive findings stated that:

> *Although the quantity of sleep achieved by the skipper of Dorthe Dalsoe was insufficient, and its quality was poor, it is difficult to determine the extent to which the effects of fatigue might have influenced his decision-making. There is no evidence to indicate that the performance of the master of Scot Explorer was affected by fatigue (p.25).*

The extract from this report shows an indication of fatigue by ascertaining evidence of insufficient and poor-quality sleep. Since the extent of fatigue cannot be measured, its presence cannot be proven. The report indicated in its conclusions that there is no evidence indicating that the performance of the master of *Scot Explorer* was affected by fatigue. Smith et al. (2006)

emphasized the cruciality of establishing a maritime industry's gold standard measure of seafarers' fatigue, to enable the confirmation of its presence as a causal factor of maritime accidents (Smith et al., 2006).

Another eligible but not included report that indicated evidence of this underreporting of fatigue because it can not be measured and proven is the collision between Arctic Ocean and Maritime Lady in the capsizing of the Maritime Lady and contact with the wreck of Maritime Lady by Sunny Blossom and its subsequent grounding in the Elbe River in 5th December 2005 (Maritime Accident Investigation Branch, 2005). The report concluded that:

> *By the time Maritime Lady was approaching Brunsbüttel, her master was undoubtedly feeling tired from his 5 hours on the bridge. While not classifying his state as being seriously fatigued, his tiredness might have been sufficient to have resulted in poor judgment and decision-making (p.37).*

Smith et al. (2006) stressed that the absence of a gold standard for measuring fatigue currently makes the tasks of comparing and assessing seafarers' fatigue levels difficult. This also makes comparison and assessing the impact of research results extremely complicated. Numerous practical pieces of evidence of this were described in the investigators' reluctance of reporting fatigue because it cannot be measured and proven. This demonstrates the importance of implementing the use of a gold standard of fatigue measure as the maritime industry's standard, or coming up with a new fatigue measure scale for research and industrial purposes to enhance managing and preventing seafarers' fatigue (Smith et al., 2006). Examples of reports with instance pointing absence of a gold standard for measuring fatigue among numerous eligible but not included reports are Accident Investigation Report 10/2005, ATSB MAIR number 151, and MAIB Accident Investigation Report 23/2009.

(g) Absence of a Multi-factor Auditing Tool. The absence of a multi-factor seafarers' fatigue auditing tool in the maritime industry to measure the various multi-factors and interrelated seafarers' fatigue causal factors, that hinders the assessment of seafarers' fatigue precisely and accurately. This absence of a multi-factor seafarers' fatigue auditing tool often causes the investigators' information reporting bias because seafarers' fatigue is difficult to measure because there was no evidence to prove and show that seafarers' fatigue was a causal factor of those maritime accidents. Smith et al. (2006) emphasized that seafarers' fatigue causal multi-factors most often occur as a combination of different interrelated causal factors, hence, a multifactor auditing tool is needed to precisely and accurately measure them. This emphazised the cruciality of reliable auditing systems, without which the success of any change, in the existing seafarers' fatigue and associated maritime accidents issues, will be impossible to evaluate. Therefore, a taxonomic or checklisting-style of auditing tool is required to be created, that can precisely and accurately measure the combination of not only those work factors known to be causal factors of fatigue but also those known from a subjective experience of these factors (Smith et al., 2006).

Example of a maritime accident with such instance that demonstrates the need for a multi-factor seafarers' fatigue auditing tool is the maritime accident involving Scot Explorer and Dorthe Dalsoe reported in 2004 (Marine Accident Investigation Branch (MAIB), 2005) and the maritime accident involving the collision between *Arctic Ocean* and *Maritime Lady* in the capsizing of the *Maritime Lady* and contact with the wreck of *Maritime Lady*, by *Sunny Blossom* and its subsequent grounding in the Elbe River in 5th December 2005 (Maritime Accident Investigation Branch, 2005). Other maritime accidents of such instances among numerous eligible but not included reports are Accident Investigation Report 10/2005, ATSB MAIR number 151, and MAIB Accident Investigation Report 23/2009.

2.4 Review Implications for Research, Policy, and Practice

More research in this direction toward regulatory amendment is crucial. All the above findings emphasized the inadequacy of the existing international regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector, including Canada, hence necessitating their amendment. Therefore, ensuring the adequacy of these seafarers' fatigue regulations is crucial for advancing maritime safety, and sustainability of the seafaring professional practice and shipping sector generally.

Apart from the determination of the adequacy of the existing international regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector from the various pieces of evidence in the reviewed maritime accidents investigation reports, it is necessary to critically analyze these existing international regulations. This will enable the gathering of more evidence for ascertaining their regulatory sufficiency of managing and preventing seafarers' fatigue. This is the essence of conducting the next review. This is done by subjecting these existing international regulations and strategies to critical analytical review, to gather more evidence concerning the confirmation of their adequacy. This will enable proving or disproving their sufficiency in managing and preventing seafarers' fatigue in the international and Canadian sectors.

CHAPTER THREE:

CRITICAL ANALYSIS OF THE ADEQUACY OF THE EXISTING INTERNATIONAL REGULATIONS AND STRATEGIES FOR MANAGING AND PREVENTING SEAFARERS' FATIGUE

3.1 Review Introduction

Smith (2007) stated that seafarers' fatigue legislation and guidance have failed because they have not been comprehensively reviewed for evaluating their adequacy in the past. The task of this review is to correct that inaction by comprehensively reviewing them to ascertain their adequacy (Smith, 2007). This third review particularly involves a critical analysis of the regulatory adequacy of the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)* (International Convention and Code on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 2011) and *Maritime Labour Convention (MLC), 2006* (International Labour Organization (ILO), 2006). The purpose of this is to ensure their suitability for managing and preventing seafarers' fatigue in the international maritime sectors. The evidence from this review will provide further answers for answering the overall review question and objectives.

3.2 Review Objective

The objective of exploring this source of evidence is to conduct a critical analysis of the adequacy of the existing international regulations and strategies for managing seafarers' fatigue in the global maritime sector. These include the *STCW* and the *MLC 2006* (International Labor Organization (ILO), 2006; International Maritime Organization (IMO), 2011) among others relevant international strategies and regulations, for managing seafarers' fatigue in the global maritime sector, for answering the overall review question, objective, and topic.

3.3 Critical Analysis of the Adequacy of the Existing International Regulations and Strategies for Managing and Preventing Seafarers' Fatigue

Many past studies indicated that despite differences in the degree of compliance with the various regulations and policies guiding fatigue issues in the maritime industry, fatigue remains a significant issue across the maritime industry (Shan & Neis, 2019; Zhang et al., 2020; Zhao et al., 2020). Also, previous literature studies pointed out the need for strong and visible fatigue prevention and controlling regulatory enforcement measures. All findings in chapters one and two confirmed this imperative need. Past literature studies showed that the determinants of seafarers' fatigue are influenced by the regulatory contexts in which the shipping companies operate (Reza Emad & Rajapakse, 2021; Zhang et al., 2020; Zhao et al., 2020). The evidence of these determinants and influences on seafarers' fatigue is described in chapter two. Moreover, despite seafarers' key contribution to the global economy via the maritime sector, seafarers' fatigue issues have not been given adequate attention in the maritime world. Past literature studies indicated that *MLC 2006* has significantly contributed to the advancement of living and working conditions of seafarers; yet, one limitation of *MLC 2006* is that seafarers' welfare is still compromised in many aspects, including stresses, fatigue, and social isolation (Exarchopoulos et al., 2018).

The *MLC 2006* has been tagged as the Seafarers' Bill of Rights. However, the maritime industry professionals declared that this Convection is not only inadequate to advance seafarers' welfare, including preventing and managing seafarers' fatigue, but also that it cannot even address seafarers' issues pertinent to the seafarers' labour rights, such as the fair treatment of seafarers in the event of a maritime accident and high workload. Hence, this necessitates crucial extensive amendment of the *MLC 2006 Convention* to address these limitations, particularly when mental fatigue and other health issues are more cause of concern in the maritime industry (Exarchopoulos

et al., 2018). Many scenarios describing these issues are in the various reviewed maritime accident investigation reports in Appendixes 2G, 2H, and 2I, showing evidence of stress, excessively high workload, and extreme seafarers' fatigue among the seafarers from all nations reviewed in this overall project, as descriptively shown in Chapter Two.

The *STCW Convention 2010, Manila Amendments*, and *MLC 2006* address fatigue issues by imposing specific requirements concerning seafarers' minimum hours of rest (Exarchopoulos et al., 2018). The hours of work and rest limits, and other requirements stipulated in the ILO's MLC 2006 and the IMO's STCW, are regarded as key fatigue risk management requirements. These set minimum compliance standards in the international shipping industry (Grech, 2016). Yet, the 2014 Concentrated Inspection Campaign (CIC) report on STCW's 'Hours of Rest' by the Paris Memorandum of Understanding (MoU) Port State Control Committee declared a general lack of STCW's hour of rest compliance in the maritime industry (Paris MoU PSC Committee, 2014). This is practical proof that further confirmed this pervasive violation of the hours of rest in the existing maritime industry, shown in chapter two and listed in Appendixes 2G, 2H, and 2I.

The *MLC 2006* echoed seafarers' minimum rest hours stipulated in the STCW. However, seafarers have not seen any significant impact due to those *MLC 2006* limitations, including in seafarers' welfare aspects, such as stress, fatigue, and social isolation. This results in crews mostly being unable to meet their mandatory hours of rest set in these acts due to their inadequacy and discrepancies (Exarchopoulos et al., 2018). Although the IMO has amended the *STCW Convention, Section A-VIII/1 fitness for duty* and *MLC (2006) Convention's regulation 2.3 standard A.2.3 hours of work and hours of rest* requirement to enable seafarers to have increased rest periods through its recent STCW Manila Amendments in line with the ILO's *MLC 2006*,

issues and discrepancies are still being experienced (International Convention and Code on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 2011).

One discrepancy is the fact that even though both regulations stipulate 77 hours minimum rest in any seven days, which leads to 91 hours of maximum work per any 7-days period. The MLC stipulates an optional 72 hours of maximum hours of work in any 7-day period. To be able to fully comply with **both** STCW and MLC and prevent the liability of false record-keeping, one only needs to comply with the hours of rest. This is a major inconsistency in the existing international regulations for managing and preventing seafarers' fatigue, as it creates confusion and violations by the maritime industries. This fact proves the inadequacy of the existing regulations for managing and preventing seafarers' fatigue in the international maritime sector. Hence, both regulations need to be harmonized with amendments, for the safety of the maritime sector, globally. Table 3.1 shows the discrepancies in the international regulations for seafarers' hours of work and rest.

Table 3.1 Inconsistency in the International Regulations for Seafarers' Hours of Work and Rest

Convention	Minimum Rest	Maximum work	Work hours Allowed in 7 Days period
*MLC 2006	10 hours / 24 hours		
	77 hours / 7 days		91 hours Max.
		14 hours / 24 hours	
		72 hours / 7 days	72 hours Max.
**STCW	10 hours / 24 hours		
	77 hours / 7 days		91 hours Max.

*See Regulation 2.3 of the Maritime Labour Convention 2006 (Maritime Labour Convention, 2006). **International Convention on Standards of Training Certification and Watchkeeping for Seafarers 1978, as amended (International Maritime Organization (IMO), 2011).

In addition, there is also another issue regarding the master's overriding authority. The *STCW Section A-VIII/1 paragraph 8* states that

> *Nothing shall be deemed to impair the right of the Master to require a seafarer to perform any hours of work necessary for the immediate safety of the ship, persons on board or cargo, or for the purpose of giving assistance to other ships or persons in distress at sea. Accordingly, the master may suspend the schedule of hours of rest and require a seafarer to perform any hours of work necessary until the normal situation has been restored. As soon as practicable after the normal situation has been restored, the master shall ensure that any seafarers who have performed work in a scheduled rest period are provided with an adequate period of rest" (International Maritime Organization (IMO), 2011, p251).*

Clearly, whenever a Master is using such an authority, appropriate documentation regarding this should be made in the ship's logbook to prevent future consequences during an inspection of rest hours. However, this condition is not stated clearly. There is also no direction as to what should follow next, including required reporting, rest, and follow-up.

However, the findings of Smith et al. (2006) pointed out that the existing reporting systems are insufficiently designed to record factors relevant to fatigue. This article stated that excessive working hours that contribute to seafarers' fatigue are often hidden through falsified fatigue audit records and under-recording or no record of hours of rest (Smith et al., 2006). Those who under-recorded their working hours were also found to report more fatigue, which proved these hours of rest record's falsification and under-recording (Smith et al., 2006; Smith, 2015). The MARTHA Project recommended the introduction of Fatigue Risk Management Systems, being used successfully in other transportation sectors, as an integrated systems approach to managing and preventing seafarers' fatigue in the international maritime sector (Barnett et al., 2017). However, the STCW and the MLC (2006) do not contain provisional requirements for Fatigue Risk Management Systems. Therefore, the STCW and the MLC (2006) are inadequate, as they are not

sufficiently effective in their relevant areas. Various pieces of evidence for this are shown in chapter two and listed in Appendixes 2G, 2H, and 2I. All these proved the inadequacy of the existing regulations in managing and preventing seafarers' fatigue in the international maritime sector.

Furthermore, the MARTHA project's results showed that long tours of duty of more than six months cause reduced motivation, increase sleepiness (insomnia), and loss of sleep quality. The MARTHA project emphasized that fatigue and stress increase as the navigation length increases (Barnett et al., 2017). This results in crews mostly being unable to meet their mandatory hours of rest set by the STCW and MLC (2006) regulatory requirements (Exarchopoulos et al., 2018). However, according to the ITF Employment Agreement, a seafarer can be employed continuously for six months, which may be increased to seven months or decreased to five months for operational convenience. But the MLC (2006) still permits long tours of duty of 12 months maximum, which is twice the 6-month period tested and suggested by the MARTHA project. This caused increased vulnerability to fatigue among global seafarers; 12 months is twice as long as the 6 months recommended by the MARTHA project (Exarchopoulos et al., 2018; Barnett et al., 2017). This situation was exacerbated during the Covid-19 period, when myriads of global seafarers were trapped on board due to Port State restrictions on crew change (De Beukelaer, 2021; Lucas et al., 2021; Yazır et al., 2020). All these substantiated the insufficiency of the *STCW* and *MLC (2006)* regulations in managing and preventing seafarers' fatigue in the international maritime sector, hence necessitating their amendment to ascertain their adequacy in their relevant areas.

These seafarers' fatigue issues demonstrate the necessity of amendment of the STCW and the MLC (2006) requirements on the Fatigue Risk Management System, and include issues due to

long tours of duty, which must decrease from a maximum of twelve months to six or fewer months. Determining how long the seafarers have been working is vital for the assessment of how safe and adequate the current operating regulatory requirements for the management and prevention seafarers' fatigue regulations are. The existing method for recording and auditing working hours of rest and work is not efficient, and hence, should be amended (Exarchopoulos et al., 2018; Smith et al., 2006). These various concerns necessitate regulatory amendments of these STCW and MLC (2006) requirements to ensure their sufficiency in doing these tasks.

The various seafarers' fatigue issues include violations of hours of rest, 6 hours on and 6 hours off watchkeeping issues, insufficient manning (under-manning), overwork due to additional duties, inefficient, or lack of development and implementation, of company/shipboard fatigue risk management plans, short-sea services and frequent port calls issues, absence of an industry-standard measure of fatigue, industrial standards for measuring fatigue, and development of a multi-factor auditing tool (Exarchopoulos et al., 2018; Smith et al., 2006). STCW and MLC (2006) requirements have not been adequate in handling all these issues, hence necessitating their amendment.

Moreover, though MLC 2006 declares that seafarers shall be granted shore leave, this is often an impracticable and unachievable target in the existing maritime industry due to the fast turnarounds at ports with the additional workload for seafarers, as shown practically in some instances referenced in chapter two. In addition, the restriction imposed by the International Ship and Port Facility Security (ISPS) Code often makes shore leave impossible, particularly for certain crew nationalities. This is another reason that makes it imperative that the contract length of seafarers be reduced; maritime firms will not stop ports' cargo operations by encouraging seafarers' shore leave (Exarchopoulos et al., 2018). Smith et al. (2006) emphasized that fatigue

can be handled at three levels, including regulation, company policy, and personal awareness/management. This article stated that success can only be achieved if all these three levels are cooperatively involved; however these are not stipulated in STCW and MLC (2006). These further point to the STCW and MLC (2006) inadequacies, hence, necessitating their amendment.

Moreover, one of the key seafarers' fatigue management and prevention strategies used by the IMO is the 2019 'Guidelines on Fatigue' which elaborated seafarers' fatigue into disparate parts and various areas of responsibilities onboard. However, this document overemphasizes the seafarers' responsibility to manage fatigue without recognizing some critical operational factors, including the manning level over which seafarers have little or no control. This highlighted the inadequacy of this strategy for managing seafarers' fatigue in the international maritime sector and hence necessitates its amendment (International Maritime Organization (IMO), 2019; Smith et al., 2006). Table 3.2 shows the various international regulations and strategies for managing and preventing seafarers' fatigue. However, many of the crucial inherent inadequacies and inconsistencies of these international regulations and strategies discussed in this review still revealed their inadequacies, and hence necessitate their imperative amendments.

Table 3.2 Various International Regulations and Strategies for Managing and Preventing Seafarers' Fatigue.

International Conventions	International Guidelines
Maritime Labour Convention, 2006 (International Labour Organization (ILO), 2006), STCW Convention and Code 2010 Manila Amendments (International Convention and Code on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 2011)	Fatigue Factors in Manning and Safety (A18/Res. 772) (1993) Guidance on Fatigue Mitigation and Management (MSC/Circ.1014) (2001) (International Maritime Organization (IMO), 2001) Guidelines on Fatigue (MSC.1 Circ. 1598) (2019) (International Maritime Organization (IMO), 2019)

The continual revision of existing seafarers' fatigue regulation and strategies is paramount to significantly lessen the various unfair treatment and exploitations of seafarers, including fatigue issues (Exarchopoulos et al., 2018). Numerous pieces of evidence showing practical field instances of various forms of this were described in chapter two. Smith (2007) pointed out that past attempts to prevent or manage seafarers' fatigue by legislation and guidance have failed because there has been little attempt to assess their adequacy. Many previous reviews on seafarers' fatigue issues and legislation are based on relatively small sample sizes, which made the 'power' of these studies low. Poor seafarers' fatigue regulation is unquestionably a causal factor causing seafarers' fatigue (Smith, 2007). This is one of the reasons for executing the current fact-finding evidence-based study to determine the current adequacy or inadequacy of the existing regulations for managing and preventing seafarers' fatigue.

The IMO Guidelines on Fatigue is a strategy to elaborate on fatigue risk factors but this cannot replace specific and implementable recommendations. This is because the focus on responsibility for fatigue management requirements is required to change from personal to operational. What is crucially needed is industry-wide and cultural safety change to manage seafarers' fatigue. For instance, if the requirements for additional manning or temporary suspension of operations had been permitted in the work schedules design, and had been incorporated into the *STCW* and *the MLC (2006)* requirements, seafarers would have the alternative of gaining more rest by working shorter hours whenever they felt fatigued (Exarchopoulos et al., 2018). However, such requirements have not been incorporated into the STCW and the MLC (2006) provisional requirements. Therefore, this further showed the inadequacies of the *STCW* and *the MLC (2006)*, and hence call for their amendments.

All the seafarers' fatigue issues are inherent in the maritime sectors of all the nations included in these reports, as they all follow the same international regulations, the STCW and the MLC (2006), for managing and preventing seafarers' fatigue for their ships navigating in international waters. Hence, all these seafarers' fatigue regulatory issues show the inadequacy of these two regulations they are using, confirming what occurs in the maritime sector. The next chapter will focus on a critical analysis of the adequacy of the existing international and Canadian regulations and strategy for managing and preventing seafarers' fatigue to find other sources of evidence address the overall project topic, objective, and question. The various evidence from Chapter Four will be representative of what occurs in each of these leading maritime nations' internal national waters, with Canada as an example.

CHAPTER FOUR:

CRITICAL COMPARATIVE ANALYSIS OF THE ADEQUACY OF EXISTING INTERNATIONAL AND CANADIAN SEAFARERS' FATIGUE MANAGEMENT REGULATIONS AND STRATEGIES

4.1 Review Introduction

This review involves a critical comparative analysis of the adequacy of the existing international and Canadian regulations and strategies for managing seafarers' fatigue. This includes a critical comparative analytical review of the Canadian Marine Personnel Regulations domestic regulations for seafarers' fatigue management's hours of rest and the existing international regulations and strategies for managing and preventing fatigue, including the Standard for Training, Certification and Watchkeeping (STCW), and the Maritime Labour Convention (MLC) 2006 requirements.

The Transportation Safety Board of Canada (TSBC) situation report update on fatigue management in Canada declared the pervasiveness of fatigue in transportation industries, including Canada's maritime transportation sector. TSBC stated that this is the reason why the Transportation Safety Board of Canada (TSB) regularly investigates whether fatigue was a causal factor in maritime accident occurrences, to ascertain whether the operator had management practices in place to manage and prevent such an accident efficiently (Transportation Safety Board of Canada (TSBC), 2020). This chapter's aim is to determine the adequacy of the Canadian maritime sector's existing regulations for managing seafarers' fatigue, including the Marine Personnel Regulations, particularly, among others, that the TSBC has been using for conducting its tasks, to determine if they are sufficient. This is done by comparing the Marine Personnel Regulations with the existing international regulations, including the *MLC 2006* and *STCW*.

4.2 Review Objective

The objective of this chapter's review is to critically compare the Canadian national fatigue management regulations and strategies, which include the Canadian Marine Personnel Regulations, with the existing international regulations and strategies, which are the minimum acceptable global standard regulations for all IMO Member States in developing their own respective national maritime regulatory standard.

4.3 Critical Comparative Analysis of the Adequacy of Existing International and Canadian Seafarers' Fatigue Management Regulations and Strategies

A critical analysis of the Canadian regulations for hours of rest indicated that the *Marine Personnel Regulations* are less stringent than the international regulations. The international regulations are the acceptable minimum international standards regulations to which all the IMO Member State must comply. (Barnett et al., 2017; Canada Consolidation Marine Personnel Regulations, 2022; Smith et al., 2006). This comparatively less stringent *Section 320, Marine Personnel Regulations (SOR/2007-115)* stipulates that:

> *The master of a vessel referred to in subsection. 319 (1) shall ensure that*
>
> *(a) the master and every crew member have*
>
> *(i) at least six consecutive hours of rest in every 24-hour period, and*
>
> *(ii) at least 16 hours of rest in every 48-hour period;*
>
> *and*
>
> *(b) not more than 18 hours but not less than six hours elapse between the end of a rest period and the beginning of the next rest period (Canada Consolidation Marine Personnel Regulations, 2022, p.228).*

The MPR subsection 319 (1) in this extract refers to the Canadian vessels that are:

engaged on near coastal voyages, Class 1 or near coastal voyages, Class 2, while the vessels are in the waters of a foreign state that has ratified the Convention…..(p.228).

Fatigue is a severe issue that has been affecting Canadian seafarers, particularly in maritime operations involving short-sea services and frequent port call operations. Part of the included investigation reports in chapter two pooled from TSBC showed evidence of maritime accidents having seafarers' fatigue as a causal factor occurring in maritime operations involving short-sea services, frequent port calls, and excessive working hours. All these instances do not give adequate time periods for the Canadian seafarers' hours of rest. These scenarios often result in chronic seafarers' fatigue and its associated maritime accident risk. These inadequate Canadian Marine Personnel Regulations (MPR) are what TSBC has been using to manage seafarers' fatigue in the Canadian maritime sector. Hence, the continued usage of the Canadian MPR as a national standard of an IMO's member state breached the *MLC (2006) regulation 2.3 standard A2.3 item 4*, which stipulated that:

"In determining the national standards, each Member shall take account of the danger posed by the fatigue of seafarers, especially those whose duties involve navigational safety and the safe and secure operation of the ship" (International Labour Organization (ILO), 2006, p.30)".

Hence, these MLC 2006 provisional requirements demand ensuring that Canada's regulations for managing seafarers' fatigue must be adequate to be able to comply with the mandatory requirement of the MLC 2006 international regulation. However, the various pieces of evidence include investigation reports gathered from Canada's TSBC in chapter two, including TSBC Report number M07L0158, listed in Appendixes 2G, 2H, and 2I, showing evidence that the Canadian Marine Personnel Regulations are inadequate. This confirmation of inadequacy is based

on evidence shown in these maritime accident investigations reports from TSBC, which indicated proof of operational circumstances that are extremely vulnerable to the development of high levels of seafarers' fatigue, including maritime operations involving the 6- hours on and 6- hours off shift schedule, insufficient manning, lack of a fatigue management plan, high workload, inadequate rest, high port calls and short sea services, 2 or fewer people watchkeeping, and an irregular work schedule. All these confirmed the pervasiveness of each of these issues in the Canadian Maritime sector. See Appendixes 2G, 2H, and 2I. These instances breached the international regulatory requirement of *MLC 2006* and *STCW*. These instances confirmed what Smith et al. (2006) indicated regarding maritime operations involving short-sea services, 6- hours on and 6- hours off shift schedules, and more frequent call operations associated with higher fatigue among those on shorter contracts (Smith et al., 2006).

This review critically compares the Canadian Marine Personnel Regulations' hours of rest with the STCW and the MLC 2006. Table 4.1 compares the international and Canadian regulations on minimum hours of rest, while Table 4.2 shows the comparative disparities in work hours allowed in a 7-day period between Canada's Marine Personnel Regulations and those in the STCW and the MLC 2006. The only practical compliance with the STCW and the MLC to prevent false record-keeping is to comply with the records of hours of rest in the international standards only, which permits 91 hours as the maximum hours of work in a 7-day period. See Figure 4.2. However, the Canadian Marine Personnel Regulations' hours of rest further lead to the propensity of seafarers for fatigue by allowing 112 hours as the maximum hours of work in a 7-day period. This does not give sufficient time allowance for adequate hours of rest. Moreover, most maritime industries in Canada use this schedule that has maximally utilized all 112 hours maximum hours of work in a 7-day period to maximize profit. The Canadian MPR regulations for near coastal

waters allow seafarers to work for 18 hours straight compared to the 14 hours stipulated in STCW/MLC. This results in making Canadian seafarers open to severe fatigue, which is a significant causal factor of not only maritime accidents in Canada's waters but also a substantial causal factor of health consequences and environmental pollution. These factors illustrated the inadequacies of the existing Canadian regulations for managing and preventing seafarers' fatigue. See Appendixes 2G, 2H, and 2I for all TSBC maritime accident investigation reports for practical instances.

Table 4.1 International and Canadian Regulations on Minimum Hours of Rest

Canadian Regulation (Canada Consolidation Marine Personnel Regulations, 2022)**	**International Regulations (STCW & MLC 2006)** (International Maritime Organization (IMO), 2011; Maritime Labour Convention, 2006) ***
Minimum hours of rest: (i) at least 6 consecutive hours of rest every 24 hours (ii) at least 16 hours of rest every 48 hours; and (iii) not more than 18 hours but not less than 6 hours elapsing between the end of a rest period and the beginning of the next rest period	Minimum hours of rest shall not be less than: (i) ten hours in any 24-hour period. (ii) 77 hours in any seven-day period

** See Section 320, Marine Personnel Regulations (SOR/2007-115) (Canada Consolidation Marine Personnel Regulations, 2022).
*** See Regulation 2.3 of the Maritime Labour Convention 2006 (International Maritime Organization (IMO), 2011; Maritime Labour Convention, 2006).

Table 4.2 Disparities Canada's Marine Personnel Regulations and the International Regulations, Using Hours of Rest and Work

Convention	**Minimum Rest**	**Maximum work**	**Work hours Allowed in 7 Days period**
*MLC 2006	10 hours / 24 hours		
	77 hours / 7 days		91 hours Max.

		14 hours / 24 hours	
		72 hours / 7 days	72 hours max
**STCW	10 hours / 24 hours		
	77 hours / 7 days		91 hours Max.
****Canada Marine Personnel Regulations (Domestic)	6 hours / 24 hours		
	16 hours / 48 hours		112 hours Max.

*See Regulation 2.3 of the Maritime Labour Convention 2006 (Maritime Labour Convention, 2006).
**International Convention on Standards of Training Certification and Watchkeeping for Seafarers 1978, as amended (International Maritime Organization (IMO), 2011).
. *** See Section 320, Marine Personnel Regulations (SOR/2007-115) (Canada Consolidation Marine Personnel Regulations, 2022).

Some TSBC reports listed in Appendixes 2G, 2H, and 2I are described below:

(a) 6 - Hours on and 6- Hours Off Shift Schedule: An instance of TSBC reports having seafarers' fatigue as a causal factor emanating from the usage of 6- hours on and 6- hours off shift schedule is the TSBC Marine Investigation Report number M16P0378, involving the grounding and subsequent sinking of an articulated tug-barge Tug *Nathan E. Stewart* and tank barge *DBL 55* in Seaforth channel, 10 NM west of Bella Bella, British Columbia, on 13th October 2016 (Transportation Safety Board of Canada (TSBC), 2018). Various extracts from this report have been described in Chapter Two page 65 to 66. This shows the complicated inefficient nature of the Canadian MPR. This will be analyzed thoroughly in chapter four of this overall review. Another example is the TSBC Marine Investigation Report number M07L0158 that operated with a 6 hours on and 6 hours off watchkeeping regime, with Short-Sea Services and Frequent Port Calls.

The the 6-on and 6-off shift-scheduling practices of the *Nathan E. Stewart*, which was in accordance with the applicable Marine Personnel Regulations (MPR) provisions. However, the MPR breached the *MLC (2006) regulation 2.3 standard A2.3 item 4* stated earlier because it increases the propensity of Canadian seafarers to become fatigued. This shows the complicated

inadequate nature of the Canadian MPR, hence, necessitating its urgent amendment. Moreover, Smith et al. (2006) claimed that most maritime accidents associated with ships operating short-services, frequent port calls, two watchkeepers system, and 6-on-hours and 6-off- hour's watchkeeping schedule involved involve mini bulkers, which represents a worst-case scenario regarding a ship environment conducive to vulnerability to seafarers' fatigue. The 6-on-hours and 6-off-hours watchkeeping schedule causes less daily sleep, more recurrent episodes of micro-sleeps (nodding), more propensity for poor-quality fragmented sleep, and excessive sleepiness hours (Härmä et al., 2008; Lützhöft et al., 2010; Marine Accident Investigation Branch (MAIB), 2004, Smith et al., 2006). All these necessitates Canadian MPR amendment for the sustainable shipping safety of Canada's inland and coastal waters, seafarers' well-being, and the safety of the environment from pollution from maritime accidents (Uğurlu et al., 2021).

(b) Insufficient manning: Another major issue in the Canadian Maritime sector is the inadequate manning issue. There are many instances of this in various TSBC's included maritime accident investigation reports, described in Appendixes 2G, 2H, and 2I. Inadequate manning occurrence in the Canadian maritime sector indicates that the existing Canadian MPR breached the *MLC (2006) regulation 2.7 on manning levels* requirement which specifies adequate manning of seafarers working on board ship, to safeguard the safe, effective, and secure operation of the ship (International Labour Organization (ILO), 2006). Furthermore, the Canadian MPR's inability to ensure adequate manning also breached the *IMO's assembly 27th session agenda item 9 in its resolution A.1047(27) on the Principles of Minimum Safe Manning*, which specified all the requirements for adequate manning and also emphasized compliance with all the SOLAS regulations regarding adequate manning, which stipulates that the vessel must be adequately manned with officers with adequate training (International Maritime Organization (IMO), 2011).

Also, the Canadian MPR, being a national standard of an IMO's member state, breached the MLC (2006) regulation 2.3 standard A2.3 item 4, stated earlier, which emphasized that national standard for all the IMO's member states by specifying that:

> *"In determining the national standards, each Member shall take account of the danger posed by the fatigue of seafarers, especially those whose duties involve navigational safety and the safe and secure operation of the ship" (International Labour Organization (ILO), 2006, p.30).*

However, the noncompliances of the Canadian Marine Personnel Regulations with the minimum international standard requirements on adequate manning emphasized the inadequacy of the the Canadian Marine Personnel Regulations to ensure adequate manning in the Canadian maritime sector. Insufficient manning is a very pervasive issue currently plaguing seafarers in the Canadian maritime industry, as confirmed by the TSBC included maritime accident investigation reports in Appendixes 2G, 2H, and 2I. One instances is TSBC Marine Investigation Report number M13L0123, involving the collision between the bulk carrier *Heloise* and Tug *Ocean Georgie Bain* in the Port of Montreal, Quebec, on 3rd August 2013 (Transportation Safety Board of Canada (TSBC), 2014). Extracts from this report have been described in Chapter Two pages 68 - 69. Other TSBC reports confirming evidence of undermanning in the Canadian maritime sector are TSBC report number M04L0099 and NTSB/MAB-17/14_ DCA16FM033. These examples ascertained the inadequacy of the Canadian MPR to manage and prevent seafarers' fatigue in the Canadian maritime sector. Therefore, the MPR breached the *MLC (2006) regulation 2.3 standard A2.3 item 4*, hence, necessitating its urgent amendment.

(c) Poor or Lack of Fatigue Management Plan (FMP): An instance of this poor or ineffective FMP issue have been described in Chapter Two pages 70 - 72 on TSBC Marine

Investigation Report number M16P0378. Another is TSBC reports showing evidence of poor or ineffective FMP is TSBC Marine Investigation Report number M14C0219 and TSBC Marine Investigation Report number M12N0017. The TSBC Marine Investigation Report number M14C0219 involved an ineffective Fatigue Management Plan (FMP), despite having a Safety Management System (SMS) in place, which resulted in the bottom contact of tanker *Nanny* in Deer Island, Chesterfield Inlet, Nunavut on 14th October 2014 (Transportation Safety Board of Canada (TSBC), 2016). Various extracts from this report were in Chapter Two pages 72 to 73. All these extracts gave vivid instances of ineffective Fatigue Management Plans, despite having a safety management system (SMS) since 2009. These examples ascertained the inadequacy of the Canadian MPR to manage and prevent seafarers' fatigue in the Canadian maritime sector. Therefore, the MPR breached the MLC (2006) regulation 2.3 standard A2.3 item 4. This necessitates urgent amendment.

(d) High Seafarers' Physical and Mental Workload, and Overwork: Many TSBC reports reviewed show instances of seafarers subjected to high stress, high physical and mental workload and overwork are in the Canadian maritime sector, involving short-sea shipping that engages in high-frequency ship manoeuvres, frequent tests and controls, frequent cargo operations, tank cleaning operations, in-between ports short distance, supplies, planned maintenance, drills, time pressure to arrive early in port, short port stays, frequent port turnarounds, only two watchkeepers (in many cases), and long periods of pilotage, inadequate safe manning, and loading and unloading operations, navigational watch, tank cleaning, and training, among others.

Numerous reports showing evidence of high physical and mental workload and overwork among the various reviewed maritime accidents investigation reports listed in Appendixes 2G, 2H, and 2I are TSBC Marine Investigation Report number M18C0225, TSBC Marine Investigation

Report number M15C0006, TSBC Marine Investigation Report number M15C0006, TSBC Marine Investigation Report number M13L0123, TSBC Marine Investigation Report number M13L0123, TSBC Marine Investigation Report number M07L0158, TSBC Marine Investigation Report number M06N0014, TSBC Marine Investigation Report number M97L0030, TSBC Marine Investigation Report number M93C0003, TSBC Marine Investigation Report number M92W1057, and TSBC Marine Investigation Report number M92W1012. The TSBC reports showing evidence of high stress among the various reviewed maritime accident investigation reports are listed in Appendixes 2G, 2H, and 2I are TSBC Marine Investigation Report number M94C0014 and TSBC Marine Investigation Report number M96L0069.

A typical report showing instances of seafarers' high mental workload associated with inadequate manning for the vivid descriptions of the presence of this issue in the Canadian Maritime sector is TSBC Marine Investigation Report number M13L0123. This is a report on the collision between the bulk carrier *Heloise* and Tug *Ocean Georgie Bain* in the Port of Montreal, Quebec, on 3rd August 2013 (Transportation Safety Board of Canada (TSBC), 2014). Extracts from this report have been described in Chapter Two pages 67 to 69.

Seafarers' overworking hours of 112 hours maximum in any seven days result in inadequate hours of rest, which is among the most critical seafarers' fatigue causal factors contributing to maritime accidents. Previous studies pointed out that Canadian seafarers experience a high operational workload while working on Canada's inland waters, particularly in Canada's Great Lakes and the St. Lawrence Seaway, among other locations on Canadian waters. This issue makes them violate rest hours and often results in acute and chronic fatigue related to lack of adequate rest hours, broken watches, and long rotations impacts (Shan & Neis, 2019; Uğurlu et al., 2021). The less stringent HOR nature of the Canadian MPR regulations for managing and preventing

seafarers' fatigue in the Canadian maritime sector results in all the issues described: hence necessitating their amendment. All these ascertained the inadequacy of the Canadian MPR to manage and prevent seafarers' fatigue in the Canadian maritime sector. Therefore, the MPR breached the MLC (2006) regulation 2.3 standard A2.3 item 4. This necessitates MPR urgent amendment.

(e) Short-Sea Services, and Frequent Port Calls: The vivid scenario that demonstrates this issue in the Canadian Maritime sector is TSBC Report number M07L0158 which involves the striking of the passenger vessel Nordik Express at Entrée Island, Harrington Harbour, Quebec, 16th August 2007 (Transportation Safety Board of Canada (TSBC), 2010). Extracts from this TSBC report and past literature supporting the existence of this issue have been described in Chapter Two pages 74 to 77.

Causal factors of seafarers' fatigue in Canadian short-sea shipping and frequent port calls shipping operations include high-frequency ship manoeuvers, shipboard equipment testing and controls, frequency of cargo operations, tank cleaning operations, in-between ports short distance, supplies, planned maintenance, drills, time pressure to arrive early in port, short port stays, frequent port turnarounds, only two watchkeepers (in many cases) navigational watch, long periods of pilotage, inadequate safe manning, loading and unloading operations, tank cleaning, and training (Shan & Neis, 2020; Smith et al., 2006; Uğurlu et al., 2021). All these issues frequently occur in Canadian short-sea shipping; however, short-sea travel times often do not give seafarers sufficient time to complete these tasks (Shan & Neis, 2020; Smith et al., 2006; Uğurlu et al., 2021). All the above characterized Canada's waters shipping operational environment; hence, these proved the lax nature of the Canadian MPR for managing seafarers' fatigue and therefore pointed to their inadequacies. Therefore, all these ascertained the inadequacy of the Canadian MPR to manage and

prevent seafarers' fatigue in the Canadian maritime sector. Therefore, the MPR breached the MLC (2006) regulation 2.3 standard A2.3 item 4. These issues necessitate the Canadian MPR urgent amendment.

(f) Violations of STCW and MLC (2006) Hours of Rest Regulations Due to Less Stringency of Marine Personnel Regulations (MPR) Hours of Rest: Numerous reports showing evidence among the various reviewed maritime accidents investigation reports are listed in Appendixes 2G, 2H, and 2I are TSBC Marine Investigation Report number M15C0006, TSBC Marine Investigation Report number M12N0017, TSBC Marine Investigation Report number M11W0091, TSBC Marine Investigation Report number M08C0024, TSBC Marine Investigation Report number M06N0014, TSBC Marine Investigation Report number M06F0024, TSBC Marine Investigation Report number M05C0063, TSBC Marine Investigation Report number M04L0099, TSBC Marine Investigation Report number M98C0197, TSBC Marine Investigation Report number M97M0022, TSBC Marine Investigation Report number M97L0030, and TSBC Marine Investigation Report number M93C0003. These various scenarios used this less stringent Marine Personnel Regulations' hours of rest as a guiding standard regulation, which allows 112 hours maximum of work, without allowing adequate hours for rest, thereby causing seafarers' fatigue that resulted in those maritime accidents.

A typical report showing instances of inadequate rest and lack of record of rest for the vivid descriptions of the presence of this issue in the Canadian Maritime sector is TSBC Marine Investigation Report number M15C0006. This is a report on the striking of the passenger vessel *Nordik Express* at Entrée Island, Harrington Harbour, Quebec on 16th August 2007. Some extracts from this report have been described in Chapter Two pages 74 to 77.

All these ascertained the inadequacy of the Canadian MPR to manage and prevent seafarers' fatigue in the Canadian maritime sector. Practical evidence of these is shown in the various TSBC's included maritime accident reports tabulated in Appendixes 2G, 2H, and 2I with instances of hours of rest requirements violations in Chapter Two. These fatigue's causal factors, coupled with compounded less stringent regulations of the Canadian hours of rest compare with the international statutory requirements for hours of rest, significantly and potentially expose Canadian seafarers to a higher risk of fatigue.

Adequate and regulated minimum hours of rest can help seafarers recuperate from fatigue and its associated risk factors, as suggested by both the Cardiff University research program and the MARTHA project (Barnett et al., 2017; Smith et al., 2006). However, the hours of rest stipulated in the Canada Consolidated Marine Personnel Regulations are less stringent (Canada Consolidation Marine Personnel Regulations, 2022), when compared with the requirements on the hour of rest in these international regulations, including the Standard for Training, Certification and Watchkeeping (STCW), and the Maritime Labour Convention (MLC) 2006 (International Labour Organization (ILO), 2006; International Maritime Organization (IMO), 2011). All the above ascertained the inadequacy of the Canadian MPR to manage and prevent seafarers' fatigue in the Canadian maritime sector. Therefore, the MPR breached the *MLC (2006) regulation 2.3 standard A2.3 item 4*. This issue necessitates its urgent amendment.

The next Chapter summarizes this overall study's conclusions from the various findings obtained from Chapters One, Two, Three, and Four from which various recommendations, which serve as an evidenced-based regulatory amendment toolkit, to guide the Canadian and international regulatory bodies on amending the existing Canadian and international regulations and strategies for managing and preventing seafarers' fatigue to ensure their adequacy.

CHAPTER FIVE:

OVERALL CONCLUSIONS AND RECOMMENDATIONS TO CANADIAN AND INTERNATIONAL REGULATORY BODIES

This Chapter summarizes the study's conclusions, and various recommendations are made from these to serve as an evidenced-based regulatory amendment toolkit that will guide the Canadian and international regulatory bodies on amending and advancing the existing Canadian

and international regulations and strategies for managing and preventing seafarers' fatigue to ensure their sufficiency.

5.1 Overall Review Conclusions

This is the overall review conclusion of reviews one, two, three, and four in chapters one to four, respectively, for answering the overall review question Table 5.1 shows all the overall review evidence summary for answering the overall review question to ascertain the adequacy of the existing regulations and strategies for managing and preventing seafarers' fatigue in the Canadian and International Maritime Sectors. The overall review conclusions summary is summarized in the paragraph below under each seafarers' fatigue interrelated causal factor or regulatory inadequacies or violations:

(a) Evidence of Significant Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents in the International and Canadian Maritime Sectors: In conclusion, the various quantitative and qualitative pieces of evidence drawn from the findings of Review One, Two, Three, and Four indicate a significant prevalence of seafarers' fatigue as a causal factor of maritime accidents in the international and Canadian maritime sectors are stated in the paragraphs below. These are Raby & Lee (2001) which indicated 23%. The Marine Accident Investigation Branch (MAIB) (2004) indicated 30% direct causal factor and 82% contributing causal factors for all groundings and collisions that occurred between 00:00 and 06:00 hours, Houtman et al. (2005) indicated a range of 11% to 20%, Smith et al. (2006) indicated 53%, Akhtar & Utne (2014) indicated 41% of vessels groundings and collisions. Tang et al. (2013) indicated 13.8 %, and Acejo et al. (2018) indicated 10.2%, respectively. All these indicate that the existing international regulations and strategies for managing and preventing seafarers' fatigue in the international and Canadian maritime sectors are **inadequate** (Acejo et al., 2018; Akhtar & Utne, 2014; Houtman et

al., 2005; Marine Accident Investigation Branch (MAIB), 2004; Raby & Lee, 2001; Smith et al., 2006; Tang et al., 2013).

Also, this overall review concluded that the wide variations in the prevalence values obtained in the various included articles in Review One was due to the variation in their precision, reliability, and validity due to differences in the quality of these respective study's design and analysis to identify and control for the various systematic and unsystematic errors in their respective analysis and design.

In addition, this review concluded that those articles with higher prevalence values (MAIB (2004), Smith et al. (2006), and Akhtar & Utne (2014)) identified and controlled for errors in their design and analysis stages, respectively, using various efficient epidemiological approaches, hence resulting in their higher precise, valid, and reliable prevalence value. In contrast, those articles with lower prevalence values (Houtman et al. (2005), Tang et al. (2013), Acejo et al. (2018)) did not identify and control for errors in their design and analysis stages, respectively, using any of the various efficient epidemiological approaches, hence resulting in their lower imprecise, invalid, and unreliable prevalence values. This was because these respective lower prevalence values have been affected by various systematic (bias and confounder) and unsystematic errors (random error) that occur during the analysis and design of these epidemiological-related studies (Acejo et al., 2018; Akhtar & Utne, 2014; Aschengrau & Seage, 2020; Marine Accident Investigation Branch (MAIB), 2004; Smith et al., 2006; Tang et al., 2013).

This review conclusions from its findings indicated that all included studies with lower prevalence values in Review One (Houtman et al. (2005), Tang et al. (2013), and Acejo et al. (2018)) that used maritime accident reports were affected by the investigators' information bias inherent in the making of those reports, including misclassification bias and reporting bias. These

two types of information biases predominantly resulted in the lower prevalence value for Tang et al. (2013), and Acejo et al. 2018) (Acejo et al., 2018; Houtman et al. 2005; Tang et al., 2013). Similarly, this investigators' reporting information bias substantially reduces all the 32-year period and yearly point prevalence values obtained in Review Two in Chapter Two. Investigators' reporting information bias occurred due to the investigators' reluctance to report seafarers' fatigue as a causal factor of maritime accident because seafarers' fatigue cannot be measured, and the evidence of their presence cannot be proven.

Furthermore, this review conclusions based on Review Two findings indicated that the 32-year (1990 to 2021 inclusive) period prevalence for each of these five countries reviewed in Review Two in Chapter Two from the highest to the lowest is: 12.6% for the United Kingdom (UK), 10.1% for Canada, 9.5% for Australia, 4.1% for the United States of America (USA), and 2% for Denmark, respectively, as illustrated in Figure 2.2. The 32-year period prevalent values for the USA and Denmark are classified as being significant because of the general substantial effects of the investigators' reporting information bias which generally lowered all the overall 32-year period prevalence values and all the yearly point prevalence values for all the five countries analyzed. Therefore, the 32 years period prevalence value and each respective country's yearly point prevalence values are all significant prevalence values, which indicate that the existing international regulations and strategies for managing and preventing seafarers' fatigue in the international maritime sector, including Canada, are **inadequate**.

Also, this review concluded based on Review Two findings that the trend pattern of the 32-year period prevalence is steeply in a sharp up-and-down pattern from 1990 up to its peak incidence percentage in 2004 and gradually fell steeply from one year to the next after 2004 till it reached zero in 2020 and 2021, as shown in Figure 2.2. Figure 2.2 confirmed that the high peak yearly

point prevalence of 26% in 2004, with the highest yearly point prevalence in all the 32 years reviewed. The are many reasons for this highest yearly point prevalence in 2004. First, the period prevalence between 1990 to 2004 inclusive is 13.2%, which is more than 8.5% obtained for the period prevalence between 2005 to 2021 inclusive. Second, many reports of maritime accidents that occurred before 2004 and in 2004 may have all gotten published in 2004 in safety preparedness anticipation of the 1st July 2004 when the maritime sector commenced worldwide enforcement of the International Ship and Port Facility Security (ISPS) Code. On the other hand, the reasons for the substantial gradual falling of the yearly point prevalence of seafarers' fatigue as a causal factor of maritime accidents obtained after 2004, between 2005 to 2021 inclusive, may be due to the manifestation of the efficacy of the prior enforced ISPC's enforcement efforts, which started on 1st July 2004 onward.

The review conclusions based on findings obtained from Review Two in Chapter Two indicated that the frequency percentages of the various types of maritime accidents occurrence having seafarers' fatigue as a causal factor include: groundings are 41%; collisions are 29%; striking and contacts are 11%; fatalities and human injuries are 9%; capsizes, floodings, and sinkings are 5%; explosions and fires are 3%; oil spillage is 1%; loss of a crew member is 1; dangerous occurrence is 1%; and cargo collapse is 1%. These indicate that groundings, collisions, striking and contacts, and fatalities and injuries are the dominant maritime accident occurrences having seafarers' fatigue as a causal factor in all included reports from 1990 to 2021, as shown in Figure 2.4. The above statistics show that seafarers' fatigue is a severe problem in the international and Canadian maritime sectors, hence the above evidence confirmed the **inadequacy** of the regulations and strategies for managing and preventing them; hence, these statistics necessitate their amendments.

(b) Evidence of Pervasive Violations of STCW and MLC (2006) Hours of Rest (HOR) Regulations: The overall review conclusion based on findings from Reviews One, Two, Three, and Four indicated that pervasive violations of *STCW* and *MLC (2006)* Hours of Rest (HOR) regulations in the Canadian and international maritime sectors is the **most dominant evidence confirming the inadequacy** of the current relevant regulations and strategies for managing and preventing seafarers' fatigue. All included articles in Review One supported this claim. **80%** of all the included maritime accident investigation reports in listed in Appendixes 2G, 2H, and 2I and various past literature supporting it in Reviews One, Two, Three, and Four confirmed the pervasive violations of *Hours of Rest (HOR)* regulations in the Canadian and international maritime sectors (Canada Consolidation Marine Personnel Regulations, 2022; International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). See Appendixes 2G, 2H, and 2I.

Moreover, part of this conclusions indicated that the existing reporting systems are ineffectively designed to record fatigue-related factors, including hours of rest, and that excessive working, under-recording, not recording or forging records of hours of rest are problematic issues due to HOR violations in the current seafaring industry. Seafarers' fatigue due to HOR violations, may be caused by a number of factors, including excessive workload, cumulative sleep debt problems because of poor sleep during the day, long working hours, lack of or poor quality sleep, prolonged work, and insufficient rest between work periods. These initiated the bulk of the seafarers' fatigue causal factor that resulted in those maritime accidents in most of the reports' instances reviewed listed in Appendixes 2G, 2H, and 2I, with few extracts and descriptions in Reviews Two, Three, and Four.

The discrepancy between STCW and MLC is that both regulations stipulate 77 hours minimum rest in any seven days, which leads to 91 hours of maximum work per any 7-day period.

The MLC stipulates an optional 72 hours of maximum hours of work in any 7-day period. Whereas to fully comply with **both** STCW and MLC and prevent the liability of false record-keeping, one only needs to comply with the hours of rest. This is a major inconsistency in the existing international regulations for managing and preventing seafarers' fatigue, as it creates confusion and violations by the maritime industries. This proves their inadequacy. Hence, both regulations need to be harmonized with amendments, for the safety of the maritime sector, globally. Also, numerous reports from the five countries reviewed, including Canada's TSBC, indicated instances of working more than the 14 hours maximum permissible time between rest periods and working more than the 91 hours maximum hours of work in a 7-day period, as analyzed on page 60 of this project, which violated the *HOR* requirements of *STCW* and *MLC 2006*. Moreover, the Canadian *MPR's* hours of rest further complicated this issue in the Canadian Maritime sector, by allowing 112 hours as the maximum hours of work in a 7-day period, which contravened the *HOR* requirements of *STCW* and *MLC 2006* as described in pages 96 to 103 of this project.

Moreover, the 2014 Concentrated Inspection Campaign (CIC) report on STCW's 'Hours of Rest' by the Paris Memorandum of Understanding (MoU) Port State Control Committee declared a general lack of STCW's hour of rest compliance in the maritime industry (Paris MoU PSC Committee, 2014). This is practical proof that further established this pervasive violation of the hours of rest in the existing maritime industry Therefore, these necessitate their amendments (Canada Consolidation Marine Personnel Regulations, 2022; International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). Hence, these show that the Hours of Rest (HOR) stipulated in the international regulations (the *STCW* and *MLC 2006*) and the Canadian *MPR* are **inadequate** in their relevant areas. Hence, these necessitate their amendments.

(c) 6 Hours On and 6 Hours Off Shift Schedule System: This overall project conclusions based on the findings from Reviews One, Two, Three, and Four indicated that the 6 hours on and 6 hours off watchkeeping regime is another significant seafarers' fatigue causal factor in the international and Canadian maritime sectors. Though this watchkeeping regime may not contravene the (*STCW* and *MLC 2006*) and the Canadian *MPR* relevant for managing and preventing seafarers' fatigue, various pieces of evidence from a few extracts and descriptions in Reviews Two, Three, and Four showed that this watch system causes considerably seafarers' fatigue because this watch system does not allow for the recommended 7-9 hours of uninterrupted adequate sleep, and this often results in seafarers' fatigue on board ships that used this watchkeeping system (Canada Consolidation Marine Personnel Regulations, 2022; Hirshkowitz et al., 2015; International Labour Organization (ILO), 2006; International Maritime Organisation (IMO), 2011). Moreover, literature indicated that this shift-scheduling practice causes less daily sleep, more recurrent episodes of micro-sleeps (nodding), more propensity for poor-quality fragmented sleep, and excessive sleepiness, which commonly happens during the early morning hours. These make a large number of maritime accidents occur on both Canadian and international waters with only two watchkeepers on the 6-on and 6-off watch system in most cases (Härmä et al., 2008; Lützhöft et al., 2010; Marine Accident Investigation Branch (MAIB), 2004). An example of a report showing instances of issues is TSBC Marine Investigation Report number M16P0378 analyzed on pages 65 to 66, and others in Appendixes 2G, 2H, and 2I listed on page 66. All these confirmed the **inadequacy** of the regulations and strategies for managing and preventing seafarers' fatigue; hence, necessitating their amendments.

(d) Insufficient Manning and Inefficiency of Two Officers' Watchkeeping System: This review concluded from its findings from Review Two, Three, and Four showed that insufficient

manning and inefficiency of two officers' watchkeeping system are other factors causing seafarers' fatigue in the international and Canadian maritime sectors. These violate *MLC (2006) regulation 2.7 on manning level* requirements and the *IMO's assembly 27th session agenda item 9 in its resolution A.1047(27) on the Principles of Minimum Safe Manning* (International Labour Organization (ILO), 2006; International Maritime Organization (IMO), 2011). Although the two officers' watchkeeping system does not violate the above-stated adequate manning requirements, many reports reviewed in this project showed pieces of evidence regarding its inefficiency. Some maritime industries complicated this issue by reducing the required two officers' watchkeeping at the same time, without equating the workload on board the ship with the manning level, nor manned with officers with inadequate training. This compromised the safety, effectiveness, and secure operation of the ship and contravened the above-stated cited manning regulatory specifications. Practical instances of report extracts describing undermanning issues are described on pages 67 to 69 of this report and other listed on page 69 and Appendixes 2G, 2H, and 2I. This review concluded from its findings that the master's incapability to execute his duties and watchkeeper manning levels are key causal factors for collisions and groundings, while inadequate lookout is a major causal factor in collisions. All these established the **inadequacy** of the regulations and strategies for managing and preventing seafarers' fatigue; hence, justify their amendments.

(e) Lack Or Inefficient Implementation Of Company/Shipboard Fatigue Risk Management System: Likewise, this review conclusion base on evidence findings from Reviews Two, Three, and Four is that another factor causing seafarers' fatigue is the inefficient implementation or lack of company/shipboard Fatigue Risk Management System, including a fatigue management plan, fatigue awareness and fatigue management training and information

campaigns, is a holistic efficient way of managing and preventing seafarers' fatigue which ensures sleep is easier for seafarers onboard, and the seafarers and agencies ashore which affects shipboard operations. Some extracts from reports scenarios describing this issue are analyzed on pages 70 to 73. The MARTHA Project recommended the introduction of Fatigue Risk Management Systems, being used successfully in other transportation sectors, as an integrated systems approach to managing and preventing seafarers' fatigue in the international maritime sector (Barnett et al., 2017). However, the STCW and the MLC (2006) do not contain provisional requirements for Fatigue Risk Management Systems. Therefore, the STCW and the MLC (2006) are **inadequate**, as they are not sufficiently effective in their relevant areas. Hence, this necessitates their amendments.

(f) Short-Sea Services And Frequent Port Calls: This review conclusion base on evidence findings from Reviews Two, Three, and Four is that another factor plaguing Canadian and international seafarers with high workload and fatigue are the short-sea services and frequent port call operations. Smith et al. (2006) confirmed these evidence by indicating that more frequent port calls were associated with increased fatigue among those on shorter contracts, while there is less fatigue among those on longer tours, depending on ship type. Mini bulkers on short-sea services and frequent port calls are the worst-case setting regarding a ship environment conducive to vulnerability to associated seafarers' fatigue, and the negative factors on this ship type that increase seafarers' workload include changing cargos, short port stays, frequent port turnarounds, only two watchkeepers (in many cases), and long periods of pilotage (Smith et al., 2006). Some extracts from reports scenarios describing this issue are analyzed on pages 73 to 77. Therefore, these short-sea services and frequent port call operations issues confirmed the **inadequacy** of the regulations

and strategies for managing and preventing seafarers' fatigue in the international and Canadian maritime sector; hence, necessitate their amendments.

(g) Absence of a Maritime Industry's Gold Standards for Measuring Seafarers' Fatigue: This review conclusion base on evidence findings from Reviews Two, Three, and Four is that the absence of a gold standard for measuring seafarers' fatigue results in the investigators' information reporting bias. The reasons for the inability to measure seafarers' fatigue are due to the absence of a maritime industry gold standard measure of seafarers' fatigue; the presence of interrelated measurement errors hindering precise and valid seafarers' fatigue assessment, including confounders, biases, and random errors. This also makes comparison and assessing the impact of research results extremely complicated. This validates the importance of implementing the use of a gold standard of fatigue measure as the maritime industry's standard or coming up with a new fatigue measure scale for research and industrial purposes to enhance managing and preventing seafarers' fatigue. Some extracts from reports scenarios describing this issue are analyzed on pages 77 and 78 of this project. All these confirmed the **inadequacy** of the relevant existing regulations for managing seafarers' fatigue; hence, necessitate their amendments.

(h) Working More Than Six-Month Long Tour Period of Duty: The conclusion based on evidence findings from Review Three indicated that working more than a six-month-long tour period of duty is an issue in the existing Canadian and international maritime sectors cause reduced motivation, increase sleepiness (insomnia), and loss of sleep quality. This is because fatigue and stress increase as the navigation length increases, which results in crews mostly being unable to meet their mandatory hours of rest set by the STCW and MLC (2006) regulatory requirements. However, the MARTHA project recommended six months maximum long tour period of duty to effectively manage seafarers' fatigue, while ITF Employment Agreement indicated six months,

which may be increased to seven months or decreased to five months for operational convenience. But the Canadian MPR permits long tours of duty of 11 months and the MLC (2006) still permits long tours of duty of 12 months maximum, which is twice the 6-month period tested and suggested by the MARTHA project as analyzed on page 90. This caused increased exposure to fatigue among Canadian and international seafarers (Barnett et al., 2017). All these confirmed the **inadequacy** of the existing Canadian and international regulations for managing seafarers' fatigue; hence, necessitating their amendments.

(i) Developing A Multi-Factor Auditing Tool: This review conclusion from evidence obtained from its findings from Reviews One, Two, Three, and Four indicated that the absence of a multi-factor seafarers' fatigue auditing tool in the maritime industry to precisely and accurately measure the various multi-factors and interrelated seafarers' fatigue causal factors hinders the assessment of seafarers' fatigue. This absence of a multi-factor seafarers' fatigue auditing tool often causes the investigators' information reporting bias because seafarers' fatigue is difficult to measure because its causal multi-factors most often occur as a combination of different interrelated causal factors, hence, a multifactor auditing tool is needed to precisely and accurately measure them. This emphazised the cruciality of reliable auditing systems, without which the success of any change, in the existing seafarers' fatigue and associated maritime accidents issues, will be impossible to evaluate. Therefore, this study concluded that seafarers' fatigue negative causal factors must be considered in combination rather than alone in order to have adequate insight into fatigue at sea. A report extract describing this issue is analyzed on pages 78 and 80 of this project. These pieces of evidence verified the **inadequacy** of these existing Canadian and international regulations. Hence, these necessitate their amendments.

(j) High Pervasiveness of Seafarers' Stress, Physical And Mental Workload, Overwork due to Excessive Demand from Additional Duties: This review conclusion based on pieces of evidence obtained from its findings from Reviews One, Two, Three, and Four indicated the existence of high pervasiveness of seafarers' stress, physical and mental workload, overwork due to excessive demand from additional duties, among other, in the Canadian and international maritime sectors. The *MLC 2006* has been identified as the Seafarers' Bill of Rights. But, the Convection is not only inadequate to advance seafarers' welfare, including preventing and managing seafarers' fatigue, but also that it cannot even address seafarers' pertinent issues, such as the fair treatment of seafarers in the event of a maritime accident, high physical and mental workload, other adverse seafarers' fatigue health consequences, and overwork due to excessive demand from additional duties. Many scenarios describing these issues are in the various reviewed maritime accident investigation reports are described with extracts in Chapter Two and listed in Appendixes 2G, 2H, and 2I. These pieces of evidence proved the **inadequacy** of these existing Canadian and international regulations. Hence, these necessitate their amendments.

(k) The Master's Overriding Authority Issues: This review's conclusion from the pieces of evidence obtained from its findings from Review Three indicated that the master's overriding authority is another significant issue initiating seafarers' fatigue. This was described with *STCW Section A-VIII/1 paragraph 8* extract on pages 88 and 89. This is because whenever a Master use such authority, no proper documentation about this is made in the ship's logbook to prevent future consequences during an inspection of rest hours. However, this condition is not stated clearly in the STCW. There is also no guidance as to what should follow next, including required reporting, rest, and follow-up, and Smith et al. (2006) supported this by pointing out that the existing reporting systems are insufficiently designed to record factors relevant to fatigue causal factors.

These pieces of evidence verified the **inadequacy** of these existing Canadian and international regulations. Hence, these necessitate their amendments.

(l) IMO 2019 Guidelines on Fatigue Overemphasized on the Seafarers' Responsibility Without Recognizing Limitations Beyond Seafarers' Control, and Overstressed Fatigue Risk Factors that Cannot Replace Specific and Implementable Recommendations: This review's conclusion from the pieces of evidence obtained from its findings from Review One, Two, and Four indicated that the IMO 2019 Guidelines on Fatigue overemphasized seafarers' responsibility without recognizing limitations beyond seafarers' control, and overstressed on fatigue risk factors that cannot replace specific and implementable recommendations. This IMO's strategic fatigue management document elaborated seafarers' fatigue into disparate parts and various areas of responsibilities onboard. However, this document overemphasizes the seafarers' obligation to manage fatigue without recognizing some critical operational factors beyond their control, including the manning level over which seafarers have little or no control. Many reports reviewed indicated this issue. Whereas the focus on responsibility for fatigue management requirements is required to change from personal to operational. What is crucially needed is industry-wide and cultural safety change to manage seafarers' fatigue. This highlighted the **inadequacy** of the IMO 2019 Guidelines on Fatigue's strategy for managing seafarers' fatigue in the Canadian and international maritime sectors, hence this necessitates its amendment (International Maritime Organization (IMO), 2019; Smith et al., 2006).

(m) Practical Impossibility of Granting Shore Leave to Seafarers: Another conclusion from this review's pieces of evidence findings indicated the practical impossibility of granting shore leave to seafarers in the international maritime industry is a significant issue in the existing maritime sector. However, this contravened the MLC 2006 requirement that stated that seafarers

shall be granted shore leave. Whereas this is often an impracticable and unachievable target in the present shipping industry, because of the fast turnarounds at ports and additional workload for seafarers. Also, the restriction imposed by the ISPS Code often makes shore leave impossible in certain crew nationalities. These further point to the STCW and MLC (2006) **inadequacies**, hence, necessitating their amendments.

(o) Absence of Previous Comprehensive Systematic Review for Assessing the Adequacy of Relevant Regulations and Strategies for Managing and Preventing Seafarers' Fatigue in the Canadian and International Maritime Sector: This review's conclusion from the pieces of evidence obtained from its findings indicated that the absence of previous comprehensive systematic review for assessing the adequacy of relevant regulations and strategies for managing and preventing seafarers' fatigue in the Canadian and the international maritime sector is an issue that prevents identifying of their regulatory inadequacies. Smith (2007) pointed out that past attempts to prevent or manage seafarers' fatigue by legislation and guidance have failed because there has been little attempt to assess their adequacy (Smith, 2007). Moreover, a comprehensive systematic review of maritime regulation is one way to enhance maritime safety because each maritime accident report offers a complete account of what happened and attempts to find the accident's causal factors, and hence these give clue to find solutions for addressing them through necessary amendments (Acejo I et al., 2018; Tang L. et al., 2013). This emphasized the **inadequacy** of the existing strategies for managing seafarers' fatigue in the Canadian and international maritime sectors, hence this necessitates their amendments.

(p) Absence of the Application of Updated Epidemiological Principles in the Design and Analysis of a Maritime Study Assessing Seafarers' Fatigue as a Causal Factor of Maritime Accidents: This review's conclusion from the pieces of evidence obtained from its findings from

Reviews One, Two, and Four indicated that there is a general lack of the application of updated epidemiological principles in the design and analysis of a maritime study assessing seafarers' fatigue as a causal factor of maritime accidents. Only these few articles among the included articles in Review One applied some epidemiological approaches to control for errors in their design or analysis, including MAIB (2004), Smith et al. (2006), and Akhtar & Utne (2014). These resulted in the higher quality and value of their quantitative and qualitative findings. Also, all the maritime accident reports reviewed are affected by the investigators' information reporting bias. This resulted in the lower quality and value of the quantitative and qualitative findings systematically analyzing them. This issue emphasized the **inadequacy** of the relevant existing strategies for managing seafarers' fatigue in the Canadian and international maritime sectors, hence this necessitates their amendments.

(q) Less Stringency of the Canadian Marine Personnel Regulations (MPR) Compared to the STCW and MLC (2006) Regulations: This review's conclusion from the pieces of evidence obtained from its findings from Reviews Two and Four indicated evidence of various less stringency of the Canadian Marine Personnel Regulations (MPR) compared to the STCW and MLC (2006) regulations. Pieces of evidence describing these less stringent factors in the Canadian maritime sector are analyzed in Review Four, and with some TSBC reports extracts are described in Review Two. Many of these factors have been discussed above. The most predominant among such factors is HOR violations because the Canadian MPR permits seafarers a maximum of 112 hours to work in a 7-day period, which breached the 91 hours maximum time allowed to work by both the STCW and MLC 2006. Hence, the Canadian MPR, as a national standard of an IMO's member state, and yet MPR requirements instigate fatigue, therefore, this breached the *MLC (2006) regulation 2.3 standard A2.3 item 4* (International Labour Organization (ILO), 2006, p.30).

This issue emphasized the **inadequacy** of the Canadian MPR for managing seafarers' fatigue in the Canadian sector, hence this necessitates its amendment.

Table 5.1. Overall Review Summary of Evidence for Integrating Reviews One, Two, Three, and Four in Chapters One, Two, Three, and Four, Respectively, for Answering the Overall Review Question, Objective, and Topic, to Ascertain the Adequacy of the Existing Regulations and Strategies for Managing and Preventing Seafarers' Fatigue in the Canadian and International Maritime Sectors

S/N	Findings Showing Evidence of Regulatory Inadequacies or Violations or Causal Factors of Seafarers' Fatigue in the International Maritime Sector, Including Canada	Sources of Evidence Confirming Findings on Regulatory Inadequacies or Violations or Causal Factors of Seafarers' Fatigue in the International Maritime Sector, Including Canada (Yes or No or NA)				Ascertaining the Adequacy of the Existing Relevant Regulations and Strategies for Managing and Prevention Seafarers' Fatigue in the International Maritime Sector, Including Canada
		Review One in Chapter One	Review Two in Chapter Two	Review Three in Chapter Three	Review Four in Chapter Four	
1	Significant Prevalence of Seafarers' Fatigue as a Causal Factor of Maritime Accidents	+Yes	+Yes	*Yes	*Yes	Inadequate
2	Violations of *STCW* and *MLC (2006)* Hours of Rest (HOR) Regulations	*Yes	*Yes	*Yes	*Yes	Inadequate
3	6 Hours On and 6 Hours Off Shift Schedule	*Yes	*Yes	*Yes	*Yes	Inadequate
4	Insufficient Manning and Inefficiency of Two Officers' Watchkeeping System	*Yes	*Yes	*Yes	*Yes	Inadequate
5	Ineffective or Lack of Implementation of the Company/Shipboard Fatigue Risk Management System	*Yes	*Yes	*Yes	Yes	Inadequate
6	Short-Sea Services and Frequent Port Calls	*Yes	*Yes	*Yes	*Yes	Inadequate
7	Absence of a Maritime Industry's Gold Standard Measure of Seafarers' Fatigue	*Yes	*Yes	*Yes	*Yes	Inadequate
8	Absence of a Multi-factor Auditing Tool	*Yes	*Yes	*Yes	*Yes	Inadequate
9	High Seafarers' Physical and Mental Workload, and Overwork	*Yes	*Yes	*Yes	*Yes	Inadequate
10	Absence of Previous Comprehensive Systematic Review for Assessing the Adequacy of Relevant Regulations and Strategies for Managing and Preventing Seafarers' Fatigue in the International Maritime Sector, Including Canada, to Ensure their Adequacy, for Continual Enhancement and Adequacy	*Yes	NA	*Yes	*Yes	Inadequate
11	More Than Six-Months Long Tour Period of Duty	*Yes	*Yes	*Yes	*Yes	Inadequate
12	Absence of the Application of Updated Epidemiological Principles in the Design and Analysis of a Study Assessing Seafarers' Fatigue as a Causal Factor of Maritime Accident	*Yes	*Yes	*Yes	*Yes	Inadequate

NOTE: **+** depicts quantitative evidence findings; ***** depicts qualitative evidence findings; **NA** depicts not applicable; **Yes** depicts that it is a source of evidence confirming findings on regulatory inadequacies or violations or causal factors of seafarers' fatigue in the international maritime sector, including Canada; **No** depicts that is not a source of evidence confirming findings on regulatory inadequacies or violations or causal factors of seafarers' fatigue in the international maritime sector, including Canada.

Table 5.1. Overall Review Summary of Evidence for Integrating Reviews One, Two, Three, and Four in Chapters One, Two, Three, and Four, Respectively, for Answering the Overall Review Question, Objective, and Topic, to Ascertain the Adequacy of the Existing Regulations and Strategies for Managing and Preventing Seafarers' Fatigue in the Canadian and International Maritime Sectors

S/N	Findings Showing Evidence of Regulatory Inadequacies or Violations or Causal Factors of Seafarers' Fatigue in the International Maritime Sector, Including Canada	Sources of Evidence Confirming Findings on Regulatory Inadequacies or Violations or Causal Factors of Seafarers' Fatigue in the International Maritime Sector, Including Canada (Yes or No or NA)				Ascertaining the Adequacy of the Existing Relevant Regulations and Strategies for Managing and Prevention Seafarers' Fatigue in the International Maritime Sector, Including Canada
		Review One in Chapter One	Review Two in Chapter Two	Review Three in Chapter Three	Review Four in Chapter Four	
13	The Master's Overriding Authority Issue	*Yes	*Yes	*Yes	*Yes	Inadequate
14	IMO 2019 Guidelines on Fatigue Overemphasized on the Seafarers' Responsibility Without Recognizing Limitations Beyond Seafarers' Control, and Overstressed Fatigue Risk Factors that Cannot Replace Specific and Implementable Recommendations	*Yes	*Yes	*Yes	*Yes	Inadequate
15	Practical Impossibility of Granting Shore Leave to Seafarers	*Yes	*Yes	*Yes	*Yes	Inadequate
16	Less Stringency of the Canadian Marine Personnel Regulations (MPR) compared to STCW and MLC (2006) Regulations	NA	*Yes	NA	*Yes	Inadequate

NOTE: **+** depicts quantitative evidence findings; ***** depicts qualitative evidence findings; **NA** depicts not applicable; **Yes** depicts that it is a source of evidence confirming findings on regulatory inadequacies or violations or causal factors of seafarers' fatigue in the international maritime sector, including Canada; **No** depicts that is not a source of evidence confirming findings on regulatory inadequacies or violations or causal factors of seafarers' fatigue in the international maritime sector, including Canada.

5.2 Recommendations to Canada and International Regulatory Bodies

The various recommendations made based on various findings and conclusions in this project to the Canadian and international regulatory bodies, including the International Maritime Organization, International Labour Organization, and Transport Canada, among others, to serve as a toolkit for amending the existing Canadian and international regulations relevant to managing and preventing seafarers' fatigue to ensure their adequacy are stated in various paragraphs below in this section.

(a) Recommendation for Cohesive Involvement and Cooperation of all Maritime Stakeholders at all Levels in Addressing Seafarers' Fatigue Issues: This project recommends that seafarers' fatigue should be handled by using an integrated involvement and cooperation of all maritime stakeholders at all levels in addressing seafarers' fatigue issues, involving International regulatory bodies (including the IMO and ILO, among others), the maritime industries, Port States, and the international and national seafarers, among others. This is because success can only be achieved if all the various levels of stakeholders are cooperatively and cohesively involved, not in isolation. Hence, the necessary amendments of the international and Canadian maritime regulations relevant to managing seafarers' fatigue should be done with harmonized involvement, contributions, and cooperation of all stakeholders at all levels.

(b) Recommendation for Executing Necessary Effective Regulatory Amendments to Address all Existing Relevant Factors that are Instigating Seafarers' Fatigue: This project recommends necessary effective regulatory amendments of the international and Canadian maritime regulations to address all existing relevant factors that are instigating seafarers' fatigue in the international and Canadian maritime sectors because existing regulatory requirements are inadequate to address these issues. These issues include violations of Hours of Rest (HOR), 6 hours

on and 6 hours off watchkeeping system, insufficient manning (under-manning) and inefficiency of two officers' watchkeeping system and inefficient lookout standard, stress and overwork due to high workload, inefficient or lack of company/shipboard fatigue risk management system, short-sea services and frequent port calls, absence of a maritime industry's gold standard measure of seafarers' fatigue, absence of a multi-factor auditing tool, more than six months long tour period of duty, master's overriding authority issues, the practical impossibility of granting shore leave to seafarers, and less stringency of the Canadian Marine Personnel Regulations (MPR) compared to *STCW* and *MLC (2006)* regulations. Relevant provisions to address these various concerns should be integrated into the amendments of STCW, MLC (2006), and Canadian MPR to ensure their sufficiency or by initiating new actions.

(c) Recommendation for Regulatory Amendments to Ensure Adequate Manning Involving Three Officers Watchkeeping to Enable the Master to Execute his Duties and to Enhance the Lookout Standard: This project recommends that crucial regulatory amendments to ensure adequate manning that requires all merchant vessels over 500gt to have least three officers watchkeeping comprising of a master plus two bridge watchkeeping officers should be done. This will address the inefficiency of the two officers' watchkeeping system in the existing requirements, enable the master to execute his duties effectively and enhance the lookout standard. This must be done on an international basis, and all IMO's member States must comply with it, and it must be made mandatory.

(d) Recommendation for Amendments Requiring Mandatory Implementation of Efficient Fatigue Risk Management System (FRMS) on all Merchant Vessels Over 500gt Navigating on International and National Waters, Including Canadian Waters: This project recommends essential amendments requiring mandatory implementation of effective Fatigue Risk

Management System (FRMS) as part of the International Safety Management (ISM) Code on all merchant's vessels over 500gt navigating on international and national waters, including Canadian waters. The FRMS will enable addressing all these seafarers' fatigue issues with a holistic efficient way of managing and preventing seafarers' fatigue. The FRSM mandatory components should include effectively changing how working and rest hours are recorded; optimising the organisation of work on board vessels; reducing administrative tasks on board vessels; fatigue awareness, and advancing fatigue management training and information campaigns; efficient Fatigue Management Program/Plan; lengthening the resting period; fewer visitors, inspectors in the harbour, and better coordination of inspections; reducing overtime; development of a management tool for fatigue; and proper implementation of the ISM-code, among others. Similarly, this must be done on an international basis, and all IMO's member States must comply with it, and it must be made mandatory.

(e) Recommendation for Establishing a Maritime Industry's Gold Standard for Measuring Seafarers' Fatigue to Enable Precise, Valid, and Reliable Measurement: This project recommends that the IMO's technical committee should establish a maritime industry's gold standards for measuring seafarers' fatigue to enable precise, valid, and reliable seafarers' fatigue assessment, enhance relevant research study on the assessment of seafarers fatigue, and prevent various errors that may cause invalid, imprecise, and unreliable seafarers' fatigue assessment.

(f) Recommendation for Establishing a Multi-Factor Seafarers' Fatigue Auditing Tool in the Maritime Industry to Measure the Various Interrelated Seafarers' Fatigue Multi-Factors Causal Factors Precisely and Accurately in a Reliable Way: This systematic review recommends that the IMO's technical committee should establish a multi-factor seafarers' fatigue auditing tool

in the maritime industry to measure the various interrelated seafarers' fatigue multi-factors causal factors precisely and accurately in a reliable way. This is essential because the seafarers' fatigue causal factors are multi-factors and they most often occur as a combination of different interrelated factors, hence, a multifactor auditin system is needed to precisely and accurately measure them.

(g) Recommendation for Amendments Requiring Reduction of Long Tours of Duty Period from the Existing Maximum of Twelve Months to Six or Fewer Months: This study recommends that the IMO, ILO, and Transport Canada, and others national and international maritime regulatory bodies should make amendments requiring reduction of long tours of duty period from the existing maximum of twelve months to six or fewer months. This is necessary because fatigue and stress increase as the navigation length increases, and which results in crews mostly being unable to meet their mandatory hours of rest specified by the STCW and MLC (2006) regulatory requirements. Moreover, the MARTHA project and the ITF Employment Agreement recommended six months maximum long tour period of duty to effectively manage seafarers' fatigue (Barnett et al., 2017; Exarchopoulos et al., 2018). Compliance with this amendment must be done on an international basis, and all IMO's member States must comply with it as a minimum manning standard, and it must be made mandatory.

(h) Recommendation for Upgrading the Existing IMO 2019 Guidelines on Fatigue to Address All its Current Limitations: This project recommends that the existing IMO 2019 Guidelines on Fatigue should be amended to address its existing limitation of performing its role as a strategic IMO document for guidelines on fatigue. This document overelaborates on fatigue risk factors which cannot replace specific and implementable recommendations. Also, more emphasis was placed on seafarers' responsibility, whereas, what is required for fatigue

management requirements is to change from personal to operational, because industry-wide and cultural safety change to manage seafarers' fatigue is what is crucially needed.

(h) Recommendation for Amendments of the Existing Canadian Marine Personnel Regulations (MPR) to Conform, at least, with STCW and MLC (2006) Regulations, Being the Minimum International Regulations in the Maritime Sector: The study recommends the amendments of the existing Canadian Marine Personnel Regulations (MPR) to conform, at least, with STCW and MLC (2006) regulations, being the minimum acceptable international regulations in the maritime sector. This is necessary to address the less stringency nature of the Canadian Marine Personnel Regulations (MPR) compared to the STCW and MLC (2006) regulations. For instance, the Canadian MPR permits seafarers a maximum of 112 hours to work in a 7-day period, which breached the 91 hours maximum time allowed to work by both the STCW and MLC 20. This prevents Canadian seafarers from having adequate hours of rest and instigates fatigue, hence, requiring necessary amendments.

(i) Recommendation for the Application of an Updated Epidemiological Principles in the Conducting the Design and Analysis of a Maritime Study Assessing Seafarers' Fatigue: This systematic review recommends that the IMO's technical committee should mandatorily require the application of an updated epidemiological principle in conducting the design and analysis of a maritime study assessing seafarers' fatigue. This is because seafarers' fatigue is an illness, and this uniqueness distinguishes it from all other causal factors of maritime accidents. Therefore, an adequate understanding of its study requires updated epidemiological principles, hence necessitating its application.

(j) Recommendation for Conducting a Periodic Comprehensive Systematic Review for Assessing the Adequacy of Relevant Regulations Relevant for Managing Seafarers' Fatigue in

the International Maritime Sector, Including Canada: This systematic review recommends that the IMO's technical committee should be conducting a periodic comprehensive systematic review for assessing the adequacy of relevant regulations relevant for managing seafarers' fatigue in the international maritime sector, including Canada. This is necessary to assess their adequacy to be able to know areas of improvement and deficiencies for the purpose of continual regulatory development for advancing safety at sea.

5.3 Originality of this Overall Review

This project is the first of its type to conduct a systematic review to ascertain the adequacies of the existing regulations and strategies relevant to managing and preventing seafarers' fatigue in the international maritime sector, including Canada. Novel clues emanated from this study for addressing seafarers' fatigue issues.

5.4 Future Research

Some future research requiring more maritime research work emanated from this project. These include the application of updated epidemiological principles in the analysis of bias, confounder, and random error in the design and analysis of a study assessing seafarers' fatigue as a causal factor of maritime accidents. This is a future research area that needs more future maritime research as its adequate involves application is critical to maritime safety. Also, the continuation of this current research should continue to explore all sources of evidence not explored by this project relevant to answering this review question for the purpose of creating a very robust regulatory amendment toolkit for amending the inadequacies in the existing regulations for managing seafarers' fatigue in the international and Canadian maritime sectors. Other areas of future research emanating from this project's recommendations include establishing a multi-factor seafarers' fatigue auditing tool in the maritime industry to measure the various interrelated

seafarers' fatigue multi-factors causal factors precisely and accurately in a reliable way; and establishing a maritime industry's gold standard for measuring seafarers' fatigue to enable precise, valid, and reliable measurement.

Appendix 1A

The Methodological Quality Assessment Summary of Included Studies

S/N	CRITICAL QUALITY APPRAISAL CRITERIA	CRITICAL QUALITY APPRAISAL RATING CODING						
		Raby & Lee (2001)	MAIB (2004)	Hottman et al. (2005)	Smith et al. (2006)	Akhtar & Utne (2014)	Tang et al. (2013)	Acejo et al. (2018)
1	*Were the criteria for inclusion in the sample clearly defined?*	✚	✚	✚	✚	✚	✚	✚
2	*Were the study subjects and the setting described in detail?*	✚	✚	✚	✚	✚	✚	✚
3	*Was the exposure measured in a valid and reliable way?*	✚	✚	✚	✚	✚	●	●
4	*Were objective, standard criteria used for the measurement of the condition?*	●	●	●	●	●	●	●
5	*Were confounding factors identified?*	●	✚	●	✚	✚	✚	━
6	*Were strategies to deal with confounding factors stated?*	●	✚	●	✚	✚	━	━
7	*Were the outcomes measured in a valid and reliable way?*	✚	✚	✚	✚	✚	✚	✚
8	*Was appropriate statistical analysis used?*	✚	✚	✚	✚	✚	✚	✚
OVERALL QUALITY SCORE.		FAIR	GOOD	FAIR	GOOD	GOOD	FAIR	FAIR
CODING MEANING		**Yes is denoted by** ✚ **No is denoted by** ━ **Unclear** ●						

Note: See Appendix 1B for an explanation.

Appendix 1B

Explanation of Critical Appraisal Quality Score.

Good: Clear and sufficiently detailed inclusion and exclusion criteria, detailed description of the study subjects and the setting, exposure measured in a valid and reliable way, objective standard criteria were used for measurement of the condition, confounding factors identified, and strategies to deal with them stated, outcomes measured in a valid and reliable way, and appropriate statistical analysis used.

Poor: Unclear and insufficiently detailed inclusion and exclusion criteria, no detailed description of the study subjects and the setting, exposure not measured in a valid and reliable way, objective standard criteria were not used for measurement of the condition, confounding factors not identified and no strategies to deal with them stated, outcomes measured in an invalid and unreliable way, and appropriate statistical analysis not used.

Fair: Moderately good characteristics.

Quality Score: Three articles included with the above optimal characteristics are good, while all the excluded articles with Unclear and insufficient characteristics are poor. Four articles with moderate characteristics were considered fair.

Critical Appraisal Coding Answers: All items included were phrased in such a way that they each relate to a single aspect of quality assessment criteria and can be assessed as **'yes', 'no', or Unclear**. An assessment of **'yes'** referred to the optimal methodological characteristic, the judgment of **'no'** referred to the less-than-optimal methodological characteristic, and an assessment of **'unclear'** referred to an uncertain methodological characteristic.

Appendix 2A

Review Overall Summary Table

Years from 1990 to 2021, from which Eligible Reports are Gathered	Number of Eligible Reports in Each Year from United Kingdom's (UK) MAIB (500GT or Higher)	Number of Eligible Reports in Each Year from Canada's TSBC (500GT or Higher)	Number of Eligible Reports in Each Year from Australia's ATSB (500GT or Higher)	Number of Eligible Reports in Each Year from United States of America's (USA) NTSB (500GT or Higher)	Number of Eligible Reports in Each Year from Denmark's DMIB (500GT or Higher)	Total Number of All Eligible Reports in Each Year from All the Five Countries (A) (500GT or Higher)	The Total Number of All Eligible Reports in Each Year that indicated Seafarers' Fatigue as a Causal factor from All of the Five Countries (B)	Prevalence (%) of Maritime Accidents which Reports are Finally Included that indicated Seafarers' Fatigue as a Causal factor in Each Year from 1990 to 2021 from All of the Five Countries (B/A)
1990	1	0	0	2	-	3	0	0
1991	1	3	13	1	-	18	1	5.55
1992	3	4	10	1	-	18	2	11.11
1993	2	14	9	0	-	25	3	12
1994	3	18	10	0	-	31	1	3.22
1995	2	21	11	4	-	38	4	10.53
1996	7	21	15	2	-	45	3	6.67
1997	8	18	19	2	-	47	8	17.02
1998	10	14	14	4	-	42	2	4.76
1999	26	17	10	0	-	53	4	7.54
2000	25	13	12	2	-	52	9	17.30
2001	21	10	12	1	-	44	9	20.45
2002	16	7	13	0	-	36	7	19.44
2003	7	8	9	3	-	27	5	18.51
2004	21	10	9	2	-	42	11	26.19
2005	12	11	9	1	-	33	5	15.15
2006	18	9	12	2	-	41	8	19.51
2007	13	2	14	4	-	33	5	15.15
2008	17	4	13	3	-	37	5	13.51
2009	10	5	9	0	-	24	4	16.67
2010	14	1	11	2	4	32	3	9.37
2011	28	6	7	4	4	49	6	12.24
2012	15	8	5	14	9	51	5	9.80
2013	18	7	7	12	6	50	6	12
2014	14	8	14	7	8	51	3	5.88
2015	12	4	6	20	3	45	2	4.44
2016	9	5	4	24	3	45	2	4.44
2017	21	14	6	16	2	59	3	5.08
2018	15	11	8	21	0	55	3	5.45
2019	8	7	0	30	3	48	1	2.08
2020	6	7	2	15	4	34	0	0
2021	1	0	1	18	3	23	0	0

Appendix 2B

United Kingdom's (UK) MAIB Summary Table

Years from 1990 to 2021, from which Eligible Reports are Gathered	Number of Eligible Reports in Each Year from United Kingdom's (UK) MAIB (500GT or Higher)	The Total Number of All Eligible Reports in Each Year that indicated Seafarers' Fatigue as a Causal factor from the United Kingdom's (UK) MAIB (500GT or Higher)	Prevalence (%) of Maritime Accidents Reports Finally Included that indicated Seafarers' Fatigue as a Causal factor in Each Year from 1990 to 2021 from United Kingdom's (UK) MAIB
1990	1	0	0
1991	1	0	0
1992	3	0	0
1993	2	1	50
1994	3	0	0
1995	2	0	0
1996	7	0	0
1997	8	3	37.50
1998	10	1	10
1999	26	3	8.33
2000	25	6	24
2001	21	7	33.33
2002	16	3	18.75
2003	7	4	57.14
2004	21	7	33.33
2005	12	3	25
2006	18	4	22.22
2007	13	1	7.69
2008	17	2	11.76
2009	10	1	10
2010	14	1	7.14
2011	28	5	17.86
2012	15	2	13.33
2013	18	5	27.78
2014	14	1	7.14
2015	12	1	8.33
2016	9	0	0
2017	21	1	4.76
2018	15	0	0
2019	8	1	12.5
2020	6	0	0
2021	1	0	0

Appendix 2C

Canada's TSBC Summary Table

Years from 1990 to 2021, from which Eligible Reports are Gathered	Number of Eligible Reports in Each Year from Canada's TSBC (500GT or Higher)	The Total Number of All Eligible Reports in Each Year that are Finally Included that indicated Seafarers' Fatigue as a Causal factor from Canada's TSBC. (500GT or Higher)	Incident Percentage (%) of Maritime Accidents Reports Finally Included that indicated Seafarers' Fatigue as a Causal factor in Each Year from 1990 to 2021 from Canada's TSBC
1990	0	0	0
1991	3	0	0
1992	4	2	50
1993	14	2	14.28
1994	18	1	5.55
1995	21	0	0
1996	21	2	9.52
1997	18	3	16.67
1998	14	1	7.14
1999	17	0	0
2000	13	0	0
2001	10	0	0
2002	7	1	14.28
2003	8	0	0
2004	10	2	20
2005	11	1	9.09
2006	9	3	33.33
2007	2	1	50
2008	4	1	25
2009	5	0	0
2010	1	0	0
2011	6	1	16.67
2012	8	2	25
2013	7	1	14.28
2014	8	1	12.50
2015	4	1	25
2016	5	1	20
2017	14	1	7.14
2018	11	1	9.09
2019	7	0	0
2020	7	0	0
2021	0	0	0

Appendix 2D

Australia's ATSB Summary Table

Years from 1990 to 2021, from which Eligible Reports are Gathered	Number of Eligible Reports in Each Year from Australia's ATSB (500GT or Higher)	The Total Number of All Eligible Reports in Each Year that are Finally Included that indicated Seafarers' Fatigue as a Causal factor from Australia's ATSB (500GT or Higher)	Incident Percentage (%) of Maritime Accidents Reports Finally Included that indicated Seafarers' Fatigue as a Causal factor in Each Year from 1990 to 2021 from Australia's ATSB
1990	0	0	0
1991	13	1	7.69
1992	10	0	0
1993	9	0	0
1994	10	0	0
1995	11	2	18.18
1996	15	1	6.67
1997	19	2	10.53
1998	14	0	0
1999	10	1	10
2000	12	3	25
2001	12	2	16.67
2002	13	3	23.07
2003	9	1	11.11
2004	9	1	11.11
2005	9	1	11.11
2006	12	1	8.33
2007	14	3	21.43
2008	13	1	7.69
2009	9	3	33.33
2010	11	1	9.09
2011	7	0	0
2012	5	1	20
2013	7	0	0
2014	14	0	0
2015	6	0	0
2016	4	0	0
2017	6	0	0
2018	8	0	0
2019	0	0	0
2020	2	0	0
2021	1	0	0

Appendix 2E

United States of America's (USA) NTSB Summary Table

Years from 1990 to 2021, from which Eligible Reports are Gathered	Number of Eligible Reports in Each Year from the United States of America's (USA) NTSB (500GT or Higher)	The Total Number of All Eligible Reports in Each Year that are Finally Included that indicated Seafarers' Fatigue as a Causal Factor from the United States of America's (USA) NTSB (500GT or Higher)	Incident Percentage (%) of Maritime Accidents Reports Finally Included that indicated Seafarers' Fatigue as a Causal Factor in Each Year from 1990 to 2021 from the United States of America's (USA) NTSB
1990	2	0	0
1991	1	0	0
1992	1	0	0
1993	0	0	0
1994	0	0	0
1995	4	2	50
1996	2	0	0
1997	2	0	0
1998	4	0	0
1999	0	0	0
2000	2	0	0
2001	1	0	0
2002	0	0	0
2003	3	0	0
2004	2	1	50
2005	1	0	0
2006	2	0	0
2007	4	0	0
2008	3	1	33.33
2009	0	0	0
2010	2	1	50
2011	4	0	0
2012	14	0	0
2013	12	0	0
2014	7	0	0
2015	20	0	0
2016	24	1	4.17
2017	16	1	6.25
2018	21	2	9.52
2019	30	0	0
2020	15	0	0
2021	18	0	0

Appendix 2F

Denmark's DMIB Summary Table

Years from 1990 to 2021, from which Eligible Reports are Gathered	Number of Eligible Reports in Each Year from the United States of America's (USA) NTSB (500GT or Higher)	The Total Number of All Eligible Reports in Each Year that are Finally Included that indicated Seafarers' Fatigue as a Causal Factor from the United States of America's (USA) NTSB (500GT or Higher)	Prevalence (%) of Maritime Accidents Reports Finally Included that indicated Seafarers' Fatigue as a Causal Factor in Each Year from 1990 to 2021 from the United States of America's (USA) NTSB
1990	0	0	0
1991	0	0	0
1992	0	0	0
1993	0	0	0
1994	0	0	0
1995	0	0	0
1996	0	0	0
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
2006	0	0	0
2007	0	0	0
2008	0	0	0
2009	0	0	0
2010	4	0	0
2011	4	0	0
2012	9	0	0
2013	6	0	0
2014	8	1	12.5
2015	4	0	0
2016	3	0	0
2017	2	0	0
2018	0	0	0
2019	3	0	0
2020	4	0	0
2021	3	0	0

Appendix 2G

Qualitative Characteristics of Included Reports Findings

S/N	Name of the Vessel	Year of the Accident	Included Reports Indicating Fatigue as a Causal Factor of Accident	Accident Type	Seafarers' Fatigue Causa Factors & Associated Factors
1	British Trent	1993	-	Collision	Lack of Rest
2	mv Cita	1997	MAIB Report nr 3/1998	Grounding	Undermanning, Inadequate sleep
3	Sandkite	1997	MAIB Report nr 2/1999	Collision	Undermanning, High workload
4	Green Lily	1997	MAIB Report nr 5/1999	Grounding	Stress, Slow action, Undermanning
5	Pentland	1998	-	Grounding	Lack of sleep, Overwork, Inadequate sleep
6	Baltic Champ	1999	MAIB Report nr 1/6/109	Grounding	Fatigue
7	Dole America	1999	MAIB Report nr 32/109	Collision	Wrong Decisions, Stress, Inadequate sleep
8	Hoo Robin	1999	MAIB Report nr 1/3/166	Collision	High workload, Accumulated Fatigue
9	Celtic King	2000	MAIB Report nr 2/2001	Collision	No lookout, Affected judgment,
10	Coastal Bay	2000	MAIB Report nr 8/2001	Grounding	Undermanning, Inadequate rest
11	European Pioneer	2000	MAIB Report nr 16/2001	Grounding	Inadequate rest, Affected alertness
12	Highland Pioneer	2000	MAIB Report nr 15/2001	Collision	Inadequate attention, Fatigue
13	Randgrid	2000	MAIB Report nr 6/2002	Oil Spillage	Fatigue, Inadequate Concentration
14	Global Mariner	2000	MAIB Report nr 35/2002	Collision	Stress, Poor decision making
15	Sand Heron	2001	MAIB Report nr 14/2002	Collision	Poor Judgment, Poor lookout, Overwork
16	Gudermes	2001	MAIB Report nr 5/2002	Collision	Inadequate sleep, Fatigue
17	Our Nicholas	2001	MAIB Report nr 26/2002	Grounding	Inadequate sleep
18	P & O Nedlloyd Magellan	2001	MAIB Report nr 18/2002	Grounding	Poor judgement
19	Resplendent	2001	MAIB Report nr 10/2002	Grounding	Inadequate sleep
20	Royal Princess	2001	MAIB Report nr 34/2002	Human Injury	Inadequate sleep, Stress, Poor concentration
21	Atlantic Mermaid	2001	MAIB Report nr 12/2002	Collision	Tiredness
22	Sardinia Vera	2002	MAIB Report nr 32/2002	Grounding	Fatigue
23	Stena Gothica	2002	MAIB Report nr 39/2002	Collision	Overwork
24	Marbella	2002	MAIB Report nr 11/2003	Collision	Inadequate sleep/rest
25	Donald Redford	2003	MAIB Report nr 6/2004	Collision	Long hours of work, Inadequate rest
26	Hilli	2003	MAIB Report nr 4/2007	Explosion	Long hours of work, Inadequate rest
27	Jambo	2003	MAIB Report nr 27/2003	Grounding	Undermanning, Fatigue
28	P&O Nedlloyd Vespucci	2003	MAIB Report nr 28/2003	Collision	Fatigue, Reduced alertness
29	Balmoral	2004	MAIB Report nr 14/2005	Grounding	Tiredness, Disrupt sleep, Poor concentration
30	Border Heather	2004	MAIB Report nr 5/2006	Explosion & Fire	Overwork, Fatigue
31	Hoo Finch	2004	MAIB Report nr 10/2004	Collision	Sleep Debt, Poor alertness
32	Hyundai Dominion	2004	MAIB Report nr 17/2005	Collision	Overwork, Poor decision making & judgement
33	Jackie Moon	2004	MAIB Report nr 5/2005	Grounding	Inadequate sleep, Fatigue
34	Scot Venture	2004	MAIB Report nr 11/2004	Contact	Undermanning
35	Reno	2004	MAIB Report nr 13/2004	Collision	Tiredness
36	Lerrix	2005	MAIB Report nr 14/2006	Grounding	6 hours on / 6 hours off, Distress
37	Likes Voyager	2005	MAIB Report nr 6/2006	Collision	Inadequate sleep, Overwork, Fatigue
38	Orade	2005	MAIB Report nr 23/2005	Collision	6 hours on / 6 hours off, High workload
39	Berit	2006	MAIB Report nr 17/2006	Grounding	Inadequate rest
40	FR8 Venture	2006	MAIB Report nr 16/2007	Fatality & Injury	6 hours on / 6 hours off
41	Neermoor	2006	MAIB Report nr 31/2007	Fatality	Fatigue, Overwork, Lack of record of rest hours
42	The Calypso	2006	MAIB Report nr 8/2007	Fire	Fatigue
43	Annabella	2007	MAIB Report nr 21/2007	Cargo Collapse	Inadequate rest, Fatigue
44	Antari	2008	MAIB Report nr 7/2009	Grounding	6 hrs on/ 6 hrs off, Short-sea work, Much port call
45	Pride of Canterbury	2008	MAIB Report nr 2/2009	Grounding	Tiredness, Increased workload,
46	Saetta	2009	MAIB Report nr 3/2010	Collision	No record of hrs of work and rest, Inadequate rest
47	Ever Excel	2010	MAIB Report nr 6/2010	Fatality	Long contract term, Overwork, High work demand
48	ACX Hibiscus	2011	MAIB Report nr 15/2013	Collision	Overworked excess hours, Fatigue
49	MV Boxford	2011	MAIB Report nr 17/2011	Collision	Inadequate rest, Stress
50	Clonlee	2011	MAIB Report nr 6/2012	Grounding	Tiredness, Risky work routine
51	FV Jack Abry II	2011	MAIB Report nr 14/2011	Grounding	Stress, Inadequate sleep
52	Karin Scepers	2011	MAIB Report nr 10/2012	Grounding	Lack of rest, Slow reaction, Slow decision-making
53	MV Beaumont	2012	MAIB Report nr 14/2013	Grounding	Fatigue, Changing in work and rest pattern
54	Spring Bok	2012	MAIB Report nr 24/2012	Collision	Sleep debt, Frequent port calls, Work demand
55	Apollo	2013	MAIB Report nr 15/2014	Contact	Inadequate sleep
56	Danio	2013	MAIB Report nr 8/2014	Grounding	6 hours on / 6 hours off, Undermanning, Workload
57	Douwent	2013	MAIB Report nr 4/2014	Grounding	Long consecutive nights watching
58	Finnarrow	2013	MAIB Report nr 24/2013	Contact & Flooding	Inadequate rest, Tiredness, Overwork
59	Fri Ocean	2013	MAIB Report nr 26/2013	Grounding	Inadequate sleep, Lack of fatigue risk management
60	Orakai	2014	MAIB Report nr 16/2015	Collision	Fatigue
61	Cemfjord	2015	MAIB Report nr 8/2016	Capsize & Sinking	6 hours on / 6 hours off, Tiredness

Note: MAIB: Marine Accident Investigation Branch. Website: www.maib.gov.uk

Appendix 2H

Qualitative Characteristics of Included Reports Findings (continuation)

S/N	Name of the Vessel	Year of the Accident	Included Reports Indicating Fatigue as a Causal Factor of Accident	Accident Type	Seafarers' Fatigue Causal Factors & Associated Factors
62	Huayang Endeavour	2017	MAIB Report nr 7/2018	Collision	Working 14 hours between rest periods
63	Karina C	2019	MAIB Report nr 18/2020	Fatality & Injuries	Tiredness, Lack of rest, Recording false rest hours
1	Zodiac	1991	ATSB MAIR 35	Collision	Fatigue
2	Carola	1995	ATSB MAIR 79	Grounding	Inadequate sleep
3	Svendborg Guardian	1995	ATSB MAIR 82	Grounding	Inadequate sleep, Poor sleep quality
4	Peacock	1996	ATSB MAIR 95	Grounding	Chronic fatigue
5	Alkaterini L	1997	ATSB MAIR 111	Grounding	Inadequate sleep
6	Exterminator	1997	ATSB MAIR 111	Collision	Sleep debt, Jet lag
7	Newreach	1999	ATSB MAIR 147	Grounding	Inadequate sleep
8	Ariake	2000	ATSB MAIR 153	Collision	Fatigue
9	Silver Bin	2000	ATSB MAIR 156	Collision	Fatigue
10	Wyuna	2000	ATSB MAIR 161	Grounding	High workload
11	Handymariner	2001	ATSB MAIR 163	Collision	Chronic fatigue
12	Maksim Mikhaylov	2001	ATSB MAIR 168	Contact	No record of work and rest, High workload
13	CSL Pacific	2002	ATSB MAIR 175	Severe Injury	Excessive work hours, Chronic Fatigue
14	ANL Excellence	2002	ATSB MAIR 181	Grounding	Fatigue
15	Doric Chariot	2002	ATSB MAIR 182	Grounding	Fatigue
16	Tauranga Chief	2003	ATSB MAIR 190	Grounding	Fatigue
17	FV Ocean Odyssey	2004	ATSB MAIR 203	Collision	Poor quality sleep
18	Spartia	2005	ATSB MAIR 211	Collision	Fatigue
19	Massive Tide	2006	ATSB MAIR 231	Grounding	Fatigue
20	Silky Ocean	2007	ATSB MAIR 240	Collision	Tiredness, Sleep debt
21	Pasha Bulker	2007	ATSB MAIR 243	Grounding	Overwork, Fatigue
22	Oceanic Angel	2007	ATSB MAIR 244	Fatality	Inadequate sleep
23	Francoise Gilot	2008	ATSB MOI 254	Grounding	Fatigue
24	Ella's Pink Lady	2009	ATSB MOI 268	Collision	Inadequate sleep, Fatigue
25	Atlantic Blue	2009	ATSB MOI 262	Grounding	Tiredness, Overwork, Inadequate sleep
26	Thor Gitta	2009	ATSB MOI 265	Fatality	6 hour on/6 hour off, Fatigue
27	Shen Neng 1	2010	ATSB MOI 274	Grounding	Inadequate rest, Inadequate fatigue management
28	Weaver Arrow	2012	ATSB MOI 296	Fatality	Fatigue
1	Queen of Saanich	1992	TSBC Report nr M92W1012	Collision	High workload
2	Queen of New Westminster	1992	TSBC Report nr M92W1057	Fatality	High workload
3	Canadian Explorer	1993	TSBC Report nr M93L0001	Bottom Contact	Tiredness, Disrupt sleep
4	Nirja	1993	TSBC Report nr M93C0003	Striking	Inadequate rest, Overwork, Sleep debt
5	Catherine Desgagnes	1994	TSBC Report nr M94C0014	Striking & Grounding	Stress
6	Wolfe Islander III	1996	TSBC Report nr M96C0032	Dangerous Occurrence	Fatigue
7	Camille Marcoux	1996	TSBC Report nr M96L0069	Fatality	Stress
8	Venus	1997	TSBC Report nr M97L0030	Grounding	Fatigue, Lack of rest, Overwork
9	Mona Pearl	1997	TSBC Report nr M97M0022	Grounding	Fatigue, Poor work/rest schedule
10	Raven Arrow	1997	TSBC Report nr M98C0197	Grounding	Sleep debt, Irregular work schedule
11	Enerchem Refiner	1998	TSBC Report nr M98C0004	Grounding	Fatigue
12	Kent	2002	TSBC Report nr M0210061	Crew Member Lost	Fatigue
13	Canada Senator	2004	TSBC Report nr M04L0099	Collison	Inadequate rest, 2 people or less watchkeeping
14	Horizon	2004	TSBC Report nr M04L0092	Grounding	Fatigue
15	Michipicoten	2005	TSBC Report nr M05C0063	Grounding	Inadequate rest
16	Picton Castle	2006	TSBC Report nr M06F0024	Grounding	inadequate quantity/quality of sleep
17	Queen of the North	2006	TSBC Report nr M06N0052	Striking & Sinking	Restless sleep, Changing in sleeping time
18	Kometik	2006	TSBC Report nr M06N0014	Fire	Sleep debt, Overwork
19	Nordik Express	2007	TSBC Report nr M07L0158	Striking	High port calls, High workload, Inadequate rest
20	Algomarine	2008	TSBC Report nr M08C0024	Grounding	Lack of sleep
21	Empire 40	2011	TSBC Report nr M11W0091	Striking	Inadequate rest, Fatigue
22	Beaumont Hamel	2012	TSBC Report nr M12N0017	Striking	Sleep debt, Poor fatigue management plan
23	Tundra	2012	TSBC Report nr M12L0147	Grounding	Sleep disorder, Fatigue
24	Ocean Georgie	2013	TSBC Report nr M13L0123	Collision	Mental workload, Undermanning
25	Nanny	2014	TSBC Report nr M14C0219	Bottom Contact	Fatigue, Ineffective fatigue management
26	Atlantic Erie	2015	TSBC Report nr M15C0006	Grounding	Overwork, Inadequate rest
27	Nathan E. Stewart	2016	TSBC Report nr M16P0378	Grounding & Sinking	6-on, 6-off shift schedule, No fatigue management
28	Tug Ocean Monarch	2017	TSBC Report nr M17P0244	Bottom Contact	Acute fatigue, Chronic sleep disruptions
29	Akademie Ioffe	2018	TSBC Report nr M18C0225	Grounding	High workload

Note: MAIB: Marine Accident Investigation Branch. Website: www.maib.gov.uk
ATSB: Australian Transportation Safety Bureau; MAIR: Marine Safety Investigation Report; MOI: Marine Occurrence Investigation; Website: www.atsb.gov.au

Appendix 2I

Qualitative Characteristics of Included Reports Findings (continuation)

S/N	Name of the Vessel	Year of the Accident	Included Reports Indicating Fatigue as a Causal Factor of Accident	Accident Type	Seafarers' Fatigue Causal Factors & Associated Factors
1	Patriot	1995	NTSB/MAR-97/01/SUM_PB97-916402	Grounding	Inadequate rest
2	Star Princess	1995	NTSB/MAR-97/02_PB96-916403	Grounding	Sleep apnea, Fatigue
3	Le Conte	2004	NTSB/MAB-05/02_DCA-04MM-020	Grounding	Fatigue, Sleep deficit
4	Alaska Ranger	2008	NTSB/MAR-09/05_PB2009-916405	Sinking	Fatigue
5	Eagle Otome	2010	NTSB/MAR-11/04_PB2011-916404	Grounding	Sleep apnea, Fatigue
6	Specialist	2016	NTSB/MAB-17/14_ DCA16FM033	Collision & sinking	Undermanning High workload
7	Cerro Santiago	2017	NTSB/MAB-17/37_ DCA17PM011	Collision	High workload, Lack of sleep
8	Shandong Fu En	2018	NTSB/MAB-19/14_ DCA18FM020	Contact	Fatigue
1	Tom Republican	2014	DMAIB Report nr 2013026421	Injury	Inadequate rest, Fatigue

Note: NTSB: National Transportation Safety Board; MAR: Marine Accident Report; Website: www.ntsb.gov
DMAIB: Danish Maritime Accident Investigation Board; Website: www.dmaib.com

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