TP 13429E

STUDY ON EXTENDED COAST GUARD CREWING PERIODS

PHASE 3

Prepared for
Transportation Development Centre
Safety and Security
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and

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Fleet Services

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16. Abstract

The current study was Phase 3 of a multi-phase project entitled "Study on Extended Coast Guard Crewing Periods" (Davis *et al*., 1997, 1998). The purpose of the investigation was to determine whether extending the crewing period from 28 days to 42 days would lead to measurable changes in crew sleep, fatigue, and performance. As in the previous phases, measures of human performance (which focused on the bridge and engineering watchkeepers) included cognitive performance, sleep, fatigue, socio-psychological well-being, and physiological adaptation to different watch schedules. Phase 3 was conducted over two crewing periods on board the icebreaker CCGS *Sir Wilfrid Laurier* in the summer of 1998.

Data were examined in relation to two issues: first, the differences across three critical intervals in the 42-day crewing period; second, the differences among three watch schedules, including a 12&12 watch (*Sir Wilfrid Laurier*, Phase 3), a 6&6 watch (*Henry Larsen*, Phase 2), and a 4&8 watch (*Pierre Radisson*, Phase 1).

Crew state on the *Sir Wilfrid Laurier* appeared to change little during the 42-day crewing periods, and it was not clear that any of the 4&8, 6&6, or 12&12 watch schedules was superior to the others. The level of fatigue experienced by participants on the *Sir Wilfrid Laurier* was insufficient to affect objectively measured performance, and was similar throughout the crewing period, suggesting that it was not the length of the crewing period, but rather other factors that were the source of the fatigue experienced by the crew. A different pattern of alertness between day and night watchkeepers was also observed. Recommendations were made to raise the awareness of the dangers of inadequate sleep.

In the comparison of the watch schedules, participants on the 4&8 watch schedule had superior results on cognitive measures, while participants on the 6&6 indicated better socio-psychological well-being, and participants on the 12&12 had the opportunity to obtain better sleep. Participants' responses to the General History Questionnaire indicated that those on a 42-day crewing period were not receiving optimal sleep at sea.

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16. Résumé

La présente étude constituait la phase 3 d'un projet en plusieurs étapes intitulé «Étude sur les affectations prolongées en mer de la Garde côtière canadienne» (Davis *et al.,* 1997, 1998). L'objectif de cette étude était de déterminer si le prolongement d'une affection en mer de 28 à 42 jours entraînait des changements mesurables sur le plan du sommeil, de la fatigue et de la performance. À l'exemple des phases précédentes, l'évaluation de la performance humaine (qui s'est concentrée sur le personnel de quart sur la passerelle et dans la salle des machines) examinait notamment les fonctions cognitives, le sommeil, la fatigue, les facteurs psychosociologiques et l'adaptation physiologique à des horaires de travail différents. La phase 3 s'est déroulée pendant deux affectations prolongées en mer à bord du navire *Sir Wilfrid Laurier* de la GCC à l'été 1998.

Les données ont été analysées en fonction de deux aspects : premièrement, les différences observées au cours de trois périodes critiques d'une affectation de 42 jours; deuxièmement, les différences notées entre trois horaires de travail par quart, notamment un horaire «douze-douze» (*Sir Wilfrid Laurier,* phase 3), un horaire «six-six» (*Henry Larsen,* phase 2) et un horaire «quatre-huit» (*Pierre Radisson,* phase 1).

Il ne semble pas que la condition de l'équipage à bord du *Sir Wilfrid Laurier* n'ait beaucoup varié au cours de l'affectation en mer de 42 jours ni qu'un de ces horaires («quatre-huit», «six-six» et «douze-douze») ne soit préférable à un autre. Le degré de fatigue ressentie par les membres de l'équipage du *Sir Wilfrid Laurier* qui ont participé à l'étude n'était pas suffisant pour modifier objectivement la performance mesurée. La fatigue semblait exister chez les participants dès le début de l'affectation en mer, ce qui permet de penser que la durée de l'affectation n'était pas à l'origine de cette fatigue et que celle-ci découlait plutôt d'autres facteurs. Les équipes de quart de jour et de nuit manifestaient des profils de vigilance différents, et des recommandations ont été formulées afin d'accroître la sensibilisation aux dangers associés au manque de sommeil.

La comparaison des horaires de travail a révélé que les participants à l'horaire «quatre-huit» obtenaient des résultats supérieurs sur le plan cognitif, alors que les participants à l'horaire «six-six» faisaient état d'une amélioration des facteurs psychosociologiques et que les participants à l'horaire «douze-douze» avaient eu l'occasion de jouir d'un sommeil plus réparateur. Les réponses fournies par les participants au Questionnaire de renseignements généraux ont montré que les membres d'équipage en affectation pendant 42 jours n'avaient pas un sommeil optimal pendant leur séjour en mer.

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EXECUTIVE SUMMARY

In the three Arctic icebreaking seasons from 1996 to 1998, the Department of Fisheries and Oceans/Canadian Coast Guard (DFO/CCG) has investigated extending the crewing periods of those operations using a lay-day operational manning system from 28 days to 42 days. The purpose of the investigation was to determine if extending the crewing period would lead to measurable changes in crew sleep, fatigue, and performance.

The current study was Phase 3 of a multi-phase project entitled “Study on Extended Coast Guard Crewing Periods” (Davis *et al*., 1997, 1998). The focus of this phase was to obtain data on a 12&12 watchkeeping schedule over 42 days. As in the previous 2 phases, measures of human performance (which focused on the bridge and engineering watchkeepers) included cognitive performance, sleep, fatigue, socio-psychological well-being, and physiological adaptation to different watch schedules. Phase 3 was conducted over two crewing periods on board the icebreaker CCGS *Sir Wilfrid Laurier* in the summer of 1998.

As in Phase 2, the following three critical times during the crewing period were examined:

- Interval 1 - Days 7 to 12;
- Interval 2 - Days 26 to 31; and
- Interval 3 - Days 36 to 41.

These intervals were selected to reflect changes between the beginning and the end of the traditional 28-day crewing period and the first few days and final days of the extended crewing period between 28 and 42 days. The baseline data were collected between Days 7 to 12 to accommodate for sailing delays and the early transition to watch schedules. This also ensured that the baseline data reflected stable watch characteristics.

Data were examined in relation to two key issues:

1. Differences across the three critical intervals in the 42-day crewing period (as described above); and
2. Differences between the following watch schedules over a 42-day crewing period:

- the 4&8 watch on the *Pierre Radisson* (Phase1):
- the 6&6 watch on the *Henry Larsen* (Phase 2); and

- the 12&12 watch on the *Sir Wilfrid Laurier* (Phase 3).

Differences Across Intervals in the 42-Day Crewing Period

In this phase, as in the previous two phases, signs of fatigue were evident in some but not all measures, and no measure showed substantial change over the 42 days. However, the level of fatigue that participants experienced was insufficient to affect objectively measured performance, as defined by the Delta test battery. The data suggested that fatigue may have been evident, but it could not be characterized as severe.

The most significant indicators of fatigue were manifested in socio-psychological factors such as deteriorating mood and group dynamics, morale, and response to stress. Results of the End of Day Log and Retrospective Alertness Inventory (RAI) indicated that levels of participant fatigue remained similar over the course of the crewing period. This suggests that it was not the length of the crewing period, but rather other factors such as workload levels, vessel tasking, sleep duration and quality, and circadian rhythms that were the source of the fatigue experienced by the crew.

The results of the RAI also illustrated differences between day and night watchkeepers. Night watchkeepers reported different patterns of alertness than day watchkeepers in each interval. The pattern of change in the night watchkeepers' alertness indicated an incomplete circadian adjustment to a night routine.

Combined, the results of the comparison across intervals indicated that participants were experiencing similar levels of fatigue throughout the crewing period, and there was little evidence that the fatigue levels were increasing with the extended crewing operations. If fatigue is present from the beginning of the crewing period, the need to address fatigue in current operations is reinforced. Even though fatigue did not appear to escalate seriously in the current study, fatigue effects are more apparent when individuals are pushed to their limits, which did not occur in these studies. Personnel should be aware of the dangers of inadequate sleep, both at sea and at home, and they should take appropriate steps to increase their alertness while on board.

It is recommended that personnel receive fatigue awareness and fatigue management training to help them avoid, as much as possible, and better manage the effects of fatigue. The implementation of systematic measures to combat fatigue will better ensure appropriate levels of alertness at critical times.

Differences Between Watch Schedules

The comparison of the 4&8, 6&6, and 12&12 watch schedules did not show that one watch schedule was superior to the others in terms of maintaining the optimal crew state. Each watch schedule had both positive and negative aspects. Participants on the 4&8 watch schedule had superior results on cognitive measures, while participants on the 6&6 indicated better socio-psychological well-being, and participants on the 12&12 had the opportunity to obtain better sleep. The superior cognitive performance of personnel on the 4&8 watch schedule may have been due to a more balanced workload level, creating a state in which the crew were neither bored nor overworked.

With all other things being equal, the most important factors in preventing fatigue are sleep duration and quality over the length of a 42-day crewing period. Therefore, the opportunity to obtain a least seven hours of uninterrupted sleep, combined with attempts to balance workload so that crews are neither bored nor overworked should provide the greatest defense against fatigue-related problems in extended crewing periods. From this perspective, the 12&12 watch schedule affords the best opportunity to minimize fatigue, though special consideration should be given to managing fatigue for the personnel working overnight.

The personnel on the 12&12 watch had the greatest opportunity for sleep quantity and quality, followed by the personnel on the 4&8, and finally personnel the 6&6. However, research indicates that the 12&12 watch schedule may only be better for day watchkeepers since sleeping during normal daytime hours is not as restorative as sleeping during normal night-time hours (Monk and Folkard, 1992). Additionally, the ideal situation is rarely encountered in operational environments. For example, even though it may be possible to get better sleep on the 12&12 watch schedule, other watch schedules may be preferred for practical reasons such as weather conditions, workload, and crew preference. Several factors including vessel workload and crew preference should be considered in the selection of watch schedules for different vessels and different modes of operation.

This study and its resulting recommendations must be considered within the context of certain limitations, including the small sample size, limited sleep and performance data, and lack of significant changes in performance data.

Summary

The safety of the crews and vessels was never seriously threatened during the operations encountered in this study, but it is not certain that the same would have been true had conditions been more demanding. The effects of fatigue have the greatest and most obvious impact in emergencies and other critical situations. To minimize crew fatigue and maximize crew and vessel safety, there must be an awareness and acceptance in CCG personnel that fatigue can occur at any point in the crewing period. It must also be accepted that while watch schedule and crewing period length may affect watchkeepers' levels of fatigue and alertness, the effects of other factors may be equal, or possibly greater, contributors to fatigue in current DFO/CCG Arctic icebreaking operations. Fatigue can be caused be a number of factors, including the following:

- personal lifestyle;
- sleep patterns;

- circadian rhythms;
- environmental conditions;
- crew and personal preparation for the crewing period;
- crew and personal preparation for the watch schedule; and
- vessel tasking and workload.

Systematic implementation of the recommendations in this report will assist DFO/CCG in minimizing crew fatigue and maximizing crew and vessel safety.

SOMMAIRE

Au cours des trois périodes d'activités de déglaçage dans l'Arctique, qui se sont déroulées de 1996 à 1998, le ministère des Pêches et des Océans/Garde côtière canadienne (MPO/GCC) a envisagé de prolonger de 28 à 42 jours la durée des affectations en mer des navires utilisant un système de rotation d'équipages. L'objectif de l'étude était de déterminer si le prolongement de la durée des affections en mer entraînait des modifications mesurables sur le plan du sommeil, de la fatigue et de la performance.

La présente étude constituait la phase 3 d'un projet en plusieurs étapes intitulé «Étude sur les affectations prolongées en mer de la Garde côtière canadienne» (Davis *et al.,* 1997, 1998). Cette phase consistait à recueillir des données sur un horaire de quart «douze-douze» pendant une affectation de 42 jours. À l'exemple des phases précédentes, l'évaluation de la performance humaine (qui s'est concentrée sur personnel de quart sur la passerelle et dans la salle des machines) examinait notamment les fonctions cognitives, le sommeil, la fatigue, les facteurs psychosociologiques et l'adaptation physiologique à des horaires de travail différents. La phase 3 s'est déroulée pendant deux affectations prolongées en mer du navire *Sir Wilfrid Laurier* de la GCC à l'été 1998.

Comme dans la phase 2, les trois périodes critiques suivantes de l'affectation en mer ont été étudiées :

- Période 1 – jour 7 à jour 12;
- Période 2 – jour 26 à jour 31;
- Période 3 – jour 36 à jour 41.

Ces périodes ont été choisies pour rendre compte des modifications entre le début et la fin de l'affectation traditionnelle en mer de 28 jours et les premiers et derniers jours de l'affection prolongée en mer, soit entre le jour 28 et le jour 42. Les données de référence ont été recueillies entre le jour 7 et le jour 12 pour tenir compte des retards de navigation et de la transition initiale aux horaires de travail. Cela visait également à s'assurer que les données de référence représentaient des caractéristiques stables des quarts.

Les données ont été analysées en fonction de deux aspects clés :

1. Différences observées au cours de trois périodes critiques d'une affectation en mer de 42 jours (décrites ci-dessus).

2. Différences notées entre les trois horaires de travail suivants pendant une affectation en mer de 42 jours :

- horaire «quatre-huit» à bord du *Pierre Radisson* (phase 1);
- horaire «six-six» à bord du *Henry Larsen* (phase 2);
- horaire «douze-douze» à bord du *Sir Wilfrid Laurier* (phase 3).

Différences entre les périodes de l'affectation en mer de 42 jours

Au cours de cette phase, comme dans les deux phases précédentes, les signes de fatigue étaient évidents selon certaines mesures, mais pas toutes. Dans l'ensemble, aucun changement important n'a été relevé à ce chapitre au cours de l'affectation en mer de 42 jours. Le degré de fatigue ressentie par les participants était toutefois insuffisant pour modifier la performance, qui a été mesurée objectivement au moyen de la batterie de tests Delta. Les données semblaient indiquer que même si la fatigue était évidente, on ne pouvait pas la décrire comme étant intense.

Les indicateurs de la fatigue les plus significatifs se manifestaient par la modification des facteurs psychosociologiques, comme la détérioration de l'humeur et de la dynamique de groupe, le moral et la réaction au stress. Les résultats du carnet Fin de quart et de l'Inventaire rétrospectif de la vigilance (IRV) ont montré que les degrés de fatigue des participants étaient demeurés semblables pendant toute l'affectation en mer. Cela semble indiquer que la fatigue ne résultait pas de la durée de l'affectation en mer, mais plutôt d'autres facteurs comme la charge de travail, les tâches exécutées, la durée et la qualité du sommeil et les rythmes circadiens.

Les résultats de l'IRV indiquaient des différences entre le personnel de quart de nuit et le personnel de quart de jour. Quelle que soit la période critique, les profils de vigilance décrits par le personnel de nuit étaient différents de ceux signalés par le personnel de jour. La modification de la vigilance du personnel de nuit révélait une adaptation circadienne incomplète au travail de nuit.

Le résultats compilés des trois périodes critiques comparées indiquaient que les participants ressentaient un degré similaire de fatigue pendant toute l'affectation en mer, et qu'on pouvait difficilement prouver que ce degré de fatigue augmentait lorsque la durée de l'affectation était prolongée. La présence de la fatigue en début d'affectation confirme la nécessité de tenir compte de ce facteur dans les activités courantes. Bien que cette étude n'ait pas fait ressortir une grave et rapide augmentation de la fatigue, les effets de celle-ci deviennent plus évidents lorsque les gens sont poussés à leurs limites, une situation qui ne s'est pas présentée pendant l'étude. Le personnel devrait être sensibilisé aux dangers d'un sommeil insuffisant tant à la maison qu'en mer et il devrait prendre les mesures appropriées pour être plus vigilant à bord.

Il est recommandé que le personnel soit plus sensibilisé au phénomène de la fatigue et reçoive une formation en gestion de la fatigue, ce qui lui permettra d'éviter le plus possible les effets de la fatigue, et de mieux gérer de tels effets. La mise en oeuvre de mesures systématiques contre la fatigue permettra de mieux s'assurer d'un degré de vigilance approprié dans les moments critiques.

Différences entre les quarts de travail

La comparaison des horaires «quatre-huit», «six-six» et «douze-douze» n'a pas révélé qu'un de ces horaires contribuait davantage qu'un autre au maintien de la bonne forme de l'équipage. Chaque horaire de travail présentait des aspects positifs et des aspects négatifs. Les participants à l'horaire «quatre-huit» avaient des résultats supérieurs sur le plan cognitif, alors que les participants à l'horaire «six-six» faisaient état d'une amélioration des facteurs psychosociologiques et que les participants à l'horaire «douze-douze» avaient eu la chance de jouir d'un sommeil plus réparateur. La supériorité sur le plan cognitif des équipes de l'horaire «quatre-huit» pourrait s'expliquer par un meilleur équilibre de la charge de travail, qui n'engendrait ni ennui ni surmenage.

Toutes choses étant égales par ailleurs, la durée et la qualité du sommeil au cours de l'affection prolongée en mer de 42 jours étaient les deux facteurs les plus importants de la prévention de la fatigue. La meilleure façon de lutter contre la fatigue au cours d'une affectation prolongée en mer serait de s'assurer de dormir au moins sept heures sans interruption, tout en tentant d'équilibrer la charge de travail de manière à ce que l'équipage ne s'ennuie pas ni ne souffre de surmenage. Sous cet aspect, l'horaire «douze-douze» permet le mieux de réduire la fatigue, mais la gestion de la fatigue chez le personnel qui travaille de nuit devrait faire l'objet d'une attention particulière.

Le personnel ayant un horaire «douze-douze» avait le plus de chances de dormir mieux et plus longtemps; le personnel avec un horaire «quatre-huit» venait au second rang, suivi du personnel dont l'horaire était «six-six» . La recherche indique toutefois que l'horaire «douze-douze» pourrait être préférable seulement pour le personnel qui est de quart le jour, puisque le sommeil pendant les heures normales de la journée n'est pas aussi réparateur que le sommeil pendant la nuit (Monk et Folkhard, 1992). De plus, la situation idéale se présente rarement en milieu opérationnel. Par exemple, même si l'horaire «douze-douze» permet de mieux dormir, les autres horaires peuvent être préférables pour des raisons pratiques, comme les conditions météorologiques, la charge de travail et la préférence de l'équipage. Plusieurs facteurs, y compris la charge de travail et la préférence de l'équipage, devraient être pris en considération dans le choix de l'horaire de travail à bord de navires différents et pour divers modes de navigation.

La présente étude et les recommandations qui en découlent doivent être examinées en fonction de certaines restrictions, notamment la petite taille de l'échantillon, les données limitées recueillies sur le sommeil et la performance, et l'absence de modifications significatives des données sur la performance.

Conclusion

La sécurité des équipages et des navires n'a pas été sérieusement mise en péril au cours des activités effectuées dans cette étude, mais il n'est pas sûr que la conclusion aurait été la même si les conditions avaient été plus exigeantes. Les effets de la fatigue sont plus grands et plus évidents dans les urgences et les situations critiques. Si on veut réduire la fatigue et augmenter la sécurité de l'équipage et du navire, le personnel de la GCC doit savoir et accepter que la fatigue puisse se manifester à tout moment de l'affectation en mer. On doit admettre aussi que, si l'horaire de travail et la durée de l'affectation en mer peuvent affecter le degré de fatigue et de vigilance du personnel, d'autres facteurs peuvent entraîner des effets équivalents et même supérieurs en contribuant à la fatigue dans les activités courantes de déglaçage dans l'Arctique du MPO/GCC. La fatigue peut résulter d'un certain nombre de facteurs, y compris les suivants :

- le mode de vie personnel;
- la structure du sommeil de chacun;
- les rythmes circadiens;
- les conditions ambiantes;
- la préparation personnelle et de l'équipage en prévision de la période d'affectation en mer;
- la préparation personnelle et de l'équipage à l'horaire de travail;
- les tâches et la charge de travail à bord du navire.

La mise en oeuvre systématique des recommandations contenues dans ce rapport aidera le MPO/GCC à réduire la fatigue et à augmenter la sécurité de l'équipage et du navire.

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1 INTRODUCTION

In the three Arctic icebreaking seasons from 1996 to 1998, the Department of Fisheries and Oceans/Canadian Coast Guard (DFO/CCG) has investigated extending the crewing periods of those operations using a lay-day operational manning system from 28 to 42 days. Such extended operations reduce the number of crew changes in the Arctic and create significant cost savings for DFO/CCG, as well as provide better service to Coast Guard clients. By reducing the downtime created by crew changes, DFO/CCG will be better able to meet their clients' needs and schedules.

While extending the crewing period increases operational effectiveness and reduces costs, little is known about the effects of a prolonged crewing period on crew state. The reason for this scarcity of knowledge is largely due to the unique situation of working on an Arctic icebreaker. DFO/CCG employees are exposed to a variety of factors particular to Arctic icebreaking:

- they perform a unique combination of tasks (i.e., scientific, ice escorts, as well as navigational aid work);
- they operate largely in daylight conditions for most of the season;
- they perform shiftwork on board a vessel under difficult circumstances (e.g., icebreaking and severe weather);
- they work rotating and fixed extended watches; and
- they work for long durations (i.e., 28 days, 42 days, or longer) without being exposed to the potential stress and distraction associated with the urban life of a typical shiftworker.

Prior to, and upon the vessel's departure from its home port, ships' personnel can adapt their daily routine and sleep schedule to match the assigned watch for the duration of the on-duty work cycle. This may have advantages over the typical shore-based shiftworkers who go home after every shift, or who work for only a few days before having to change to another shift.

Given that this environment is unique among mariners and sufficiently different from other types of shiftwork, the influence of fatigue in these operations becomes critical. The potential benefits of extended crewing periods depend on maintaining an acceptable level of efficiency and competency in DFO/CCG personnel. In extended crewing periods, the potential for cumulative fatigue can reach an unacceptable level, impairing the operational effectiveness the crew. It is the responsibility of DFO/CCG to ensure that crew fatigue does not reach unacceptable levels through the implementation of fatigue countermeasures strategies, helping to maintain and potentially improve levels of operational effectiveness.

1.1 Background

The Transportation Development Centre (TDC) and DFO/CCG have recently conducted several studies relevant to human performance and fatigue at sea. Included in these studies are projects designed to determine the extent to which watch schedules and extended crewing periods affect aspects of crew state, particularly fatigue.

In 1995, TDC compared the impact of two watch schedules (6&6 versus 4&8) on CCG personnel over a 28-day crewing period (Donderi *et al.*, 1995). The impact of each watch schedule was assessed based on cognitive performance, socio-psychological well-being, and sleep. The aspects of human performance measured were choice reaction time and short-term memory. Measures of well-being included ratings of mood, alertness, and sleep quality. Sleep was assessed through sleep diaries. The literature suggests that the 6&6 schedule should have been more fatiguing because the 4&8 schedule allowed for longer periods of continuous sleep. However, no operationally significant performance, mood, or sleep differences were reported in the two watch schedules.

One issue of particular concern, however, was the amount of sleep that the crew obtained in one sleep episode. Although significantly longer anchor (main) sleep was reported for personnel on the 4&8 watch, both the 4&8 and 6&6 watches were sleep restricted and both watches obtained their sleep in two episodes. Poorer sleep quality was also recorded in subjective comments from sleep diaries. The likelihood that personnel on both watches experienced sleep deprivation underscored the importance of looking at sleep characteristics more thoroughly.

Donderi *et al.* (1995) concluded that, based on these results, one watch schedule could not be recommended over the other. Recommendations were made, however, for implementing a modified 4&8 watch schedule for the day watch and a 6&6 schedule for the night watch (Donderi *et al.*, 1995). This recommendation was made to optimize sleep patterns and sleep duration for the day and night shifts.

While this study raised the possibility that fatigue due to sleep loss may result in performance impairment regardless of the watch schedule, these results could not be used to predict the effects of extended crewing periods beyond 28 days. For this reason, a study of fatigue in extended crewing periods was necessary.

1.2 Study on Extended Coast Guard Crewing Periods

As a consequence of the observations in the Donderi *et al.* (1995) study and the lack of scientific data regarding fatigue in extended crewing operations, TDC/CCG tasked the Ergonomics and Human Factors Group at BC Research Inc. to conduct a multi-phase project entitled "Study on Extended Coast Guard Crewing Periods" (Davis *et al*., 1997, 1998). The purpose of the study was to determine whether extending the crewing period in Arctic icebreaking operations from 28 to 42 days led to measurable changes in crew sleep, fatigue, and performance.

Human performance, which focused on the bridge and engineering watchkeepers, included measures of cognitive performance, sleep, fatigue, socio-psychological well-being, and physiological adaptation to different watch schedules. These measures were also evaluated in terms of watch type. Table 1 summarizes the watch schedules evaluated, the length of the crewing period, and the vessels that participated in each TDC/CCG study.

Table 1:
Watch schedules and vessels studied.

Study	Watch Schedules	Length of the Crewing Period	Vessels
Donderi *et al*., 1995	4&8, 6&6	28 days (both watch schedules)	CCGS *Ann Harvey*, CCGS *Sir Wilfred Grenfell*, CCGS *Earl Grey*, CCGS, *Sir Humphrey Gilbert*
Phase 1, 1997	12&12, 4&8	28 days, 42 days	CCGS *Sir Wilfrid Laurier*, CCGS *Pierre Radisson*
Phase 2, 1998	12&12, 4&8, 6&6	28 days, 42 days, 42 days	CCGS *Sir Wilfrid Laurier*, CCGS *Pierre Radisson*, CCGS *Henry Larsen*
Phase 3, 1999	12&12, 4&8, 6&6	42 days (all watch schedules)	CCGS *Sir Wilfrid Laurier*, CCGS *Pierre Radisson*, CCGS *Henry Larsen*

1.2.1 Phase 1

In Phase 1 of the project, data were collected during the summer of 1996 on board the *Sir Wilfrid Laurier* (12&12 watch, western Arctic) and the *Pierre Radisson* (4&8 watch, eastern Arctic). Along with assessing the impact of extended crewing periods and watch type, Phase 1 included analysis of the impact of prolonged versus shorter icebreaking operations, and the relative dates (early or late) of icebreaking operations within the patrol.

Measures of crew state showed signs of deterioration (e.g., perceived performance degradation by the crew, increased frustration, withdrawal, irritability, apathy, and reduced sleep associated with extending the crewing period beyond 28 days. Crew state was moderately better for personnel on the 12&12 watch, compared to personnel on the 4&8 watch. Day watch personnel reported a better crew state than the night watch personnel. Icebreaking activity was an important factor in that more time spent icebreaking and icebreaking activity late in the crewing period led to a greater negative impact on crew state.

Recommendations in Phase 1 included that, if implemented, extended crewing periods should be monitored to ensure that there is no detrimental effect on crew state or human performance. This recommendation led to Phase 2 of the project: a study of 42-day crewing periods on board the icebreaker *Henry Larsen* (Davis *et al*., 1998).

1.2.2 Phase 2

The primary objective of Phase 2 was to further evaluate the impact of extending crewing periods from 28 to 42 days on watchkeepers assigned to Arctic icebreaking operations. As in Phase 1, the same measures of fatigue, alertness, sleep, cognitive performance, and socio-psychological well-being were used in Phase 2. As personnel on board the *Henry Larsen* were on a 6&6 watch schedule, a second objective of Phase 2 was to evaluate the differences, if any, between the 4&8, 6&6, and 12&12 watch schedules.

In Phase 2, crew state on the *Henry Larsen* appeared to change little during the 42-day crewing periods. Also, the results of the Donderi *et al*. (1995) study and the results of Phases 1 and 2 did not clearly indicate that any of the 4&8, 6&6, or 12&12 watch schedules was superior to the others. However, in Phase 2 serious concerns were expressed by some officers and crew members regarding the levels of fatigue experienced by individual watchkeepers on the 6&6 watch schedule. These concerns were supported by the experimenters' subjective observations of fatigue. It was not clear whether the fatigue effects observed in individual watchkeepers were related to the watch schedule, workload levels, or both. Finally, participants' responses to the General History Questionnaire indicated that crew on a 42-day crewing period were not receiving optimal sleep at sea. Future work was recommended for the proper implementation of 42-day crewing periods.

1.2.3 Phase 3

The third phase of the study was conducted in 1998. Its focus was to obtain data on a 12&12 watchkeeping schedule over 42 days. As in the previous phases, the same measures of fatigue, alertness, sleep, cognitive performance and socio-psychological well-being were used, with minor modifications to improve the sensitivity of the methods. Linking the 1996 and 1997 studies with the current study demonstrates the effectiveness of integrating systematic research in lengthy, expensive field studies.

2 EXPERIMENTAL METHODOLOGY

2.1 Patrol and Watch Characteristics of the *Sir Wilfrid Laurier*

2.1.1 Patrol Characteristics

During the summer of 1998, personnel on board the icebreaker CCGS *Sir Wilfrid Laurier* participated in a study that examined the effects of extended crewing periods on crew state. The *Laurier* was assigned to the Western Arctic, and the dates of the two crewing periods were from 1 July to 11 August, and 12 August to 22 September.

2.1.2 Watch Characteristics

All watchkeepers on the *Sir Wilfrid Laurier* were on a 12 hours on and 12 hours off (12&12) watch schedule, with watch rotations taking place at 0000 hrs and 1200 hrs. The day worker watch on the *Laurier* was from 0700 to 1900 hrs (Table 2).

Both the bridge and the engine room normally maintained a two-man watch with the Captain and the Chief Officer providing relief as required. In the engine room, the Chief Engineer and Senior Engineer provided relief as required. The Captain, Chief Officer, Chief Engineer, and Senior Engineer were on a 12&12 day worker watch beginning at 0700 hrs and ending at 1900hrs.

Table 2:
Watch schedule for the *Sir Wilfrid Laurier.*

2.2 Crew

2.2.1 Participants

Participants were DFO/CCG crew assigned to Arctic icebreakers. Data collection focused on watchkeepers on the bridge and in the engine room, with day workers participating in questionnaire based measures. A summary of personnel who participated is provided in Table 3. Details of the sea duty and DFO/CCG experience of crew members who participated in the study are given in Table 4.

Table 3:
Summary of crew members from the *Sir Wilfrid Laurier* who participated in Phase 3.

Personnel	Age Range (years)	Number
Watchkeepers	22-47	13 (4 females and 9 males)
Day workers	29-56	22 (5 females and 17 males)
Rotating	38-39	2 (2 males)

Table 4:
Summary of sea duty and DFO/CCG experience of crew members from the *Sir Wilfrid Laurier* who participated in Phase 3.

	Number	Mean	sd
Years of sea duty in DFO/CCG	33	11.0	8.3
Years of sea duty on present watch schedule	31	4.7	4.3
Years of icebreaking duty	30	3.7	4.4
Overall years of duty in DFO/CCG	33	11.7	8.6
Years of duty on current vessel	32	1.4	1.0

2.3 Procedures

2.3.1 Data Collection

Data were obtained on cognitive performance, sleep, fatigue, and socio-psychological well-being. The data collection schedule and a summary of the measures used in Phase 3 are provided in Table 5. Data were collected in the hour before and after the participants' sleep and in the last hour of their watch. For Watch 1, self-recorded sleep log information for the previous sleep period was collected at 0000 hrs and post-watch information was collected at 1200 hrs. For Watch 2, sleep log information was collected at 1200 hrs and post-watch information was collected at 0000 hrs.

As in Phase 2, the following three critical times during the crewing period were examined:

- Interval 1 - Days 7 to 12;
- Interval 2 - Days 26 to 31; and
- Interval 3 - Days 36 to 41.

These intervals were selected to reflect changes between the beginning and the end of the traditional 28-day crewing period and the first few days and final days of the extended crewing period between 28 and 42 days. The baseline data were collected between Days 7 to 12 to accommodate for sailing delays and the early transition to watch schedules. This also ensured that the baseline data reflected stable watch characteristics.

In accordance with current research ethics standards, participants signed an informed consent document explaining the purpose and experimental protocol for the study. Crews were informed that all data would be kept confidential and that information would be provided to DFO/CCG in aggregate form only, making it impossible to identify the response of any individual. Individuals were free to withdraw their consent at any time during the study without prejudice.

Table 5:
Summary of data collection procedures.

Experimental Parameter	Measures	Schedules of Data Collection	Participating Groups
Cognitive	• Delta performance battery: short-term memory; grammatical reasoning; mathematical processing; spatial processing; and choice reaction time	Post-watch	Watchkeepers
	• Subjective workload assessment	Post-watch	All
Sleep	• Activity monitor (PAM/2)	24 hours per day	Watchkeepers
	• Sleep assessment (NightCap)	While sleeping, during Intervals 1, 2, and 3 of the study	Watchkeepers
	• Sleep log	Once per day	All
	• Circadian rhythm-body temperature (tympanic)	At regularly scheduled intervals throughout each day of the crewing period	Watchkeepers
Fatigue	• Subjective assessment of performance	Post-watch	All
	• Commanding Officer and Chief Engineer assessment of crew fatigue and workload	Once per day	Commanding Officer and Chief Engineer
	• End of Day Log	Post-watch	All
	• Retrospective Alertness Inventory	Post-watch	All
Socio-psychological well-being	• Mood assessment questionnaire (alertness, cheerfulness, calmness, irritability, confidence, withdrawal)	Pre and Post-watch	All
	• Group dynamics, morale, and response to stress	Once at the beginning of Intervals 1 and 2 and at the beginning and end of Interval 3	All
Additional crew measures	• Symptoms experienced before and after watch (general discomfort, stomach awareness, headaches, yawning, physical fatigue, drowsiness, apathy, tension/anxiety, dizziness)	Post-watch	All
Vessel workload	• Fleet Activity Information System	Logged by bridge watchkeepers daily	Watchkeepers

2.3.2 Data Collection in the Field

Participants were instructed to begin data collection on all measures except the Delta test battery on the seventh day of the crewing period. To reduce learning effects, the participants began data collection on the Delta test battery on the second day of the crewing period and continued twice daily until Day 7. On Day 7, they began collecting data once daily at the end of their watch.

2.3.3 Changes Made to Measures in Phase 3

Changes were made to the procedures in Phase 3 to improve the sensitivity of data collection. During crew debriefings following data collection, participants in Phase 2 of the study expressed a desire to assess mood prior to beginning the watch. To accommodate this request, a pre-watch mood assessment was added to the Phase 3 methodology so that mood was collected both pre- and post-watch. Also, in an attempt to further understand participants' alertness over the course of the crewing period, the Retrospective Alertness Inventory (RAI) was added to the Phase 3 data collection (Appendix B).

Developed by Folkard *et al*. (1995), the RAI was added to assess alertness over a 24-hour period. To complete the RAI, participants rated their level of alertness on a scale of 1 (very alert) to 9 (very sleepy), with 0 indicating normal sleep times. At the end of each watch, participants were asked to recall their alertness for each hour in the day and record their responses in the RAI. Ratings on the RAI have been found to correlate highly with daily alertness ratings and performance data (Sanquist *et al*., 1996). The RAI has also been used in a DFO/CCG study entitled "Sweep-Width Prediction Simulation (The Effects of Vessel Motion on Target Detection in Marine Search and Rescue Operations)" (Ritmiller *et al*., 1998).

2.4 Analysis

Data were examined in relation to two key issues:

1. Differences across the three critical intervals in the 42-day crewing period (described in Section 2.3.1); and
2. Differences between the following watch schedules over a 42-day crewing period:
   - the 4&8 watch on the *Pierre Radisson* (Phase1);
   - the 6&6 watch on the *Henry Larsen* (Phase 2); and
   - the 12&12 watch on the *Sir Wilfrid Laurier* (Phase 3)

Although following the same crew members on each of the three watch schedules would have been the preferred experimental design, this was not possible due to logistical constraints within DFO/CCG, including regional location of crew and assignment of crew to different vessels.

This approach was adopted to encourage participation in the study and accommodate some of the expected limitations of field data, including small or incomplete data sets due to a limited number of watchkeepers on any particular measure. In many instances, the analysis examined effects arising from very few subjects. This also raises the issue that an individual's data could bias the overall findings.

Body temperature and NightCap data were collected in each of the three intervals; however, insufficient data were available from these measures for analysis. NightCap data were insufficient because few participants were willing to use the NightCap and some participants who began wearing the NightCap stopped wearing it after some time. Results for the remaining measures are presented and discussed in Sections 3.1 and 3.2.

Analysis of the Differences Across Intervals in the 42-Day Crewing Periods

In the comparison of the three critical time intervals (i.e., Intervals 1, 2, and 3), data from each day were averaged over each six-day interval for each group on each measure. This provided a more stable estimate against which to compare the changes observed across the three intervals.

A repeated measures analysis of variance (ANOVA) was used to compare the measures for Intervals 1, 2, and 3. Significant effects or trends were reported across intervals. Where limited data were available (e.g., the CO's and CE's assessments of crew fatigue and workload) changes across intervals were expressed as percent differences.

Analysis of the Differences Between the Watch Schedules

For the comparison of differences between the 6&6, 4&8, and 12&12 watch schedules, data were grouped into the appropriate category depending on participant watch schedule and averaged over the crewing period. Depending on whether categorical or measurement data were collected, Chi-square or t-test procedures were employed to test for statistical significance.

Significant Effects

Where sufficient data were available for statistical analysis, significant differences were reported when the probability of an error was less than or equal to 0.05. Trends were reported when the probability of an effect was greater than 0.05 and less than or equal to 0.10. Because of limited data sets on some of the measures (e.g., the CO's and CE's assessments of fatigue and the NightCap), statistical analysis was not always possible. In these instances, descriptive results were reported.

The key to interpreting the data was to examine results from all measures simultaneously, looking for consistent patterns of change and converging evidence. Effects were interpreted as meaningful when one measure was consistent with patterns of change observed in other measures.

3 RESULTS AND DISCUSSION

Note: Unless otherwise stated, the data reported in Section 3.1 represent Phase 3 data collected on board the Sir Wilfrid Laurier *during 1998.*

3.1 Differences Across Intervals in the 42-Day Crewing Periods

To determine the effects of the extended crewing period on crew performance and well-being, differences in crew state were examined across Intervals 1, 2, and 3. Changes in crew state were assessed by measures of cognitive performance, sleep duration and quality, subjective assessment of fatigue and socio-psychological well-being and symptoms experienced after watches (general discomfort, stomach awareness, headaches, yawning, physical fatigue, drowsiness, apathy, and tension/anxiety).

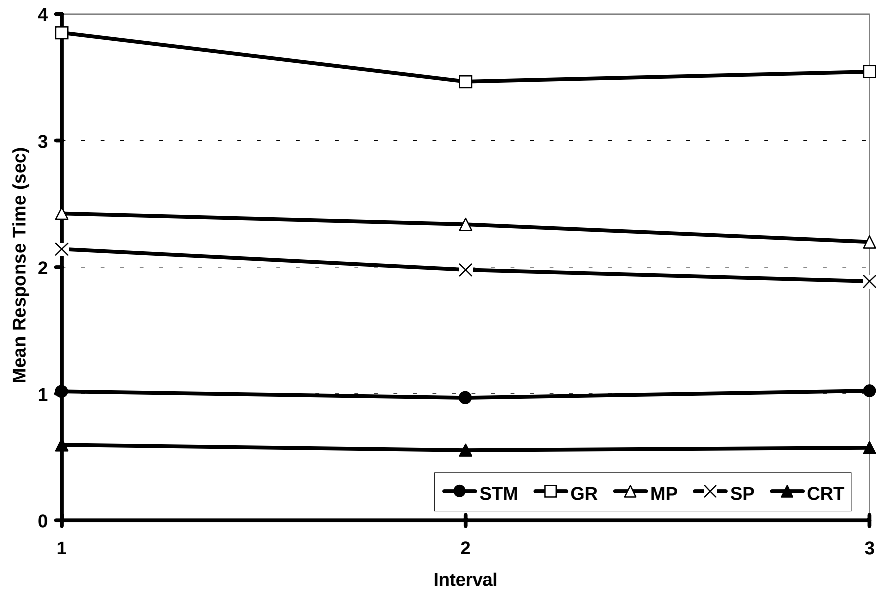
3.1.1 Cognitive Assessment

Performance

Cognitive performance was assessed using the Delta computerized performance assessment battery. Tests in the battery assessed short-term memory (STM), grammatical reasoning (GR), mathematical processing (MP), spatial processing (SP), and choice reaction time (CRT). Performance was evaluated based on participants' response time and accuracy (as measured by the percentage of correct responses they supplied). Faster response times and greater accuracy indicated superior performance.

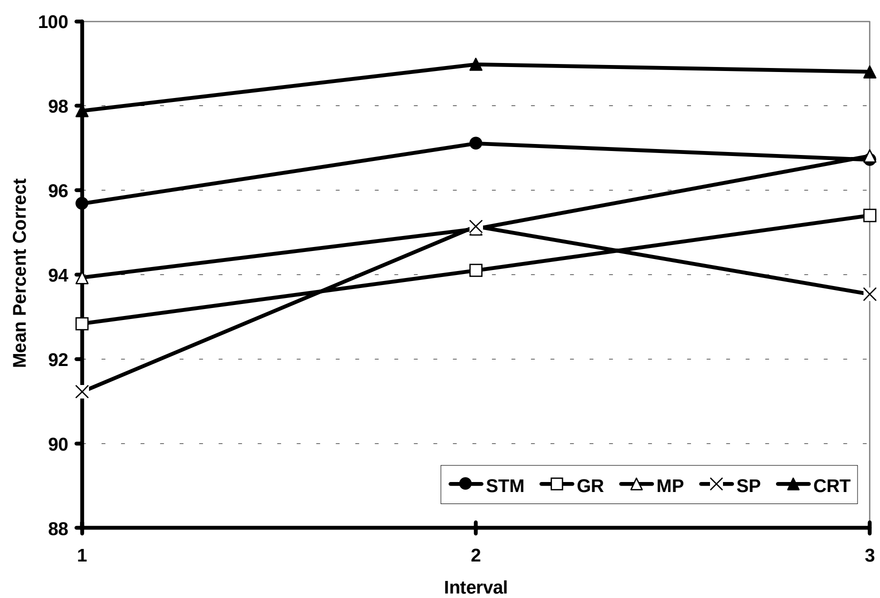
There was no change in cognitive performance across the intervals as measured by the Delta test battery; meaning, there were no significant changes in mean response time (Figure 1) or mean percent correct (Figure 2) on any of the Delta tests.

In Phase 2, the tests of SP, STM, and CRT showed a decline in accuracy. Although this decline was not statistically significant, it may have reflected a change in strategy by watchkeepers as they became fatigued. Similar results were not seen in Phase 3, indicating that the results of Phase 2 were specific to the 6&6 watchkeepers on the *Henry Larsen* in 1997.



STM = short-term memory; GR = grammatical reasoning; MP = mathematical processing; SP = spatial processing; CRT = choice reaction time.

Figure 1:
Mean response time (seconds) on the computerized cognitive performance tests (Delta) for watchkeepers, as a function of data collection interval.



STM = short-term memory; GR = grammatical reasoning; MP = mathematical processing; SP = spatial processing; CRT = choice reaction time.

Figure 2:
Mean percent correct on the computerized cognitive performance tests (Delta) for watchkeepers, as a function of data collection interval.

Subjective Workload

Participants rated the following aspects of workload: mental, visual, physical, temporal, satisfaction with performance, level of effort, level of frustration, overall workload, and relative workload. Participants indicated no changes in any aspect of workload.

3.1.2 Sleep

Sleep Duration and Quality

Sleep data were collected from PAM/2 activity monitors, daily sleep logs completed by each participant, and NightCap sleep monitors. It was intended that data from the NightCap would be used as an objective measure of sleep duration and quality; however, insufficient data were obtained on this measure to perform meaningful analysis. NightCap data were insufficient because few participants were willing to use the NightCap and some participants who began wearing the NightCap stopped wearing it after some time. Therefore, sleep duration was assessed using data from the PAM/2 and sleep log, and sleep quality was assessed using subjective ratings in the sleep log.

There were no changes in either sleep duration as measured by the PAM/2 activity monitor and the sleep log (Figure 3) or sleep quality as measured by the sleep log (Figure 4). Participants obtained a similar amount of sleep in each interval, with an average of 428 minutes of sleep over the three intervals. Sleep quality ratings did not change significantly across intervals, with the average rating being 4.28 on a scale of 1 to 7. This corresponded to a sleep quality rating of “fair”.

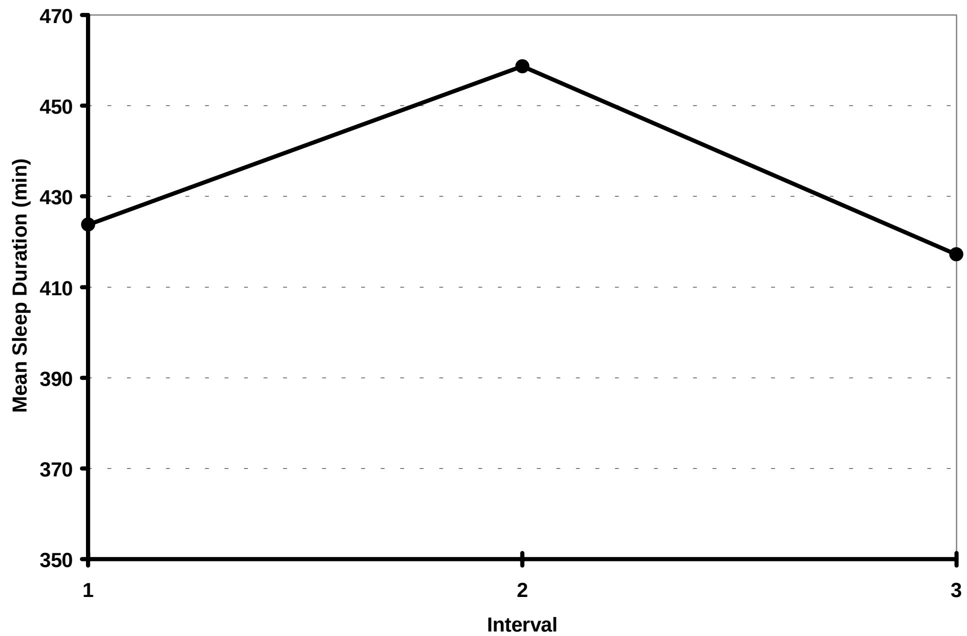


Figure 3:
Average sleep duration (minutes) for watchkeepers.

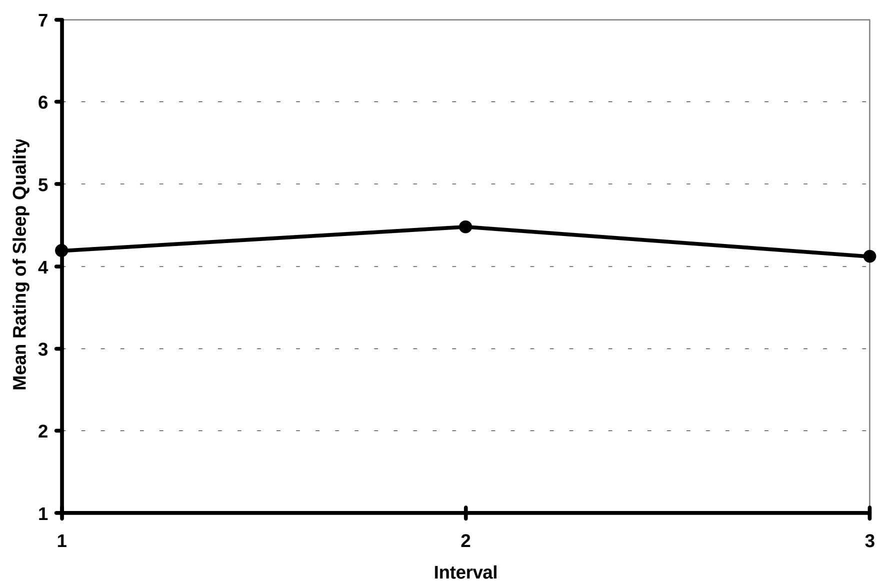


Figure 4:
Average sleep quality for watchkeepers. The scale ranged from 1 = poor to 7 = excellent.

3.1.3 Fatigue

Subjective Assessment of Task and Mental Performance

As illustrated in Figure 5, participants indicated significant difficulty with simple tasks around the 28th day (Interval 2) and an increase in difficulty with memory by the end of the crewing period (Interval 3).

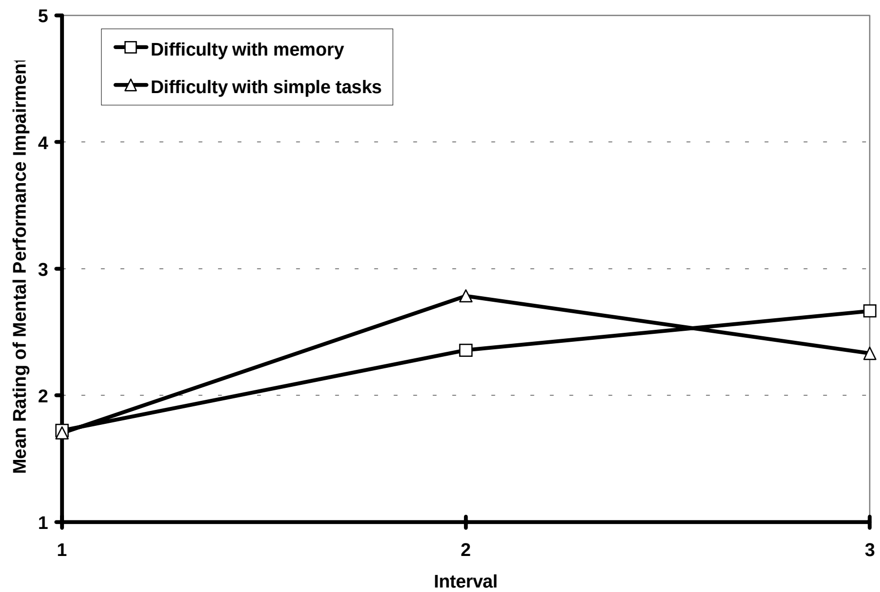


Figure 5:
Average rating of mental performance impairment. Impairment ratings included 1 = not at all, 2 = a little, 3 = somewhat, 4 = quite a bit, 5 = extremely.

CO and CE Assessment of Crew Fatigue and Workload

In both Interval 2 and Interval 3, the commanding officer of the second crew (CO2) indicated the highest rating of crew fatigue (Figure 6) and the lowest rating of crew workload (Figure 7). The low workload levels indicated by CO2 may reflect the boredom reported by the crew in their ratings of mood. This boredom may then have lead to the crew fatigue the commanding officer indicated in his log.

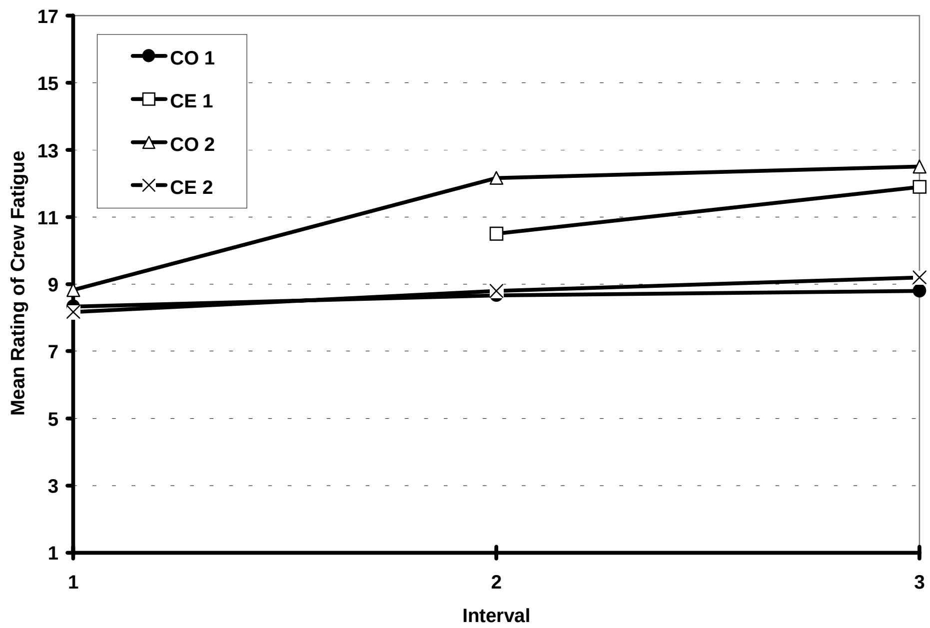


Figure 6:
Commanding Officer's (CO's) and Chief Engineer's (CE's) ratings of crew fatigue. The scale ranged from 1 = low to 17 = high.

*No data were available in Interval 1 from CE1.

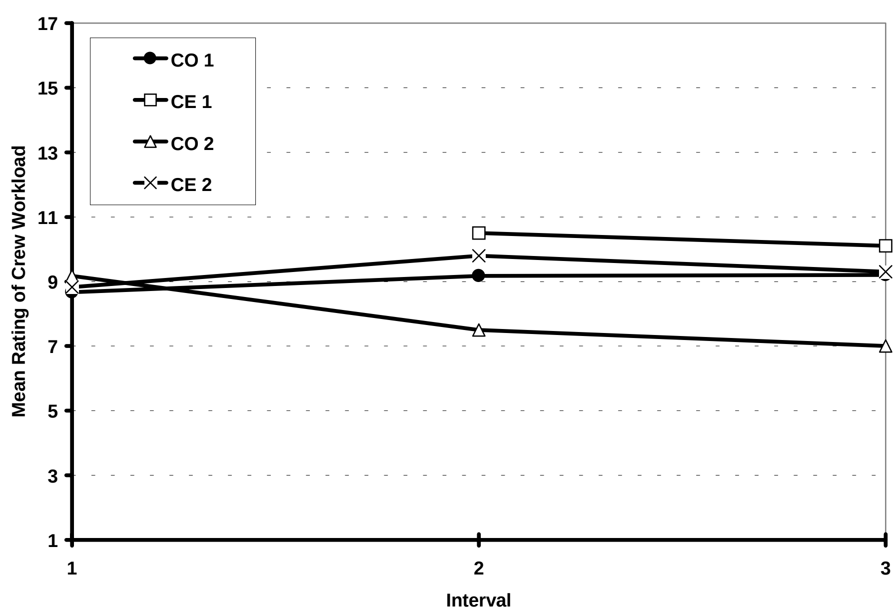


Figure 7:
Commanding Officer's (CO's) and Chief Engineer's (CE's) ratings of crew workload. The scale ranged from 1 = low to 17 = high.

*No data were available in Interval 1 from CE1.

End of Day Log

In the End of Day Log, participants were asked to note anything that occurred during their watch that they could attribute to being tired or fatigued and to categorize the event as happening to themselves, to another person, or to a group of people. This log was based on one used in a study by Sanquist *et al*. (1996), entitled "Fatigue and Alertness in Merchant Marine Personnel: A Field study of Work and Sleep Patterns". The log was designed to help gather information on events or "near misses" that would not have been included in the ship's log.

No change occurred in the frequency of reported fatigue-related events across intervals. However, the events themselves indicated significant levels of fatigue in some crew members (Appendix A). For example, one participant noted falling asleep while on duty, on two separate occasions. The first event occurred on Day 7, and the second event occurred on Day 11 between 2130 and 2200 hrs. On Day 7, this watchkeeper indicated a poor quality sleep the night before (a rating of 1 on a scale of 1 to 7). This watchkeeper also had a disrupted sleep pattern in Interval 1, waking in the night on several occasions. As they occurred early in the crewing period, these events were not a function of the length of the patrol.

Although no other participants indicated falling asleep on watch, several crew members did indicate feeling sleepy while on duty. These incidents occurred in each interval, also suggesting that it was not the length of the patrol that was causing the sleepiness. Rather, other factors such as workload levels, vessel program, sleep duration and quality, activities outside duty hours, and circadian rhythms were the likely source of the fatigue experienced by the crew. This highlights the importance of improved fatigue management and the necessity for crew members to begin adjusting their circadian rhythms before beginning their crewing period and employing appropriate fatigue countermeasures while on board.

Retrospective Alertness Inventory (RAI)

The RAI (Appendix B) was added to the Phase 3 data collection to further understand participants' daily alertness over the course of the crewing period. The RAI was completed by the participants once daily after each watch. To complete the RAI, participants rated their level of alertness for each hour in the day on a scale of 1 (very alert) to 9 (very sleepy), with 0 indicating normal sleep times. In Figure 8 and Figure 9, the rating scale has been reversed from the questionnaire, with 0 representing "sleep" and 9 representing "very alert". In the analysis of the RAI, data for each hour of the day were compared across intervals for each watch.

Figure 8 and Figure 9 illustrate that there were no significant differences across intervals in day or night watchkeepers' ratings of alertness. This means that as the crewing period progressed, the watchkeepers' retrospective assessment of fatigue did not change. This does not mean that their alertness did not change over this period; rather, watchkeepers' may not have recalled their alertness changing.

The RAI data were also analyzed to assess the changes, if any, in participants' ratings of alertness over the length of the watch and to determine whether this time-on-watch effect changed as the crewing period progressed. The day watchkeepers indicated a significant decrease in alertness over the length of the watch (Figure 8), which is a well-known time of day (circadian) effect. However, changes over the course of the watch were consistent across intervals, indicating that the length of the crewing period was not a significant factor in day watchkeepers ratings of alertness.

The night watchkeepers did not report a statistically significant change in alertness over the course of the watch (Figure 9). However, the pattern of change in each interval was much different than the day watchkeepers. Whereas the day watchkeepers indicated a similar pattern of change over the length of the watch in all intervals, the night watchkeepers indicated different patterns in each interval.

The night watchkeepers' ratings of alertness were indicative of people adjusting their circadian rhythm as the crewing period progressed. In the first interval, night watchkeepers indicated the expected dip in alertness between 0400 and 0600 hrs, which is the time when most people are typically least alert. By Interval 2, the alertness ratings of night watchkeepers were similar over most of the watch, but the dip occurred some 5 hours later, indicating a phase adjustment of the circadian rhythm to the new shift. By Interval 3, the phase adjustment appeared more complete in terms of the subjective alertness, following a more predictable circadian course. This circadian course is, however, only advanced 6 hours rather than 12 hours, and the precipitous decline during the day is more evident. This indicates that even after 42 days, night watchkeepers perceive that they are not completely adjusted to their watch schedules.

The results of the RAI analysis suggests that both day and night watchkeepers need to improve their alertness while on duty. This reflects the need for greater fatigue management and education in fatigue countermeasures. Fatigue awareness and training may help the day watchkeepers improve their alertness over the length of the watch and may help night watchkeepers adapt to night work.

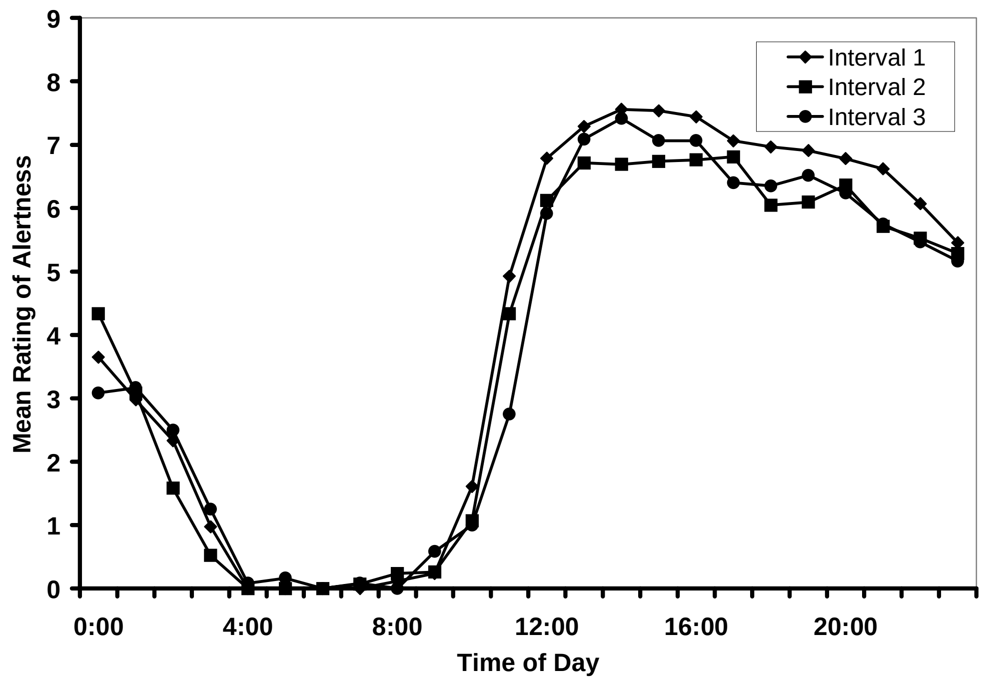


Figure 8:
Ratings in each interval on the Retrospective Alertness Inventory for day watchkeepers. The scale ranged from 0 = asleep to 9 = very alert.

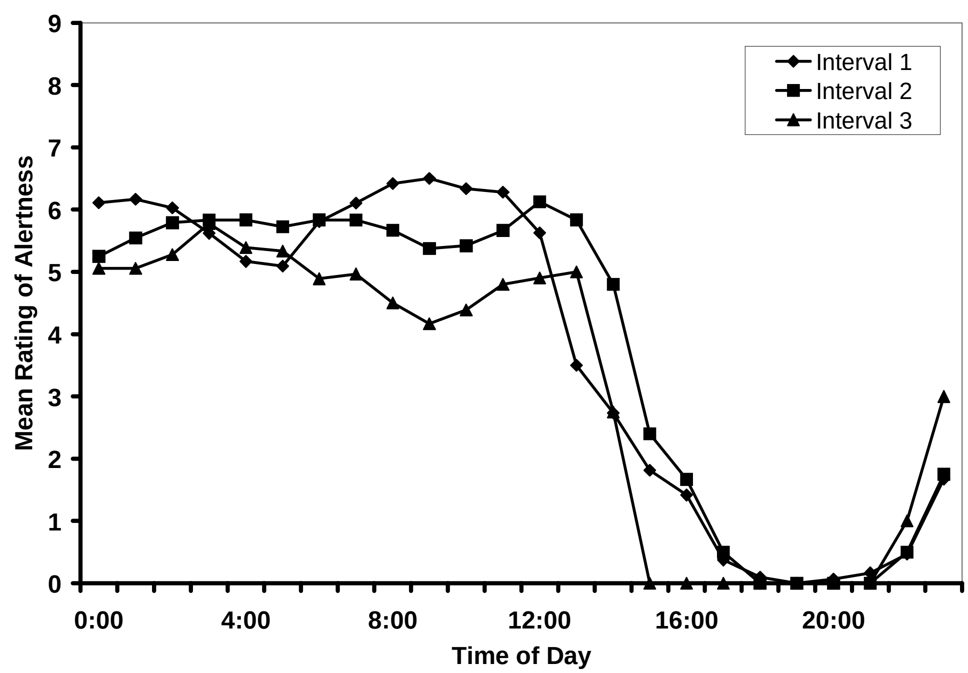


Figure 9:
Ratings in each interval on the Retrospective Alertness Inventory for night watchkeepers. The scale ranged from 0 = asleep to 9 = very alert.

3.1.4 Socio-Psychological Factors

Mood

Several aspects of mood were assessed before and after each watch. Aspects assessed included alertness, cheerfulness, calmness, irritability, confidence, withdrawal, boredom, and mental stimulation. As illustrated in Figure 10, the mood of participants worsened toward the end of the crewing period, with significant increases in withdrawal (both pre-and post-watch) and boredom (post-watch only).

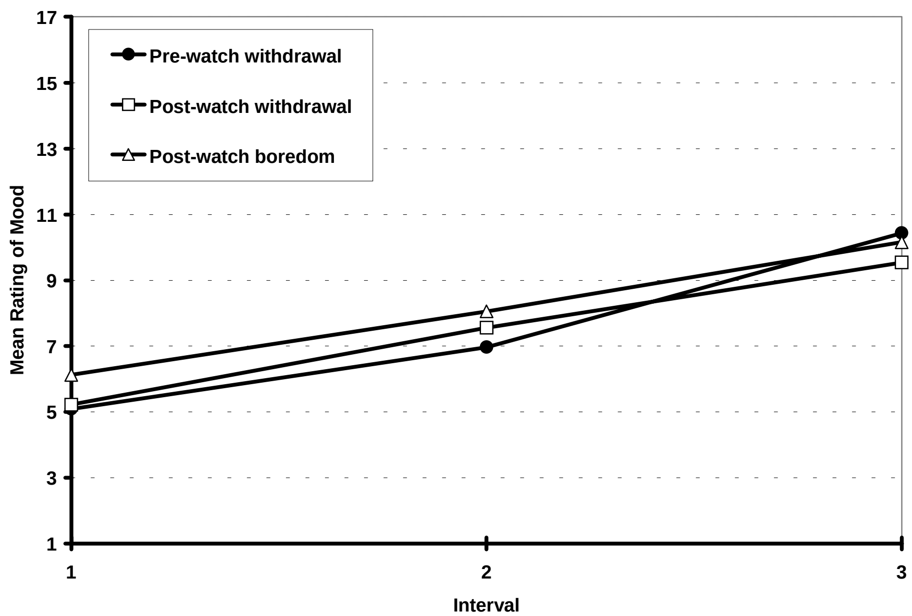


Figure 10:
Ratings of select pre- and post-watch mood scales for watchkeepers. The scale ranged from 1 = low to 17 = high.

Group Dynamics, Morale, and Response to Stress

Several aspects of group dynamics, morale, and response to stress were also evaluated. Aspects of group dynamics and morale included overall morale and group cohesion, professional morale, and leadership skills. Aspects of response to stress included logistical support and personnel resources, work scheduling, family separation, personal control and well-being, and work relationships. Higher ratings of group dynamics and morale indicated improved crew state, but higher ratings of response to stress indicated worsening crew state.

Participants completed the Group Dynamics, Morale, and Response to Stress questionnaire once in Intervals 1 and 2, but twice in Interval 3. The questionnaire was completed twice in the third interval (Days 31 and 36) to obtain a more complete picture of the effects of extending the crewing period beyond 28 days.

Some aspects of group dynamics and morale declined toward the end of the crewing period, while some stressors simultaneously increased. Morale and cohesion were lowest, and stress caused by work scheduling and a lack of personal control and well-being were highest in Interval 3 (Figure 11). An increase in stress caused by work scheduling may seem to conflict with an increase in boredom, as indicated in the measurement of mood. However, some participants indicated that long periods of inactivity and boredom were often followed by short periods of intense activity and high stress. It may be that even if actual work stress was not increasing, the perceived stress of the work increased due to fatigue, reduced morale, and a decreased sense of well-being. Whether or not the increase in work stress was actual or perceived, the impact of poor socio-psychological well-being, poor mood, and lower morale may lead to difficulties in crew relations, motivation to complete tasks, and reactions in high-stress situations.

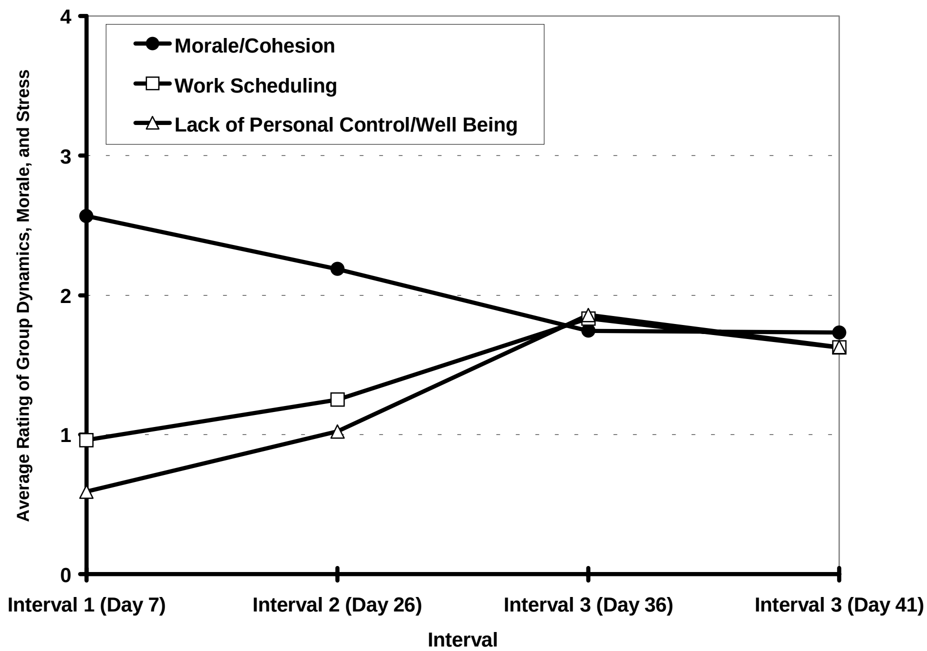


Figure 11:
Group dynamics, morale, and response to stress ratings for watchkeepers. The rating scale ranged from 1 = not at all to 5 = extremely.

3.1.5 Additional Measures

Symptoms and Body Temperature

Several fatigue-related symptoms were assessed at the end of each watch. Symptoms assessed included discomfort, stomach awareness, headache, yawning, physical fatigue, mental fatigue, drowsiness, apathy, tension, and anxiety. Fatigued-related symptoms did not show any significant changes across the intervals.

Attempts were made to collect body temperature data from night watchkeepers over the course of the crewing period. Body temperature data were recorded by five participants; however, the data collected from night watchkeepers were insufficient for analysis.

3.1.6 Summary of the Differences Across Intervals in 42-Day Crewing Periods

In the present study, the most significant indicators of fatigue were manifested in socio-psychological factors such as deteriorating mood and group dynamics, morale, and response to stress. However, the level of fatigue that the crew experienced was not enough to affect performance as measured by the Delta test battery. These results were similar to observations in the previous two phases where fatigue was reported at some level in CCG icebreaking operations. Nonetheless, the changes that were observed can lead to difficulties in crew relations, motivation to complete tasks, and appropriate reactions and decision-making in high-stress situations.

The analysis of the End of Day Log results indicated that fatigue was present in some participants in all intervals. This suggests that it was not the length of the crewing period but rather other factors, such as workload levels, vessel program, sleep duration and quality and circadian rhythms that were the source of the fatigue experienced by the watchkeepers.

The results of the RAI indicated that levels of participant fatigue were similar over the course of the crewing period. While there was a change in watchkeepers' retrospective rating of alertness over the course of the watch, this change was consistent across intervals, indicating that the length of the crewing period was not a significant factor in watchkeepers' ratings of alertness. The RAI also illustrated differences between day and night watchkeepers. Day watchkeepers reported similar alertness over the course of the crewing period, but night watchkeepers reported different patterns of alertness in each interval. The pattern of change in the night watchkeepers' alertness indicated an incomplete circadian adjustment to a night routine.

3.2 Differences Between 6&6, 4&8, and 12&12 Watches

The following watches on a 42-day crewing period were compared to examine whether any differences in crew state were observed between the 6&6, 4&8, and 12&12 watch schedules:

- the 4&8 watch on the *Pierre Radisson* (Phase 1);
- the 6&6 watch on the *Henry Larsen* (Phase 2); and
- the 12&12 watch on the *Sir Wilfrid Laurier* (Phase 3).

Since different crews were assessed under different crewing conditions, differences observed between the watch schedules may reflect individual crew abilities rather than true differences between watch cycles.

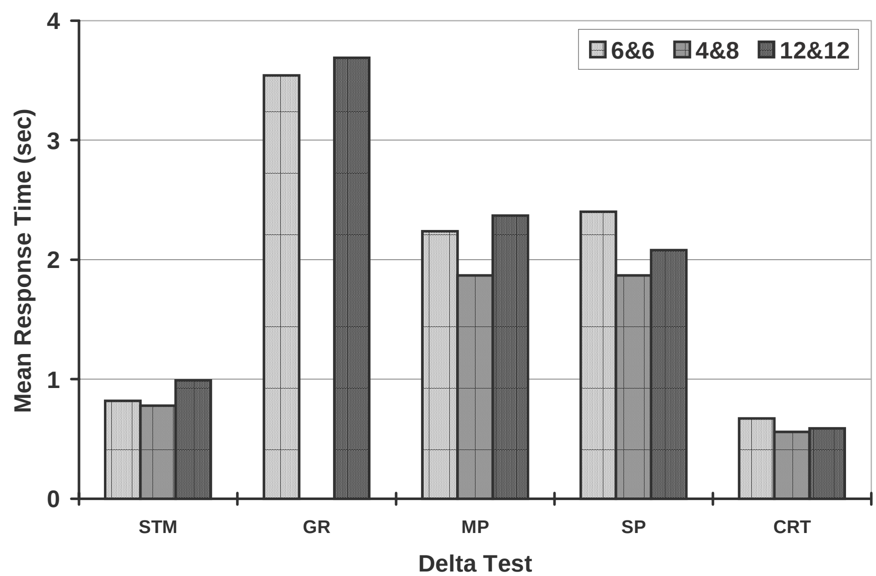
3.2.1 Cognitive Assessment

Performance

Cognitive performance of watchkeepers was assessed using the Delta computerized test battery. On all tests, faster response times and greater accuracy indicated superior performance.

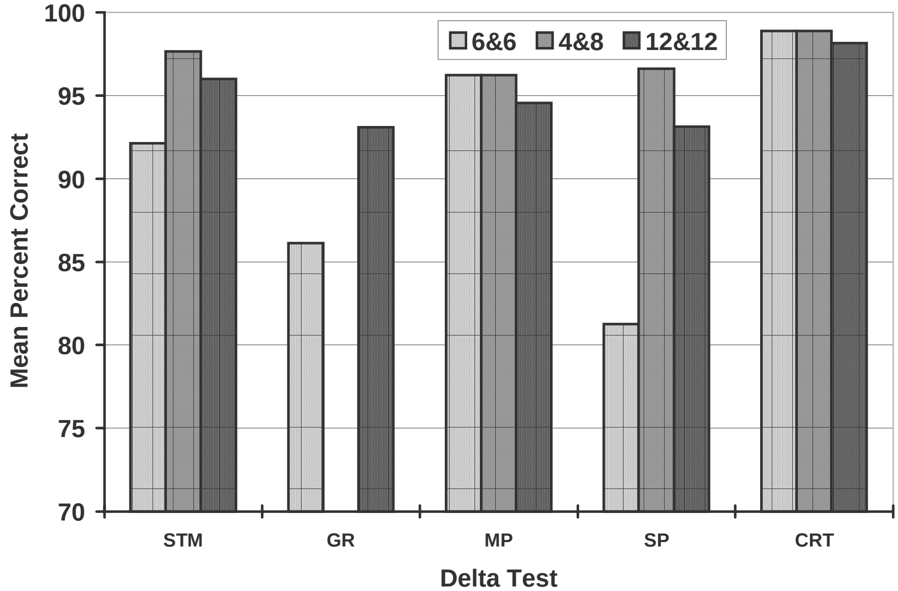
The 4&8 watch did not perform the Grammatical Reasoning (GR) test. Participants on the 4&8 watch were primarily francophone, and unfortunately, the grammatical reasoning test could not be appropriately translated from English into French.

As illustrated in Figure 12 and Figure 13, cognitive performance among participants on the 4&8 watch schedule was superior to that of participants on the 6&6 and 12&12 watch schedules. Compared to participants on the 6&6 and 12&12 watches, participants on the 4&8 were significantly faster on the tests of short-term memory (STM), mathematical processing (MP), spatial processing (SP), and choice reaction time (CRT). Participants on the 4&8 watch were also more accurate than the participants on the 12&12 on STM. Scores of participants on the 6&6 were similar to scores of participants on the 12&12 in terms of speed, except for spatial processing where those on the 6&6 were slower. However, in terms of accuracy, participants on the 6&6 were less accurate than participants on the 12&12 and 4&8 on the STM, MP, and SP tasks (and on the GR task in comparison with the 12&12 watch only). Together these data suggest that the 6&6 watch cycle resulted in poorer performance than either the 4&8 or 12&12 watches.



STM = short-term memory; GR = grammatical reasoning; MP = mathematical processing; SP = spatial processing; CRT = choice reaction time.

Figure 12:
Mean response time (seconds) on the computerized cognitive performance tests (Delta) for each watch schedule.



STM = short-term memory; GR = grammatical reasoning; MP = mathematical processing; SP = spatial processing; CRT = choice reaction time.

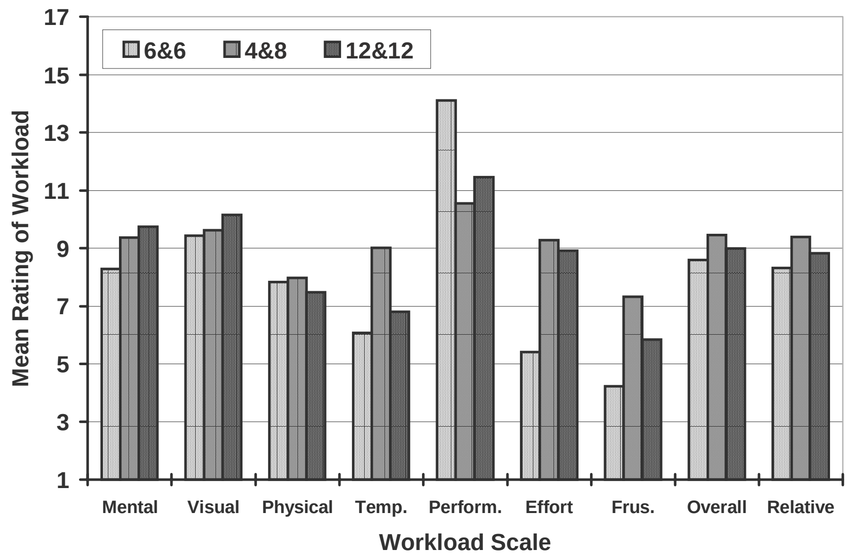
Figure 13:
Mean percentage correct on the computerized cognitive performance tests (Delta) for each watch schedule.

Subjective Workload

Participants on the 6&6 reported the lowest level of effort and significantly greater satisfaction with their performance (Figure 14). Compared to participants on the 4&8 watch, these 6&6 participants also reported significantly lower levels of frustration and relative workload. Participants on the 4&8 watch schedule also reported the highest levels of temporal workload.

Thus, participants on the 4&8 schedule indicated greater levels of workload while maintaining superior cognitive performance as measured by the Delta test battery. These results may indicate that participants on the 4&8 schedule had an optimal workload level, providing a balance between being overworked and being bored. Such a workload level would provide a buffer against fatigue, improving the cognitive performance of these participants.

Because crew workload is a function of several factors including, among others, vessel type, vessel tasking, watch schedule, and work location, it is difficult to determine which factors have the greatest impact on crew performance. In these studies, it appeared that vessel tasking, not watch schedule, was most important. Therefore, it should be possible to balance workload levels on the 12&12 and 6&6 watch schedules to achieve improved cognitive performance.



Temp. = Temporal workload, Perform. = Satisfaction with performance, Frus. = Frustration.

Figure 14:
Mean subjective workload ratings (NASA TLX) for each watch schedule. The scale ranged from 1 = low to 17 = high.

3.2.2 Sleep

Sleep Duration and Quality

The effects of watch schedule on sleep are summarized in Table 6, Figure 15, Figure 16, and Figure 17.

Based on information from the PAM/2 activity monitors and sleep logs (Table 6 and Figure 15), no significant differences in the amount of total sleep were obtained by participants on the 6&6 watch and participants on the 12&12 watch. However, participants on the 4&8 watch obtained less sleep than those on the other two watches, and significantly less sleep than personnel on the 12&12 watch. On average, personnel on the 12&12 watch obtained 37 minutes more sleep than personnel on the 4&8 watch each day (who averaged 391 minutes each day). Over the course of 42 days, 37 minutes of sleep lost each day may lead to a significant sleep debt.

The effect of vessel tasking on sleep duration and quality should not be underestimated. Vessel tasking probably had a significant effect on the amount of sleep obtained by participants in each phase. The shorter sleep episodes of personnel on the 4&8 watch may have been a result of the amount of icebreaking performed in Phase 1 compared to Phase 3. Icebreaking has a significant impact on the amount of sleep personnel are able to obtain, and more icebreaking occurred in Phase 1 than in Phase 3.

The watch structure used on each vessel also affected the amount and quality of sleep obtained by participants. Total daily sleep in this study equalled the anchor, or core sleep, plus any nap sleep. The anchor sleep of participants provided the longest period for restorative sleep that is continuous in nature. Nap sleep was sleep obtained to supplement insufficient anchor sleep. Because of the watch structure, the maximum length of the anchor sleep for workers on the 6&6 watch was less than 6 hours, for workers on the 4&8 watch it was less than 8 hours, and for workers on the 12&12 watch it was less than 12 hours. The data in Figure 16 represent one watchkeeper on each schedule and are provided simply to illustrate the sleep patterns of participants on each watch. Data in Figure 16 are from Phase 1 and Phase 2, and were included in the Phase 2 report.

In Phase 2, the shorter anchor sleep did not seem to affect socio-psychological factors (e.g., mood), or cognitive factors (e.g., subjective workload); however, the Phase 3 data indicate a need for caution. A short anchor sleep may have lead to poor socio-psychological well-being in watchkeepers on the 4&8, and poor cognitive performance in watchkeepers on the 6&6.

Although there were no differences in the sleep quality ratings of participants on the three watch schedules (Figure 17), split sleep generally leads to reduced quality of sleep (Colquhoun *et al*., 1988). When disrupted, sleep cannot adequately restore alertness, even when total split sleep (anchor plus nap) is similar to total undisturbed sleep. Split sleep increases fatigue effects, such as drowsiness during the day, and leads to impaired performance (Colquhoun *et al*., 1988).

If sleep is consistently obtained in the form of split sleep, cumulative fatigue may result. Cumulative fatigue occurs over a period of successive days or weeks with a major contributing factor being insufficient sleep recovery time. As highlighted in the Phase 2 report, cumulative fatigue has several effects, including:

- declines in attention, motivation, vigilance and concentration (making an individual more susceptible to distractions);
- changes in performance criteria (e.g., people trade off speed/accuracy operating characteristics) (Hockey, 1996); and
- greater physiological effort to maintain levels of performance while fatigued; depending upon the severity of the fatigue, this extra effort may or may not be sufficient to prevent performance impairment (Heslegrave, 1994).

Table 6:
Average total sleep duration of the three watch schedules.

Watch schedule	Average Total Sleep Duration (minutes)
6&6	422
4&8	391
12&12	428

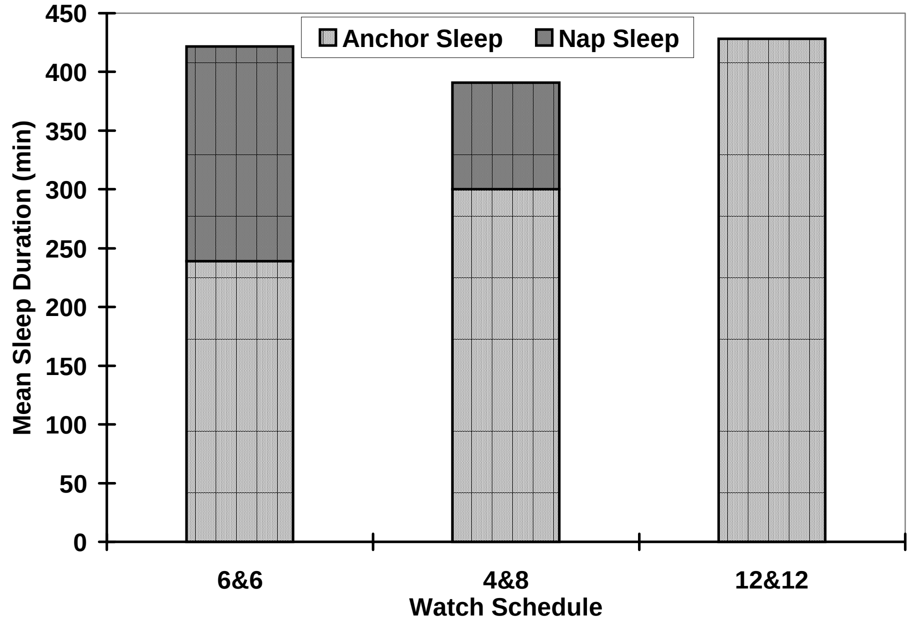
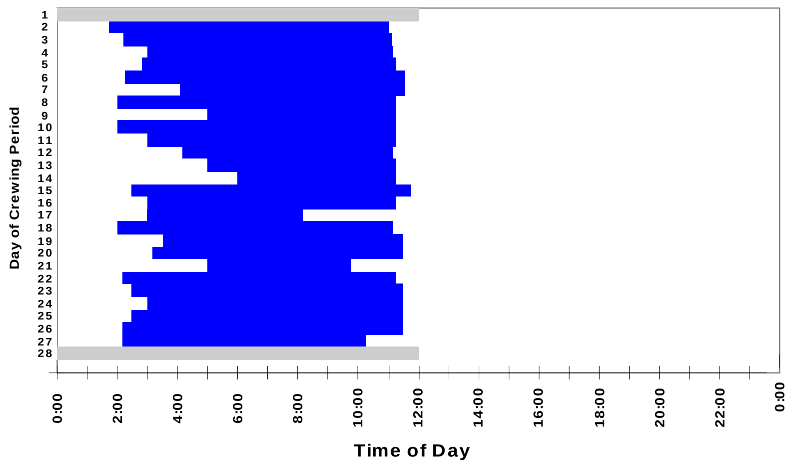
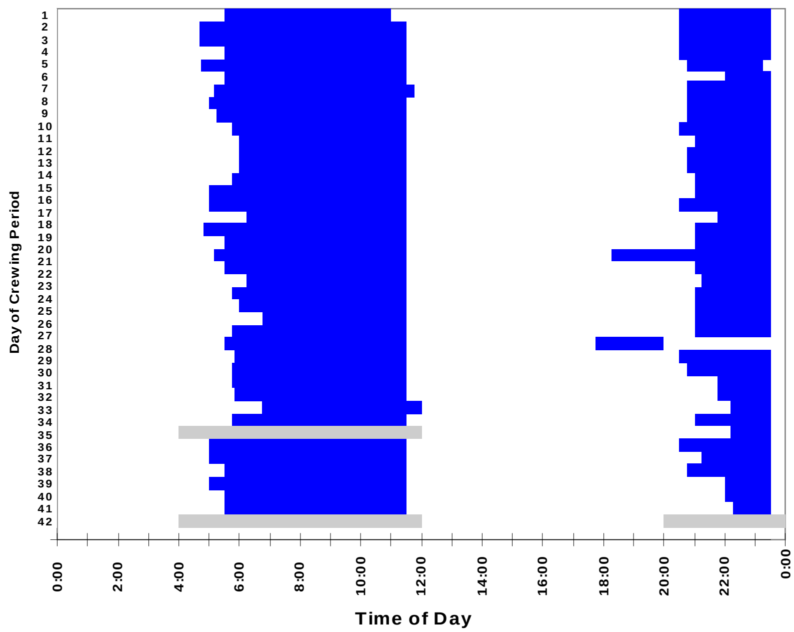


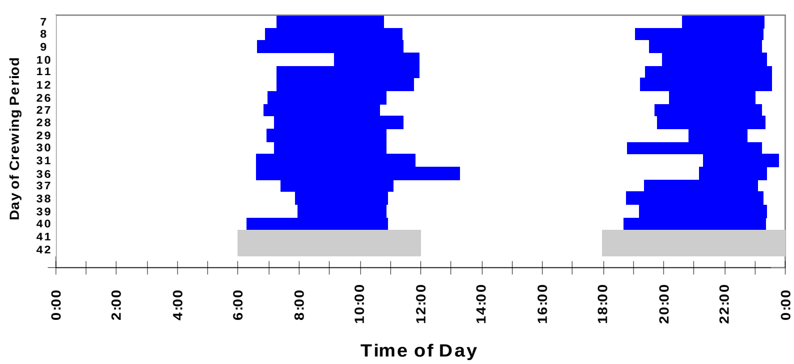
Figure 15:
Average anchor sleep and nap duration (minutes) for each watch schedule.



12&12 Day Watch



4&8 Night Watch



6&6 Night Watch

Figure 16:
Sleep patterns over a 24-hour period for individual days of the crewing period for participants on a 12&12 day watch, 4&8 night watch, and 6&6 day watch (black lines indicate sleep episodes, grey lines indicate missing data, and white spaces indicate waking periods).

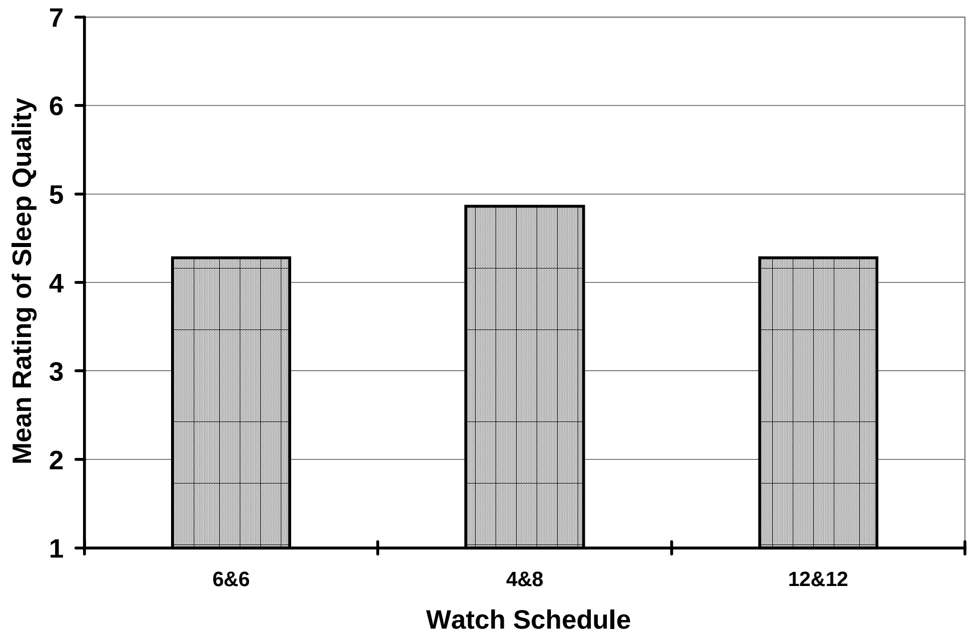
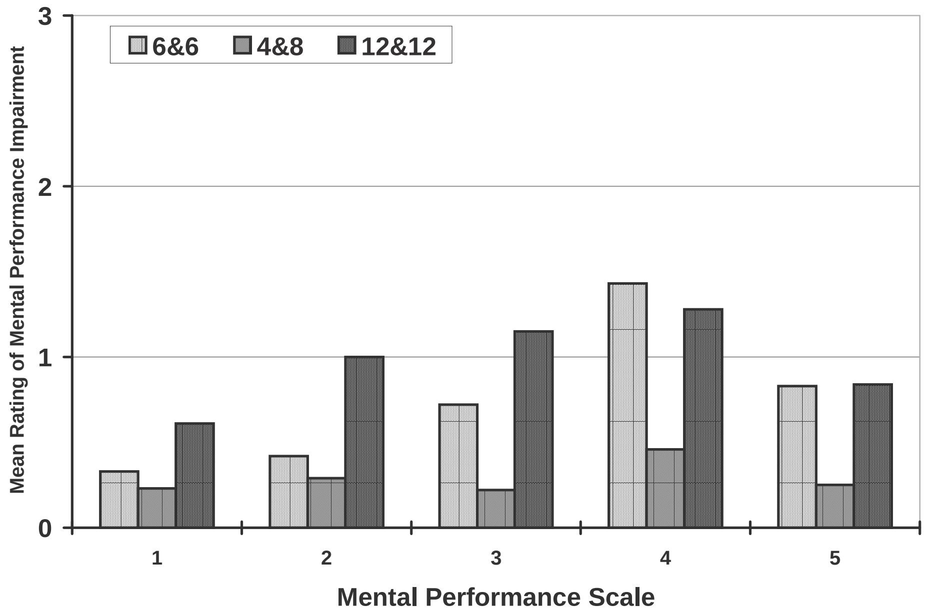


Figure 17:
Average sleep quality rating for each watch schedule. The scale ranged from 1 = poor to 7 = excellent.

3.2.3 Fatigue

Subjective Assessment of Task and Mental Performance

Compared to other watchkeepers, personnel on the 4&8 schedule indicated the least impairment of task and mental performance (Figure 18). Participants on the 4&8 indicated less impairment in the following: memory, simple tasks, concentration, and apathy. This may have been due to an optimization of workload for participants on a 4&8 watch schedule on the *Radisson* in 1996, or it may have been a function of individual differences and composition of that specific crew.



1 = difficulty making decisions; 2 = difficulty with memory; 3 = difficulty with simple tasks; 4 = difficulty with concentration and attention; 5 = general apathy

Figure 18:
Ratings of subjective mental performance for each watch schedule. The scale ranged from 1 = not at all to 5 = extremely.

End of Day Log

The End of Day Log was added as a measure after the 4&8 watch schedule was studied; therefore, only the 6&6 and 12&12 watches were compared on this measure. Participants on the 12&12 watch schedule reported more fatigue-related events happening to themselves and to others. However, participants on the 12&12 watch may have had a better understanding of the purpose of this measure. Participants on the 6&6 watch recorded events that were likely to cause fatigue rather than events resulting from fatigue. Responses to the End of Day Log are included in Appendix A.

3.2.4 Socio-Psychological Factors

Mood

The mood of participants on the 4&8 watch schedule was slightly worse than that of participants on the other watches (Figure 19). Participants on the 4&8 watch schedule were less cheerful, less confident, and somewhat more irritable than participants on other watch schedules. The mood of participants on the 6&6 watch schedule was similar to that of participants on the 12&12.

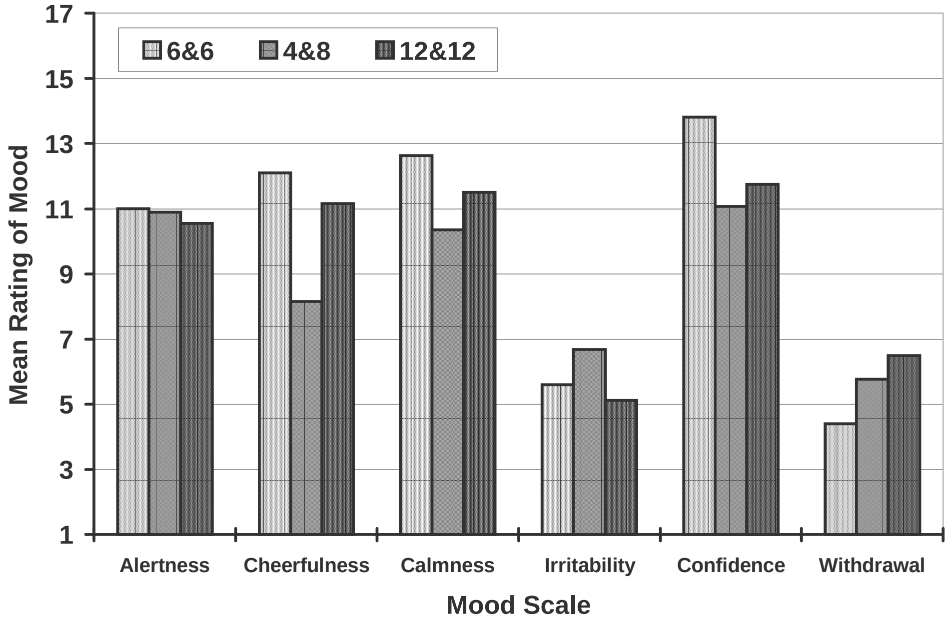


Figure 19:
Post-shift mood ratings for each watch schedule. The scale ranged from 1 = low to 17 = high.

Group Dynamics, Morale, and Response to Stress

Participants on the 4&8 watch schedule had the lowest group dynamics and morale (Figure 20), but along with participants on the 6&6 watch schedule, they also reported the lowest amount of stress (Figure 21). Combined with the mood assessment, these results may indicate that symptoms of fatigue were being expressed in the form of poor socio-psychological well-being for participants on the 4&8 watch schedule. In terms of response to stress, personnel on the 12&12 watch generally reported increased responses to stress, though it must be recognized that responses to stress were relatively small given the size of the scale. Poor socio-psychological well-being, such as poor mood and low morale, may lead to difficulties in crew relations, motivation to complete tasks, quality of task execution, and inappropriate reactions in high stress situations.

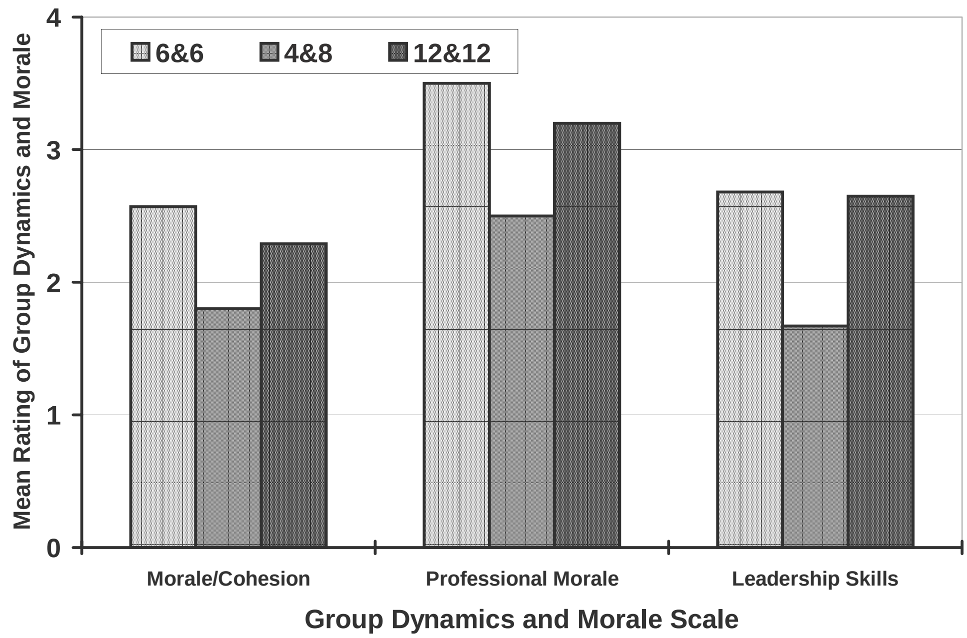


Figure 20:
Mean group dynamics and morale ratings for each watch schedule. The scale ranged from 1 = not at all to 5 = extremely.

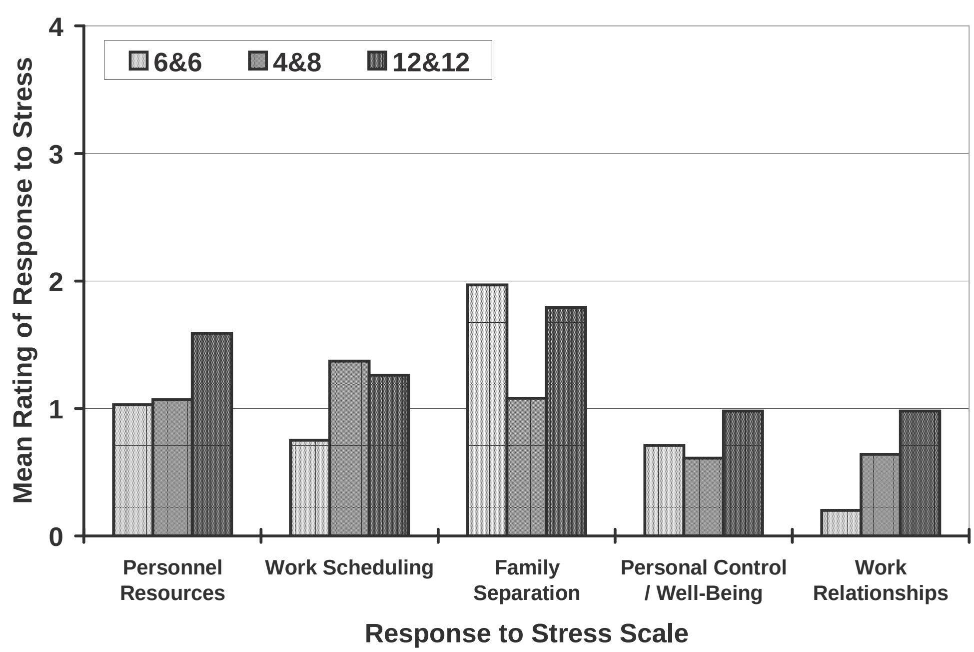


Figure 21:
Mean response to stress ratings for each watch schedule. The scale ranged from 1 = not at all to 5 = extremely.

3.2.5 Additional Measures

Symptoms

Participants on the 12&12 watch schedule reported more fatigue-related symptoms than participants on the other two watch schedules (Figure 22). Compared to the participants on the 6&6 watch, participants on the 12&12 watch schedules experienced significantly more stomach awareness, yawning, and drowsiness. Personnel on the 12&12 watch also experienced significantly more mental fatigue than personnel on the 4&8 watch. The level of fatigue-related symptoms reported by participants on the 4&8 watch schedules was similar to that reported by participants on the 6&6.

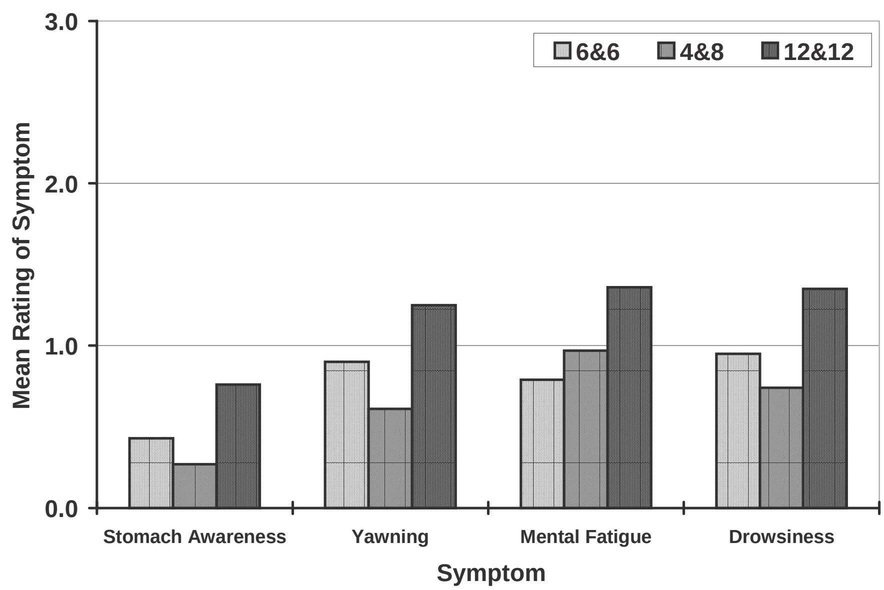


Figure 22:
Post-shift symptom ratings for each watch schedule. The scale ranged from 1 = not at all to 5 = extremely.

3.2.6 Summary of the Differences Between the 6&6, 4&8, and 12&12 Watches

From a human factors perspective, the second purpose of this study was to examine whether one type of watch schedule (i.e., 6&6, 4&8, or 12&12) was superior to the others. Over three phases, the comparison included personnel on board the DFO/CCG vessels *Pierre Radisson* (1996), *Henry Larsen* (1997), and *Sir Wilfrid Laurier* (1998).

The comparison of the 6&6, 4&8, and 12&12 watch schedules did not show that one watch schedule was markedly superior to the others in terms of maintaining an optimal crew state. Each watch schedule had both positive and negative aspects.

Participants on the 4&8 watch schedule had superior results on cognitive measures, while participants on the 6&6 indicated better socio-psychological well-being, and participants on the 12&12 had the opportunity to obtain better sleep. It must be stressed, however, that since these crews were operating on real taskings, the taskings were different. Any of the reported differences found in this study may be related to the differences in the taskings rather than the differences between watch schedules. Although vessel tasking may have had a true impact on crew fatigue, it was not possible to control for vessel tasking for logistical reasons.

With respect to human performance, the most important factors in preventing fatigue are sleep duration and quality over the length of a 42-day crewing period. Therefore, the opportunity to obtain a least 7 hours of uninterrupted sleep, combined with attempts to balance workload so that crews are neither bored nor overworked should provide the greatest defence against fatigue-related problems in extended crewing periods. From the perspective of sleep quantity and quality, only the 12&12 watch provided ample opportunity for sleep, with all sleep being obtained in one continuous period of just over 7 hours. While personnel on the 4&8 watch obtained less total sleep than personnel on the 6&6 watch (about 31 minutes each day), personnel on the 4&8 watch obtained more than 60 extra minutes of continuous sleep, thereby improving sleep quality. However, both the 4&8 and 6&6 watch schedules restricted the amount of continuous sleep participants were able to obtain. Participants on the 4&8 watch obtained a total of 5 hours continuous sleep, and participants on the 6&6 obtained only 4 hours of continuous sleep. Based on this analysis of sleep as the primary contributor to the maintenance of alertness (and prevention of fatigue), the best watch would be the 12&12 watch followed by the 4&8 watch and finally the 6&6 watch.

However, the superiority of the 12&12 watch may still be disputed. The Phase 3 study did not focus on the differences in the effects of the various watch schedules on "day" and "night" watchkeepers. Research indicates that the 12&12 watch schedule may only be better for day watchkeepers since sleeping during normal day-time hours is not as restorative as sleeping during normal night-time hours (Monk and Folkard, 1992).

Additionally, even though it may be possible to get better sleep on the 12&12 watch schedule, other watch schedules may be preferred for practical reasons such as weather conditions and workload. Some crew members expressed concerns that crew workload levels might become too fatiguing over 42 days on a 12&12 schedule if vessel workload was extremely heavy. Imposition of an impractical or unpopular watch schedule might affect crew morale and compromise vessel safety. Several factors including vessel workload and crew preference should be considered in the selection of watch schedules for different vessels and different modes of operation.

3.3 General History Questionnaire

At the beginning of each crewing period, participants were asked to complete a questionnaire to assess on board performance, general well-being, watch scheduling and fatigue. The results of the questionnaire included general demographic information such as DFO/CCG experience and type of duty cycle, as well as information about the relationship between watch schedule and the participants' sleep patterns at home and on board ship.

The General History Questionnaire was based, in part, on a questionnaire that was distributed to Canadian air traffic controllers to assess shiftwork and well-being (Heslegrave *et al.*, 1995). The General History Questionnaire was also based on a questionnaire that was distributed by Sanquist *et al*. (1996), to merchant marine seamen in a study of fatigue entitled "Fatigue and Alertness in Merchant Marine Personnel: A Field Study of Work and Sleep Patterns". Analysis of the General History Questionnaire consisted of descriptive statistics only (i.e., no hypothesis tests were performed on the data).

The results of the General History Questionnaire which relate to tiredness, fatigue, and sleep revealed several areas that might indicate a deterioration in crew state with extended crewing periods. For consistency, the terms used to describe the responses are the same ones that were used in the specific questions. In the responses, the term "tired" referred to feeling weary or fatigued, whereas "sleepy" referred to feeling drowsy or inclined to sleep.

Fatigue-related experience during the crewing period:

Based on the following observations, approximately one quarter to one third of the crew experienced daily fatigue during the crewing period.

- 24.3% indicated their typical state during work was less than alert;
- 33.3% felt sleepy at work two or three times a week while 9.1% felt sleepy at work about every day;
- 27.3% felt tired at work once a week, 30.3% felt tired at work two or three times a week and 21.2% felt tired at work about every day for a total of 78.8% of respondents; and
- 27.3% felt quite mentally tired at the end of a normal workday.

These results indicate that, while on the ship, between one quarter to one third of the respondents experienced, or were in danger of experiencing, cumulative fatigue. These results are similar to those of Phase 2, which indicated many of the participants may have experienced cumulative fatigue.

Sleep behaviour at home vs. during a crewing period:

Participants provided conflicting information about differences in sleep behaviour on the ship and at home. The following results suggest differences in sleep behaviour at sea compared to at home:

- 24.3% of respondents indicated having difficulty getting up while at sea compared to 6% indicating difficulty getting up at home (suggesting greater fatigue at sea);

- 89.2% indicated getting less than 8 hours of daily sleep at the beginning of the crewing period, and 77.7% indicated less than 8 hours of sleep near the end of a 42-day crewing period, while only 66.6% reported getting less than 8 hours of sleep on a typical day off; and
- 42.5% reported getting less than enough sleep at sea compared to 94% getting less than enough sleep at home.

In the current phase of the study, it was clear that participants' sleep behaviour at sea was different than it was at home. Even though icebreaking did not contribute significantly to fatigue in Phase 3, participants reported obtaining less sleep at sea than at home, less sleep than they thought they needed, and greater difficulty arising from sleep when at sea compared to when at home. Together, these data suggest that participants in Phase 3 obtained less sleep at sea than necessary and were at risk of developing a chronic sleep debt over time. In Phase 2, this problem was exacerbated because significant icebreaking operations exaggerated the sleep loss over time.

Irrespective of the differences between Phases 2 and 3, personnel should be aware of the dangers of inadequate sleep, both at sea and at home. It is recommended that personnel receive fatigue awareness and fatigue management training to help them avoid, as much as possible, and better manage the effects of fatigue.

3.4 Fleet Activity Information System (FAIS) Analysis

The Fleet Activity Information System (FAIS) logs maintained on board the *Sir Wilfrid Laurier* were evaluated to track vessel workload (Appendix C). Examination of the FAIS logs provided information on icebreaking activities, critical incidents, contact with other vessels, and other events that may have related to levels of crew fatigue. Vessel workload was compared across the two crewing periods in 1998 and during the same time period in 1997.

Individual activities in the FAIS analysis are grouped under broad headings (e.g., icebreaking operations). The amount of time spent in each activity is calculated as a proportion of chronological time (i.e., the number of hours logged in each activity divided by the number of possible hours in the crewing period). It is possible to obtain proportions greater than 1.0 in this analysis because of the grouping of activities and because more than one activity may be logged during the same time period in the FAIS.

The task analysis conducted during Phase 1 of the study revealed that icebreaking operations and search and rescue (SAR) were the most critical and stressful activities performed by crews on board Arctic icebreakers. In the FAIS analysis, these two activities were the primary factors used to determine vessel workload.

The FAIS data indicated that there were no major differences in vessel workload between the two Arctic crewing periods in 1997 and the two Arctic crewing periods in 1998. The *Laurier* logged more activity in the first crewing period of 1998 than in the other crewing periods, and most of the activity in the first crewing period of 1998 was categorized as "at sea other". In the two years analyzed, the only time spent icebreaking was logged during the second crewing period of 1997. During its second crewing period in 1997, the *Laurier* spent 25% of the time in icebreaking operations, compared to no icebreaking during the same period in 1998. In both 1997 and 1998, no time was logged as SAR in the FAIS.

4 SUMMARY AND CONCLUSIONS

4.1 Differences Across Intervals in the 42-Day Crewing Period

This study was Phase 3 of a multi-phase study of extended crewing periods and watch schedules in DFO/CCG Arctic icebreaking operations. As in the previous two phases (which were conducted in 1996 and 1997), signs of fatigue were evident in some, though not in all measures, and no measure showed substantial change over the 42 days. However, the level of fatigue that participants experienced was insufficient to affect objectively measured performance as defined by the Delta test battery. There are many reasons why this might be the case: insufficient training on the part of subjects, less than optimal testing conditions, or indeed limited fatigue effects. It is likely that if fatigue were marked or severe in nature, degradation in objective, behavioural measures of performance (such as the Delta test battery) would have been more evident.

While the data suggest that fatigue may have been evident in this study, it could not be characterized as severe. This is not to say that the level of fatigue observed in this study would be acceptable under different operational conditions. In many situations where conditions are moderate to ideal, fatigue has limited impact; nevertheless, under conditions of more extreme physical or mental demands, the same level of fatigue may have devastating consequences.

In the present study, the most significant indicators of fatigue were manifested in socio-psychological factors such as deteriorating mood and group dynamics, morale, and response to stress. These changes can lead to difficulties in crew relations, lack of motivation to complete tasks, and inappropriate reactions and decision-making in high-stress situations.

The analysis of the End of Day Log results indicated that fatigue was present in some participants in all intervals. This suggests that it was not the length of the crewing period but rather other factors such as workload levels, vessel program, sleep duration and quality, and circadian rhythms that were the source of the fatigue experienced by the crew.

If personnel are fatigued from the outset of their crewing period, their level of fatigue is more likely to increase over the course of the crewing period. This fact is apparent in the results of the General History Questionnaire, which indicated that between one quarter to one third of the respondents experienced, or were in danger of experiencing, cumulative fatigue.

The results of the Retrospective Alertness Inventory (RAI) indicated that levels of participant fatigue were similar over the course of the crewing period. While there was a change in watchkeepers retrospective rating of alertness over the course of the watch, this change was consistent across intervals, indicating that the length of the crewing period was not a significant factor in watchkeepers ratings of alertness. The RAI also illustrated differences between day and night watchkeepers. Day watchkeepers reported similar alertness over the course of the crewing period, but night watchkeepers reported different patterns of alertness in each interval. The pattern of change in the night watchkeepers' alertness indicated an incomplete circadian adjustment to a night routine.

Combined, the results indicated that participants were experiencing similar levels of fatigue throughout the crewing period, and there was little evidence that the fatigue levels were increasing with the extended crewing operations. It is possible that fatigue became stable prior to the normal duty cycle of 28 days and remained stable for some time thereafter. This would be consistent with more acute sleep deprivation studies (Heslegrave and Angus, 1985).

If fatigue is present from the beginning of the crewing period, the need to address fatigue in current operations is reinforced. Although fatigue did not appear to escalate seriously in the current phase, fatigue effects are more apparent when individuals are pushed to their limits, which did not occur in this study. Personnel should be aware of the dangers of inadequate sleep, both at sea and at home and they should take appropriate steps to increase their alertness while on board. It is recommended that personnel receive fatigue awareness and fatigue management training to help them avoid, as much as possible, and better manage the effects of fatigue. The implementation of systematic measures to combat fatigue will better ensure appropriate levels of alertness at critical times.

4.2 Differences Between Watch Schedules

The second purpose of this study was to examine whether one type of DFO/CCG watch schedule (i.e., 4&8, 6&6, or 12&12) was superior to the others in terms of optimizing crew state. This comparison included personnel on three watches on board three DFO/CCG vessels over three years:

- the 4&8 on the *Pierre Radisson* (1996);
- the 6&6 on the *Henry Larsen* (1997); and
- the 12&12 on the *Sir Wilfrid Laurier* (1998).

The comparison of the three watch schedules did not show that one watch schedule was superior to the others in terms of maintaining the optimal crew state. Each watch schedule had both positive and negative aspects. Participants on the 4&8 watch schedule had superior results on cognitive measures, while participants on the 6&6 indicated better socio-psychological well-being, and participants on the 12&12 had the opportunity to obtain better sleep. The superior cognitive performance of personnel on the 4&8 watch schedule may have been due to more balanced workload level, creating a state in which the crew were neither bored nor overworked. However, since the same personnel were not tested on the three watches, individual differences may have contributed to the results.

With all other things being equal, the most important factors in preventing fatigue are sleep duration and quality over the length of a 42-day crewing period. Therefore, the opportunity to obtain a least seven hours of uninterrupted sleep, combined with attempts to balance workload so that crews are neither bored nor overworked should provide the greatest defence against fatigue-related problems in extended crewing periods.

In this regard, personnel on the 12&12 watch had the greatest opportunity for sleep quantity and quality followed by personnel on the 4&8 and then the 6&6. However, research indicates that the 12&12 watch schedule may only be better for day watchkeepers since sleeping during normal day-time hours is not as restorative as sleeping during normal night-time hours (Monk and Folkard, 1992). Additionally, the ideal situation is rarely encountered in operational environments. For example, even though it may be possible to get better sleep on the 12&12 watch schedule, other watch schedules may be preferred for practical reasons such as weather conditions, workload, and crew preference. Several factors including vessel workload and crew preference should be considered in the selection of watch schedules for different vessels and different modes of operation.

Summary

The safety of the crews and vessels was never seriously threatened during the operations encountered in this study, but it is not certain that the same would have been true had conditions been more demanding. The effects of fatigue have the greatest and most obvious impact in emergencies and other critical situations. To minimize crew fatigue and maximize crew and vessel safety, there must be an awareness and acceptance in CCG personnel that fatigue can occur at any point in the crewing period. It must also be accepted that while watch schedule and crewing period length may affect watchkeepers' levels of fatigue and alertness, the effects of other factors may be equal, or possibly greater, contributors to fatigue in current DFO/CCG Arctic icebreaking operations. Fatigue can be caused be a number of factors, including the following:

- personal lifestyle;
- sleep patterns;
- circadian rhythms;
- environmental conditions;
- crew and personal preparation for the crewing period;
- crew and personal preparation for the watch schedule; and
- vessel tasking and workload.

Systematic implementation of the recommendations in this report will assist DFO/CCG in minimizing crew fatigue and maximizing crew and vessel safety.

5 RECOMMENDATIONS

DFO/CCG will achieve the maximum benefit from this study through the following stages:

- evaluating and prioritizing the recommendations in this report;
- incorporating the recommendations into standard procedures; and
- systematically implementing the changes, (including monitoring the effects of change), and following up with further change as required.

The following summarizes the recommendations made in all phases of the project entitled "Study on Extended Coast Guard Crewing Periods."

- Extended crewing periods should be implemented in an organized manner, including continued evaluation of the effects of extended crewing. The current information suggests that members of the 12&12 night watch do not adapt completely to a night routine. However, the current information is not adequate to determine whether there may be adaptation to extended crewing with further experience or whether the deterioration in crew state seen in this study is a precursor to significant performance impairment should operating conditions worsen.
- 12&12 watches may offer better opportunities for improved watch management through modifications to procedures during relatively low workload periods. Crew working night shifts should be provided with opportunities for strategic rest periods to take naps when opportunities permit.
- Anticipated workload should be matched to crew requirements so that the crew can achieve maximal sleep and rest. Such optimal assignment will promote improved morale and a more alert crew when they are working.
- Crew preference must be considered when implementing watch schedules, especially if it is in a region unfamiliar with a particular type of watch.
- Fatigue-sensitive tasks (identified by the Phase 1 Task Analysis, Davis *et al.*, 1997) should be minimized wherever possible during weeks 5 and 6. When these types of activities cannot be reduced, care should be taken that ample time is allocated for their completion and that they are monitored or checked frequently.
- Fatigue-sensitive tasks should be minimized at night.

- Opportunity for crew to rest should be provided during periods of extended icebreaking (see the Phase 1 report for a discussion of the effects of 8 versus 15 days of icebreaking).
- If icebreaking is late in the duty cycle, additional rest and extra precautions are required. At this time, fatigue-sensitive tasks are most vulnerable to disruption and should be minimized wherever possible and carefully monitored if they are essential to vessel operations.
- CCG should implement a training program to provide ships' crew and management with information about coping strategies that will help them deal effectively with extended crewing periods. At the time of this report, CCG was considering implementation of this recommendation.
- If crew are given a day off during the crewing cycle, they should be encouraged to maintain the same sleep/wake pattern as if they were working.
- Older crew members should be considered for watches other than the watch that spans 2300 to 0600 hrs as aging affects an individual's ability to adapt to changes in sleep patterns. However, it may be that certain individuals are better adapted to night work regardless of age and should be given consideration to stand this watch if requested.
- Sufficient time off needs to be provided between successive 42-day cycles, to ensure that crew can adequately recover.
- If the opportunity arises, and if prolonged periods of icebreaking are anticipated, crew should be given a recovery period (usually characterized by anchoring) prior to engaging in activities that are likely to promote cumulative fatigue.
- When appropriate, the Commanding Officer and Chief Engineer should authorize and provide relief to watchkeepers, or temporarily assign other qualified personnel to the watch, including the Chief Officer and the Senior Engineer.
- Training for sleep hardiness, which would enhance the quality of sleep, should be implemented for crew prior to extended crewing periods (Alsten *et al*., 1995). Sleep hardiness training is designed to help individuals to fall asleep with minimal effort and awaken feeling more alert, refreshed and ready to start the day's activities.
- The work schedule during crewing periods should be based not necessarily on hours of work, but on fatigue management, considering such things as vessel tasking, circadian adjustment to a particular watch, and the amount and quality of sleep the crew is obtaining. Other industries such as trucking are looking at work rest cycles as a fatigue management problem.
- Unless it is absolutely necessary, the crews' normal sleep routine should not be disrupted to perform overtime duties.

- To provide a recovery period during the crewing cycle, crew members should be given the opportunity for adequate sleep for at least two nights (or two days for the night shift). Two nights of sleep can lead to full recovery from an accumulated sleep debt (Smiley and Heslegrave, 1997). The DFO/CCG should consider scheduling such a routine every two weeks, staggered across crew members to counteract the accumulation of fatigue. If two nights sleep is not possible, shorter durations will still provide a measure of recovery.
- If further study is undertaken, more specific assessments of performance and sleep during extended crewing should be implemented. Specific assessments should be arrived at and agreed upon by fatigue experts and CCG.

6 LIMITATIONS OF THE STUDY

There are two important types of limitations that need be considered when interpreting the results from this study. The first concern operational and crewing characteristics of vessel taskings. The second concern the level of crew participation. Both may affect the extent to which results can be generalized to other operational settings, but these types of challenges are expected when collecting data in a field study. Decisions should not be made on anecdotal or biased information. The data, conclusions, and recommendations need to be interpreted in the context of limitations that are common to all field and laboratory studies. For consistency, the limitations from both Phase 1 and Phase 2 are provided.

6.1 Limitations Related to Operational Issues and Crewing Characteristics

- Due to logistical constraints, the timing of the data collection was not identical between vessels.
- To refine the data collection procedures, measures were added in Phases 2 and 3. While the addition of new measures added valuable information to the study, it was not possible to compare the measures in all phases.
- The timing of data collection was modified beginning in Phase 2. In Phase 2, data were collected in three critical intervals, rather than over the entire crewing period.
- Because measures were taken during vessel operations, some of the measures such as the cognitive performance tests were limited to brief time periods before and after watch, and frequently were not completed at all due to time or operational constraints.
- The vessel workload, patrol characteristics, and crewing periods were different for each vessel.
- For logistical reasons, there were different data collection schedules for each vessel. For example, the second crewing period on board the *Larsen* in Phase 2 was changed from 42 to 38 days.

- The watch schedule comparison involved an average of data over the entire 42 days for the 4&8 watch on the *Radisson*, and an average over the three critical intervals (18 days in total) for personnel on the 6&6 and 12&12 watches on the *Larsen* and the *Laurier*.
- There were different crewing cycles on the vessels, with the entire crew of the *Henry Larsen* and *Sir Wilfrid Laurier* being on a lay-day system and part of crew of the *Pierre Radisson* being on a conventional cycle.
- There were different locations of sleeping quarters on the vessels, which affected the level of noise exposure experienced by different personnel.
- There were different types of personnel on the vessels (e.g., some watchkeepers on the *Larsen* and *Laurier* were quartermasters whereas all watchkeepers on the *Radisson* were officers).
- There were different numbers of personnel scheduled for duty on the bridge and in the engine room on each patrol and on each vessel.
- There were different relief schedules on the vessels for breaks and meals. For example, watchkeepers on the *Radisson* worked one additional hour each day to make up for meal times.
- General limitations in testing were posed by the operational environment. For example, testing was split or stopped when vessels or individuals were in periods of high workload.
- Because of the restricted time frame for measurement during shipboard operations, it was not possible to obtain any objective measures of vigilance by means of sustained cognitive tests. Therefore, the cognitive test scores in this study likely underestimate performance deficits associated with extended crewing and associated fatigue.
- Measures were collected during summer operations that had periods of 16 to 24 hours of daylight per day. Had data been collected during times of the year with fewer hours of daylight per day, this may have had a different influence on some measures such as crew mood.

6.2 Limitations Related to Crew Participation

- Participation in the study was voluntary and several crew members chose not to participate, or withdrew from all or parts of the data collection while the study was in progress.
- There were limited numbers of participants. Limited numbers of participants reduce the power of statistical comparisons and introduce the possibility of individual differences having a stronger effect.
- Because of a limited number of subjects and missing data, it was difficult to perform statistical analysis on some of the data.

- Pooling of participants wherever possible has the advantage of increasing sample size but also introduces increased variability from crew-related variables that are not specific to watchkeeping positions.
- Some participants had difficulty operating equipment during periods when investigators were not on board (e.g., problems with computer procedures for the cognitive performance tests).
- Some participants removed monitoring equipment if it had the potential to interfere with activities including sleep (e.g., the PAM/2 activity monitor was frequently removed prior to sleep).
- Evaluation of the effects of fatigue on vigilance require a longer, continuous test (at least 10 minutes). If implemented in future studies, co-operation of the crew could become a problem.

REFERENCES

Alsten, C., Downey, R., and Jackson, T. B. (1995). Preliminary Evaluation of a "sleep training" program to enhance the quality and quality of aircrew sleep during extended missions. Twelfth International Symposium on Night and Shiftwork, Storrs, Connecticut, June. Shiftwork International Newsletter, 12, p. 107.

Colquhoun, W.P., Condon, R., and Gordon, D.S. (1988). Watchkeeping in Fleet support vessels, Medical Research Council. London: Report to the Royal Navy Personnel Research Committee.

Davis, S.C., Hamilton, K., Heslegrave, R.J., and Cameron, B.J. (1997). Study on extended Coast Guard crewing periods, Transportation Development Centre, TP 12976E & F.

Davis, S.C., Cameron, B.J., Heslegrave, R.J., and Hamilton, K. (1998). Study on extended Coast Guard crewing periods, phase 2, Transportation Development Centre, TP 13248E.

Donderi, D.C., Smiley, A., and Kawaja, K.M. (1995). Shift schedule comparison for the Canadian Coast Guard, Transportation Development Centre, TP 12438E.

Folkard, S., Spelten, E., Totterdell, P., Barton J., and Smith, L. (1995). The use of survey measures to assess circadian variations in alertness. Sleep, 18(5), 355-361.

Heslegrave, R.J. and Angus, R.G. (1985). The effects of task duration and work-session location on performance degradation induced by sleep loss and sustained cognitive work. Behavior Research Methods, Instruments, & Computers, 17, 592-603.

Heslegrave, R.J. (1994). Using psychophysiology to understand fatigue, Proceedings of the 12th Triennial Congress of the International Ergonomics Association, 5: 350-352.

Heslegrave, R., Rhodes, W., Szlapetis, I., Ujimoto, V., Hahn, K., and Moldofsky, H. (1995). Subjective performance deficits in air traffic controllers as a function of nightshift, chronobiological typology and age. Shiftwork International Newsletter, 12(1).

Hockey, R. (1996). Skilled performance and mental workload. In: P. Warr (Ed.), Psychology at Work, 4th Ed. New York: Penguin Books, 13-38.

Monk, T.H. and Folkard, S. (1992). Making shift work tolerable. Taylor and Francis, London.

Ritmiller, L.M., Heslegrave, R.J., Cameron, B.J., Hamilton, K., Roddan, G., Darvill, D.J., and Kaufmann, R. (1998). Sweep Width Prediction-Simulation (Effects of vessel motion on target detection in marine search and rescue operations). Department of Fisheries and Oceans: Canadian Coast Guard.

Sanquist, T.F., Raby, M., and Maloney, A.L. (1996). Fatigue and alertness in merchant marine personnel: A field study of work and sleep patterns, Department of Transportation, U.S. Coast Guard, CG-D-06-97.

Smiley, A. and Heslegrave, R.J. (1997). A 36-hour recovery period for truck drivers: Synopsis of current scientific knowledge, Transport Canada, TP 13035E.

APPENDIX A

Participant Comments from the End of Day Log

In the End of Day Log, participants were asked to note anything that occurred during their watch that they could attribute to being tired or fatigued and to categorise the event as happening to themselves, to another person, or to a group of people. The comments included in this appendix appear exactly as written by participants.

Table A-1:
End of Day Log comments from watchkeepers on a 12&12 schedule (Phase 3).

Day	From?	To?	What happened?	What contributed	Could prevent it?	Comments
7	12:00	0:00	Nodded off while sitting in control room.	A shitty sleep	A better sleep.	
7	7:00	11:00	Fatigue gradually set in	Hours of the night shift are contrary to my cycles of alertness and fatigue	Energy level drops after breakfast. Night shift could be changed from 00:00 to 12:00 to 19:00 to 7:00	
7	7:00	7:10	A crew member was taking a job of mine and didn't say it was my dam on deck.	He doesn't know the job (new crew)	Teaching	I was tired out and it really annoyed me.
7	12:00	0:00	At various times my ability to make quick navigational decisions was affected by fatigue	Overall fatigue	More relief during a navigational watch.	
8	12:00	0:00	Forgot to write down generator readings during 21:00 rounds	Mental Fatigue?	More quality sleep.	
8			I got sleepy after lunch	No pressing duties	Cappuccino - 1 cup	
8	8:00	10:00	Multiple repairs, unexpected delays	Time restrictions	inevitable	
8	17:00	18:00	I forgot send a fax as I was engaged in another activity	Neglected to understand the priority		
9	14:00	17:00	Lack of stimulation/work due to fuelling requirements	Tasks at hand	Not a whole lot	
9	10:00	21:00	fuel vessel	long hours - low activity	nothing	
9	15:00		Boson was short tempered	Lack of communication		
9	8:00	9:30	Just tired out, slow working	Sleepiness		
10						I'm tired out - legs ache due to onset of cold and sleepiness. Going to bed very soon.

Table A-1 Continued:
End of Day Log comments from watchkeepers on a 12&12 schedule (Phase 3).

Day	From?	To?	What happened?	What contributed	Could prevent it?	Comments
11	21:30	22:00	Fell asleep while sitting in control room.	Be tired.	Move around.	I had just come back from a break out of Eng. Room. Had a light snack and chatted with a few people. Felt sleepy at this time.
11	8:00		A steward was later cleaning cabins. She appeared tense. Seemed overworked. Looked tired and tense.	Later hours last night, increased work load, conscientiousness.	Hire another steward, get more sleep.	
11	7:30	12:00	On standby in control room.	Not being able to move around, keep busy.		
11	9:30	11:30	Didn't hearing course called out to me while at the helm.	Tired out mentally.	Sleep, not being on 0:00-12:00 watch.	Daydreaming and not knowing it or catching yourself doing it because you're burnt out. Six weeks is a long time.
11	16:00	20:00	One of our hydrographers forgot some equipment ashore.	Increased tempo in workload and fatigue.	Unknown	
12			World cup final had to try and listen.	The hunt for the cup.	Absolutely nothing!	France won 3-0 vs. Brazil!
12						I was beginning to resent the time intrusion to fill in this log!
12	0:00	5:00	On standby in control room.	Not being able to move around, keep busy.	Unable to avoid standby situation.	Standby is a necessary safety precaution.
12						Had a great day, especially my last half of watch. Helicopter work and painting beacons. Fresh air always wakes me up.
26	12:00	19:00	Wanting a day off, lack of motivation.	Coming up to 28 days.		

Table A-1 Continued:
End of Day Log comments from watchkeepers on a 12&12 schedule (Phase 3).

Day	From?	To?	What happened?	What contributed	Could prevent it?	Comments
26			Not able to sleep after watch, For myself, I found the time after watch where I could fall asleep. If I stayed awake past that time I would get a second wind and not sleep until much later.	An activity we were involved in. An opportunity to go ashore or noise due to ships operation.	In some cases very little can be done. Sleep habits vary with all individuals, activities are scheduled to try to accommodate everyone.	My sleep routine while on the night shift is to sleep by 14:00 and wake by 22:00. If I interrupt this I will have problems. I would like to try a shift from 18:00 to 6:00.
26	7:00	12:00	People just seem moody, irritable.	fatigue	Go home after 4 weeks.	We're all just getting run down, tired and ready to go home.
27			I have a horrible headache today, hard to concentrate.	I really need to go to sleep , rest.	It's hard to get rid of a headache when you're standing watch for 12 hours.	
28	21:00	22:15	Was extremely tired in wheelhouse wanted to sleep.	29 days at sea working 12 hr day.	A little time off, shore leave.	
28			Forgot to take computer tests.	Broken sleep	Shorter trips	
28			I was irritable.	Tired, run down, tired of being here.	I just need some space some time alone away from here	
29			General irritability.	People are tired, moody etc.	You are seeing people are run down, catching colds, apathetic.	
30			I forgot to fill out post watch assessment.	I was working past 1900 then shut off the computer and relaxed.		
30	12:00	23:00	Lack of enthusiasm.	Tired and bored.	Get closer to land – we've seen land twice in 30 days.	
30			Everyone is moody!	Tired out	I could have gone home 2 days ago	Six weeks is far too long

Table A-1 Continued:
End of Day Log comments from watchkeepers on a 12&12 schedule (Phase 3).

Day	From?	To?	What happened?	What contributed	Could prevent it?	Comments
31	6:00		Our captain told another officer off in front of me for no reason – just an ego trip.	This officer wanted to give his department a sleep in day and was to going to cover for them. CO didn't like the plan.	I don't see why we can't have a rest type day. People are run down tired, sick and angry. The reason this all went bad is because one person is too ignorant and selfish to think of the rest of the crew. He gets an afternoon nap daily. Why can't we?	
36			Nothing specific, you're just never too sure how people are going to act, it feels tense here.	Overworked, run down, tired out	4 weeks is long enough, 6 just drains you completely. Every day of 23:00 that I get up at it's harder and harder.	
37			Myself-I kept dropping off when reading or studying. I feel tired. I am getting lots of sleep.	Every day is similar. Long workday, short social period after. Grey skies.	We are out of touch with the world. No TV, very staticy [sic] radio.	A seaman on bridge lookout while steaming through fog had his attention deviated, then turned around and started reading a book. He had to be reminded to look out the window. Even being tired this struck me as abnormal. The man is normally conscientious.
37			I find myself not wanting to be around people – I'd rather be alone - have some peaceful time.		Not much.	

Table A-2:
End of Day Log comments from watchkeepers on a 6&6 schedule (Phase 2).

Day	From?	To?	What happened?	What contributed	Could prevent it?	Comments
8	19:30	22:30	Worked on computers with CE, thus didn't get much sleep.	Too much interest in computers.	Avoid cutting into sleep time with extra circular activities.	
8	0:00	6:00	6 hour watch with no time away from it just to relax; Kick up your feet for a couple of minutes away from the bridge.	Nothing or get promoted to a day job.		
9	18:00	21:00	Working on computer installation on my own time	N/A		
9	0:00	6:00	Went aboard another ship	Should have come back early and got a couple hours sleep.		
11	19:30	20:00	Ship blacked-out while steaming (ship in dark).	Propulsion fault.	Instantaneous fault.	Instantaneous fault and shut down, unpreventable.
11			Tension over upcoming Arctic circle initiation ritual.	Daily reminders, postings of victim lists, general harassment.		
11						Phone call today, in real good mood.
12	18:00	23:00	Arctic circle crossing initiation. "Tension" attributed to waiting for event. Fatigued by participating in event and gathering afterwards i.e., no sleep for "off" shift.			
12	0:00	6:00	Staring through binoculars.	Staring through binoculars.	Nothing	Eyes get too tired.
12	12:00	16:00	A lot of noise and vibration.	Heavy ice escorting ship.	0	0
12			Tired, no sleep on watch off, in heavy ice.			
26						Felt a little bit better about the trip because crew change is 4 days early.

Table A-2 Continued:
End of Day Log comments from watchkeepers on a 6&6 schedule (Phase 2).

Day	From?	To?	What happened?	What contributed	Could prevent it?	Comments
28						Feel just like a rechargeable battery would feel if not left on charger long enough. Worn out very decidedly.
29						Frustration level running high in watchkeeping personnel because day working personnel get breaks during the day where watchkeepers don't
29			No sleep between watches.	restless, headaches.		
29						happy day, found out crew change information, getting off ship a few days early
30						Felt especially tired going on watch at 6: 00
30			No sleep off watch.			
31						Was called for 1 hour overtime at 14:20. did not get any more sleep in the afternoon.
31			Went for a walk ashore during off hours to use the only phone available at Nanisivik (all others were in places that had already closed for night)	Upon getting to the phone I found a line up of on-duty personnel waiting for phone.		I am tired of day workers getting the breaks while the watchkeepers have to continuously put in the full hours of work.
31			No sleep, In a 24 hour period 3 hours and 45 minutes.			
32			Little sleep.			
33						Although I was given 3 hours off yesterday I was still equally tired when called at 5:20. The extra sleep I got from my time off wouldn't have made up for the time I lost the day before when I was called out for mooring operations at 14:20
38	9:30	11:00	Ice breaking in heavy ice.	Operational requirements.	nothing	

APPENDIX B

Retrospective Alertness Inventory

Alertness Inventory

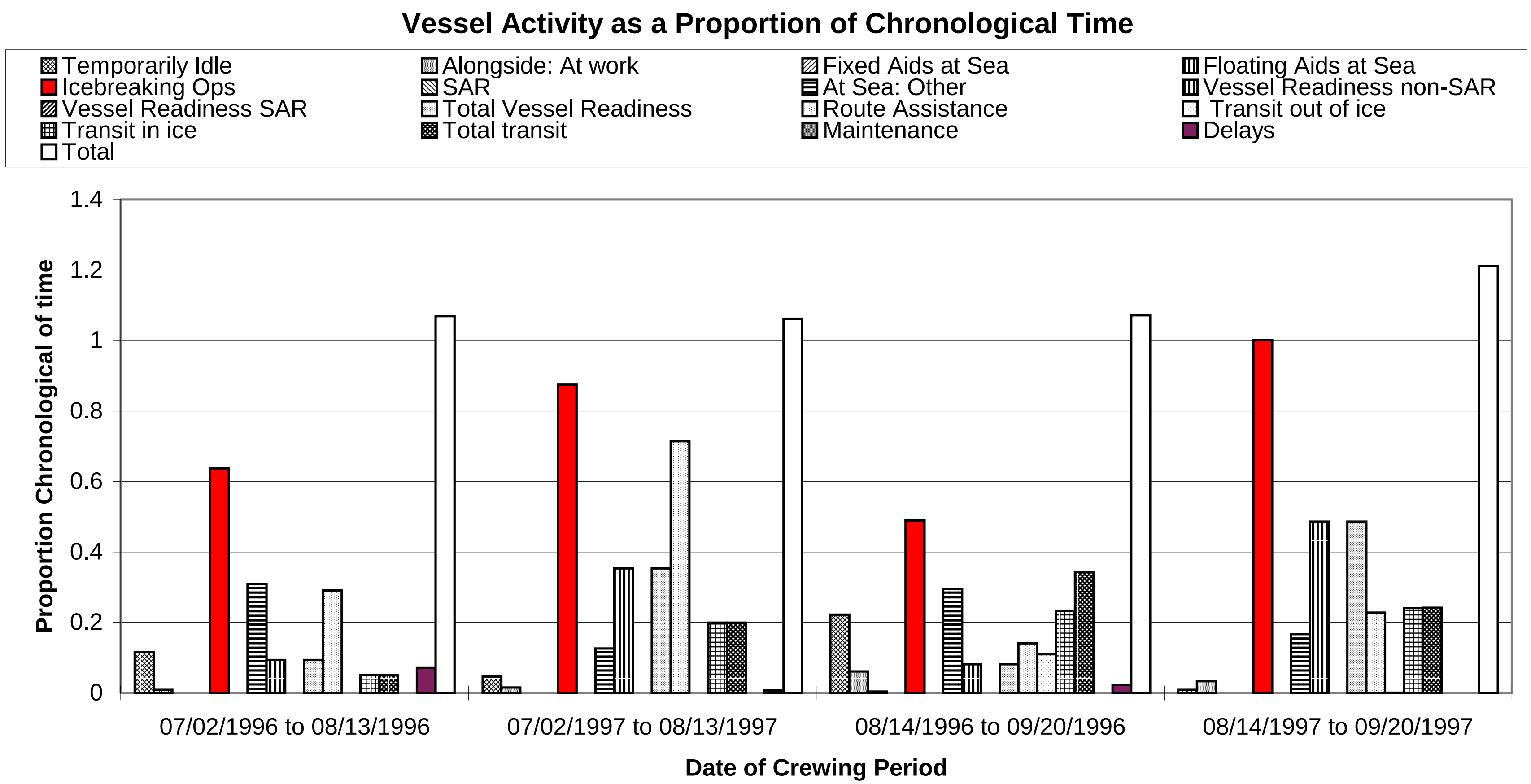
The purpose of this questionnaire is to obtain some information regarding your work schedule and how alert/sleepy you tend to be throughout the day.

Please rate how alert or sleepy you normally felt at one-hour intervals over the past 24 hours. Use the 0 rating to indicate your normal sleep periods.

	Very alert		Alert	Neither alert nor sleepy		Sleepy (but not fighting sleep)		Very sleepy (fighting) sleep)		Usually Sleeping
0000	1	2	3	4	5	6	7	8	9	0
0100	1	2	3	4	5	6	7	8	9	0
0200	1	2	3	4	5	6	7	8	9	0
0300	1	2	3	4	5	6	7	8	9	0
0400	1	2	3	4	5	6	7	8	9	0
0500	1	2	3	4	5	6	7	8	9	0
0600	1	2	3	4	5	6	7	8	9	0
0700	1	2	3	4	5	6	7	8	9	0
0800	1	2	3	4	5	6	7	8	9	0
0900	1	2	3	4	5	6	7	8	9	0
1000	1	2	3	4	5	6	7	8	9	0
1100	1	2	3	4	5	6	7	8	9	0
1200	1	2	3	4	5	6	7	8	9	0
1300	1	2	3	4	5	6	7	8	9	0
1400	1	2	3	4	5	6	7	8	9	0
1500	1	2	3	4	5	6	7	8	9	0
1600	1	2	3	4	5	6	7	8	9	0
1700	1	2	3	4	5	6	7	8	9	0
1800	1	2	3	4	5	6	7	8	9	0
1900	1	2	3	4	5	6	7	8	9	0
2000	1	2	3	4	5	6	7	8	9	0
2100	1	2	3	4	5	6	7	8	9	0
2200	1	2	3	4	5	6	7	8	9	0
2300	1	2	3	4	5	6	7	8	9	0

APPENDIX C

Fleet Activity Information System (FAIS) Analysis


Vessel Activity as a Proportion of Chronological Time
Temporarily Idle
Alongside: At work
Fixed Aids at Sea
Floating Aids at Sea
Icebreaking Ops
SAR
At Sea: Other
Vessel Readiness non-SAR
Vessel Readiness SAR
Total Vessel Readiness
Route Assistance
Transit out of ice
Transit in ice
Total transit
Maintenance
Delays
Total
Proportion Chronological of time
1.4
1.2
1
0.8
0.6
0.4
0.2
0
07/02/1996 to 08/13/1996
07/02/1997 to 08/13/1997
08/14/1996 to 09/20/1996
08/14/1997 to 09/20/1997
Date of Crewing Period