

Project

MARTHA

The Final Report



Acknowledgements

The partners wish to acknowledge the following, without whom, this project could not have been a success:

First and foremost, the volunteer participants who gave up their time to complete questionnaires, undertake weeks of diary keeping and wore actiwatches for long periods in the service of the project and for the benefit of their fellow seafarers.

Secondly, the companies who participated. We are indebted to the two Chinese state-run companies who operate bulk carriers and tankers for their kind help and support. In Europe, we were privileged to work

with the MF Shipping Group (MFG) of Delfzijl ('Company A') and the Zodiac Shipmanagement Co was ('Company B'). We appreciated the friendly help and support they gave us during the project and we hope that the experience has helped them in their understanding of fatigue management of the fatigue risk.

The many individuals, fellow researchers and maritime organisations who have supported us over the last three years.

Finally, our sponsors – the TK Foundation who have supported the project throughout and without whom, we could not have achieved so much.



The partners met many times during the project and several staff from each organisation made contributions. The main researchers were:

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I.

Introduction

Fatigue at sea and related issues, such as stress and workload, are highly topical and important areas of research as the problems of mental health and wellbeing are being increasingly recognized by society. Ships' crews are under increasing pressure from competitive voyage schedules and have to handle their tasks with fewer crew members. Evidence from accident records and research literature both point to the serious impact that sleepiness and fatigue may have on the safety and welfare of seafarers.

The shipping industry has recognized the need for research in this area and the findings from the predecessor, project HORIZON, have had a significant impact already on the understanding within the shipping industry of the importance of managing fatigue, both in terms of sleepiness and also in its longer term psycho-social effects. The latter is much less well-researched, and the results from the MARTHA project have indicated that fatigue and stress increase for most crew as the voyage length increases, and motivation decreases. Captains suffer more than their colleagues from both fatigue and stress. Port work is particularly demanding: the results also show that no one onboard gets adequate sleep, with the night watch keepers being particularly at risk of falling asleep. High sleepiness levels can occur at any stage of the voyage but the quantity and quality of sleep deteriorates over long voyages. The results from the use of actigraphy have also confirmed many of the perceptions of seafarers from their interviews and weekly diaries.

MARTHA was conducted by an international partnership of researchers and industry. The \$3 million project was sponsored by the TK Foundation over a three year period from 2013 to 2016.

The Partners

The Stress
Research
Institute



II.

Methodology and Research Design

The aim of the study was to explore the levels of sleepiness and the psychosocial issues associated with long term fatigue and motivation, using a sample of volunteer seafarers in the naturalistic setting of work onboard their vessels.

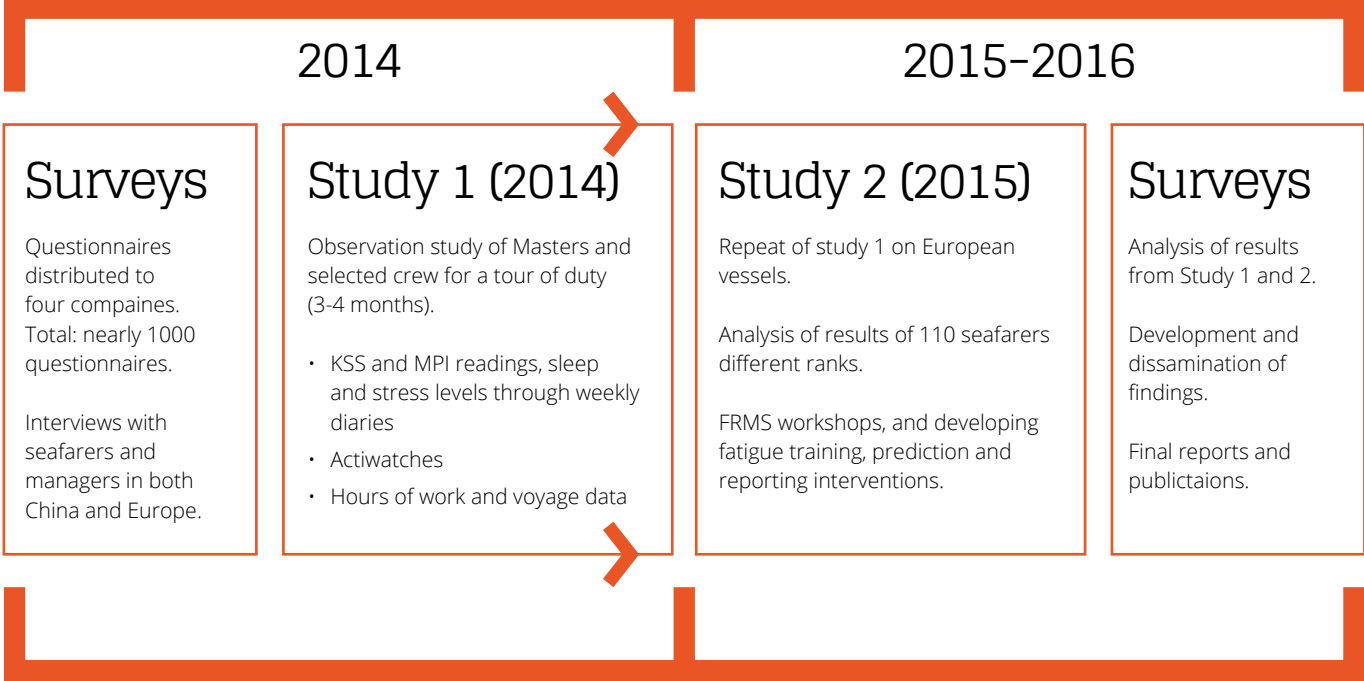
Four shipping companies were selected to assist in the collection of data. Two companies are managed in Europe: 'Company A' operates 43 small product tankers in North West Europe. The vessels have an intensive trading pattern with port calls every three days. The fleet is manned primarily with European officers and Filipino crew. 'Company B' manages 34¹ large container ships on liner routes which included the Far East to Europe, and Asia to South America. The number of port calls in each continent was interspersed with periods on oceanic passage. The ships were manned with European officers and mixed nationality crew. Two state-owned Chinese shipping companies also took part in the project. 'Company D' operated 400 bulk carriers trading worldwide, and 'Company T' operated 40 tankers in Far Eastern waters. Both Chinese managed companies employed all Chinese officers and crew.

The project employed three main methods for data collection:

- Questionnaires and interviews with managers and seafarers in the four shipping companies. (Nearly 1,000 questionnaires were completed).
- Onboard diaries of volunteer seafarers from the four shipping companies over a tour of duty. (The highest number of continuous weekly diaries was 17 weeks, but depending when the diary started, they covered as long as up to 6 months of a tour of duty).
- Actigraphy data from selected volunteers. The wearers were requested to wear the watches continuously for two weeks at the start of their tour and two weeks before signing off at the end of their tour.

¹Numbers for both companies were accurate at the time of the study

MARTHA: The Research Plan – Europe*



*Interviews, questionnaires and Study 1 conducted in both Europe and China, but Study 2 only with European companies

Before considering the findings of the project in more detail, it is important to distinguish between two separate but related phenomena: **sleepiness** and **fatigue**. The research literature tends to blur the definitions, but the following diagram provides an explanation of the major differences:

Distinguishing Sleepiness and Fatigue

Short-term Sleepiness	Long-term Fatigue
Healthy individuals	May cause health disorders (physical and mental)
Rapid onset	Insidious onset
Short duration	Persists over time
Single cause	Multi-factor causes
Short-term effect on daily activities	Significantly affects behaviour and wellbeing

III.

The Results

The project comprised of three studies carried out simultaneously. Each study was led by a different partner and progress was discussed at regular partner meetings. The results presented here are given in three separate sections

III.1 Questionnaires and Interviews

The questionnaires and interviews with both European and Chinese seafarers and managers had two main objectives:

- To examine cultural differences in the interpretation of regulatory frameworks on hours of work and rest through interviews with managers and seafarers:
 - How do organisational practices affect seafarer fatigue?
 - What are the differences between Europe and China?
- To consider the ways in which the incidence and effects of fatigue, and the risk of injuries and accidents at sea, can be reduced.

Interviews and questionnaires were conducted with seafarers and managers as shown in the table to the right:

Europe			
	'Company A'	'Company B'	TOTALS
Questionnaires	314	140	454
Interviews	5	9	14

China			
	'Company D'	'Company T'	TOTALS
Questionnaires	230	253	483
Interviews	20	17	37

TOTAL = 937 questionnaires and 51 in-depth interviews

The potential consequences of fatigue



- The health effects of fatigue can be physical: for example, muscle fatigue, body aches, feeling uncomfortable or weak in extremities following intensive work or sustained posture.

“If I stand in the same posture for a long time, I feel slightly that I am unable to walk any further. Although I am young, I have had such problems. Sometimes I felt particularly uncomfortable and one of my feet can not touch the floor. Once it touched the ground, the other foot would quickly take over. This is caused by long-time standing, I guess.”

A Chinese AB from Company D

Engineering seafarers also mentioned the problem of heat related disorders in hot weather under intensive physical work.

The health effects of fatigue also cover mental fatigue, and there can be at least four recognisable symptoms:

- Being fretful, irritable, unhappy and finding it easy to get into conflict with others;

“When I am tired, I feel fretful, taking extreme views. I think even a good-tempered guy is easy to have conflict with others when he is fatigued”

A Third Engineer from Company B

- Slow responses, poor concentration and sleepiness

“The symptom of fatigue, for me, is tiredness and slow response. When somebody told me something, I nodded. One minute later, I forgot. When I was reminded, oh, yes, I forgot ...”

A Second Officer from Company A

- Incidents of insomnia and homesickness are more serious when seafarers are fatigued.

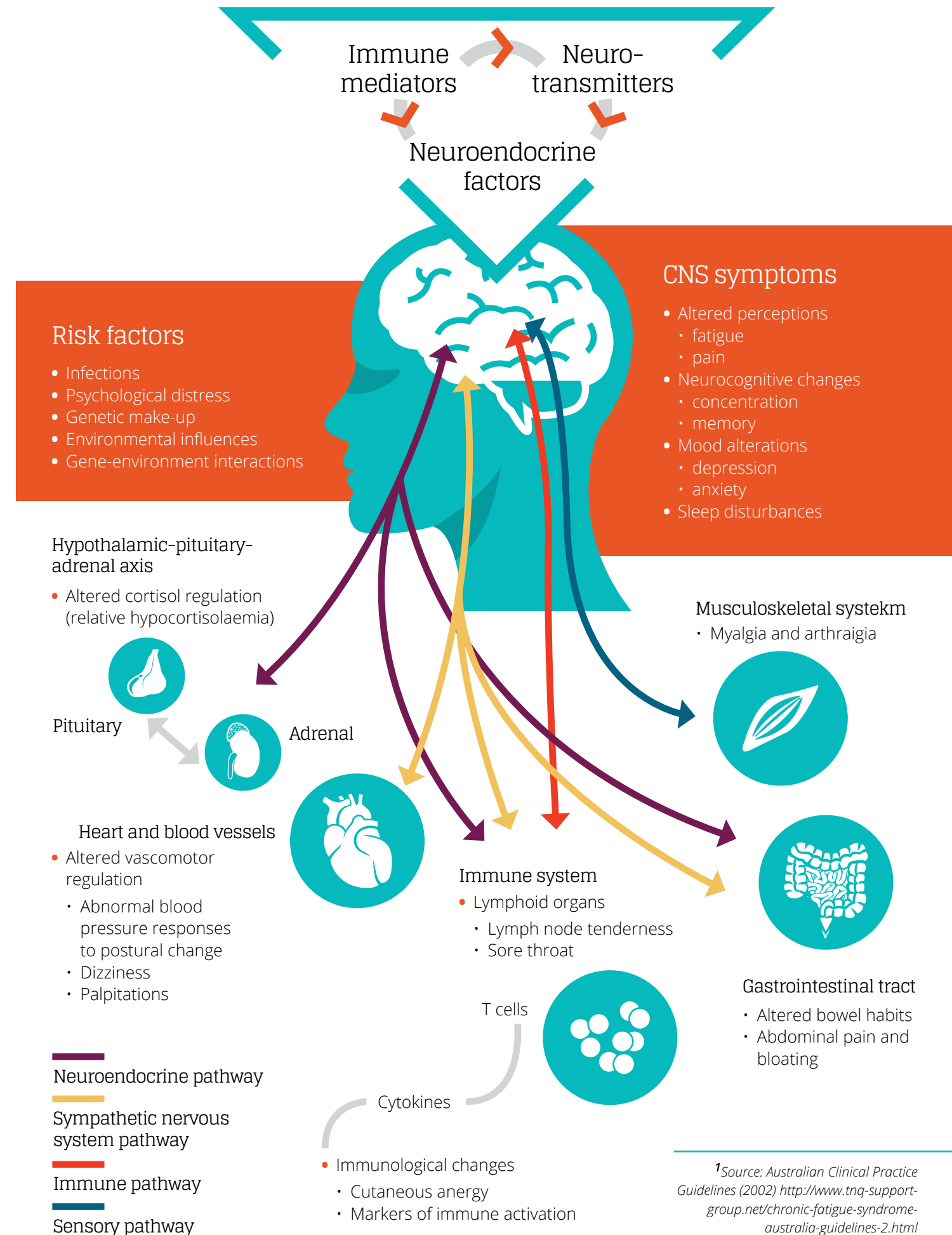
The effects of sleepiness and fatigue can also be a significant and contributory factor in accident causation, which can result in environmental pollution, machinery damage and fire:

“Due to the typhoon on that day, other ships all stopped. But our captain insisted on sailing. We were very tired at that time actually. Sea water poured into the engine room, but nobody noticed that. When it was noticed, it was too late to take any actions. The ship sank. Fortunately nobody died.”

An AB from Company T

“I heard that while the ship was sailing ahead, the officer felt so tired that although he did not fall asleep, he had already lost his consciousness and forgot to alter course. The shallow water area was just around the corner and the ship was stranded...”

A Third Officer from Company D



The Chronic Health Effects of Fatigue

<ul style="list-style-type: none"> • Sleeping disorders <ul style="list-style-type: none"> • Insomnia • Sleepapnoea • hypopnoea • Delayed/advanced sleep phase syndrome 	<ul style="list-style-type: none"> • Cardiovascular disorders <ul style="list-style-type: none"> • Myocardial infarction • Stroke • Hypertension 	<ul style="list-style-type: none"> • Metabolic disorders <ul style="list-style-type: none"> • Metabolic syndrome • Hyperlipemia • Diabetes
<ul style="list-style-type: none"> • Common infections 	<ul style="list-style-type: none"> • Gastrointestinal disorders <ul style="list-style-type: none"> • Peptic ulcer • Irritable bowel syndrome 	<ul style="list-style-type: none"> • Mental disorders <ul style="list-style-type: none"> • Depression
<ul style="list-style-type: none"> • Cancer 		<ul style="list-style-type: none"> • Multiple sclerosis

Increased prevalence of several of these conditions has been demonstrated in seafarers³.

Competing factors onboard that contribute to the adverse health effects of fatigue

- Nutrition
 - Quality
 - Quantity
 - Soft drinks
 - Sweets
- Energy expenditure
 - Sedentary work
 - Exercise
- Smoking
- Alcohol
- Drugs
- Sedentary Work

III.2 Findings from the questionnaire data

The results from the questionnaires showed that there were some differences between the ideal and actual sleep lengths for officers and ratings; their perceptions of sleepiness, quality of sleep and levels of stress were quite similar to each other.

Differences between officers and ratings in actual versus ideal⁴ sleep length

	Av. sleep in a 24 hour period	Ideal sleep length in a 24 hour period
Officers	7.8	8.1
Ratings	8.4	8.4

Note that this result suggests that officers get a little less sleep than they wish, and a little less than ratings do.

Differences between officers and ratings in their perceptions of sleepiness, quality of sleep and stress

	Sleepiness at work	Quality of sleep	Stress at work
Officers	1.7	1.2	1.2
Ratings	1.4	0.9	0.9

The perceptions are on a scale of 0 to 4, with the higher numbers indicating worse sleep or stress. The results suggest that officers in general are a little more tired at work, suffer a lower quality of sleep and a higher level of stress than ratings. These findings are supported by the results of the field study, described in the next section.

The main differences were found to exist between European and Chinese seafarers, indicating some interesting differences between the cultures of the two different management styles. All companies employed Asian crew, suggesting that these

differences are a result of organisational culture than national culture.

The main differences were:

- Age and years at sea between crews in European and Chinese companies;
- Sleep requirements between crews in European and Chinese companies; and
- Perceptions of sleepiness, quality of sleep and stress levels between crews in European and Chinese companies.

A comparison of age and experience levels between European and Chinese seafarers

	Companies	Age	Av years at sea
Europe	"B"	39	14.6
	"A"	38	13.1
China	"D"	33	7.5
	"T"	36	9.3

Note the difference between the experience of the European crews compared to the Chinese crews, given their similar ages.

³Source: Poulsen, T.R. (2014) "Health of Danish seafarers and fishermen 1970-2010: What have register-based studies found?" *Scandinavian Journal of public Health* DOI: 10.1177/1403494814534538

^{4&5}"Ideal" in this context refers to the personal preference for length of sleep as expressed by the individuals in the questionnaire.

A comparison of different sleep requirements between European and Chinese seafarers

	Companies	Av. Sleep in 24 hour period	Ideal ⁵ sleep length in hours
Europe	"B"	8.3	7.6
	"A"	7.9	7.8
China	"D"	7.7	8.6
	"T"	8.4	8.8

Note the difference between the European crews compared to the Chinese crews, with regard to the amount of sleep actually got as opposed to their ideal.

A comparison of perceptions of sleepiness, quality of sleep and stress between European and Chinese seafarers

The perceptions are on a scale of 0 to 4, with the higher numbers indicating worse sleep or stress. Note the difference in stress between Europeans and Chinese.

	Companies	Sleepiness at work	Quality of sleep	Stress at work
Europe	"B"	1.5	0.94	0.66
	"A"	1.3	0.92	0.75
China	"D"	1.9	1.3	1.5
	"T"	1.6	1.2	1.3

Chinese and European seafarers were also asked about the factors which contributed to their fatigue and sleepiness levels. Although different priorities were given depending on their nationality, the following factors all featured highly:

- Job security
- Environmental issues
- Job demands
- Sleep quality
- Irregular working hours
- Rest hours

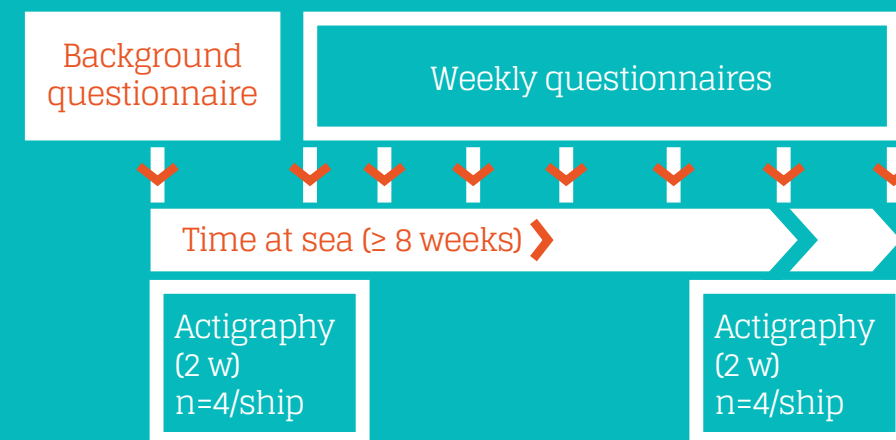
Issues which were repeatedly mentioned by seafarers as contributing to their fatigue and sleepiness levels were (in no particular order of priority):

- New regulations and more requirements placed on seafarers;
- Increased inspections and more paperwork;
- The bad condition of ships' accommodation
- The lack of proper maintenance
- Work in port;
- Working onboard a new ship;
- The quality and professionalism of work colleagues.

III.3 Field Study

The research design of the field study is shown below. After completing a background questionnaire, covering various aspects of health and normal sleeping patterns, each volunteer was asked to complete a diary on a weekly basis. All diaries were emailed once a week for the duration of the seafarer's tour of duty.

Selected volunteers were asked to wear an Actiwatch for two periods during a tour of duty – the first two weeks after starting the diary, and the final two weeks before departing the vessel at the end of the tour of duty.



The data collected from each of the 110 participants in the field study included:

- Background questionnaire for each volunteer;
- Weekly diaries (including KSS and MFI⁶) for each volunteer;
- Actiwatch data for two weeks at the beginning and end of tour for selected volunteers;
- Voyage reports of vessel to cover period of study; and
- Official hours of work/rest for each individual volunteer.

Who took part?

European companies only

'Company A' – small product tankers

Study 1: April to July 2014

Ship	Capt	C/O	2/O	3/O	C/E	2/E	3/E	AB	Cook	Total
4	7	7	2	4	5	2	1	7	4	39

Study 2: May to August 2015

Ship	Capt	C/O	2/O	3/O	C/E	2/E	3/E	AB	Cook	Total
2	4	3	4	3	1	3	0	7	1	26

'Company B' – large container 'vessels

Study 1: April to July 2014

Ship	Capt	C/O	2/O	3/O	1/E	2/E	Elect	Bosun	MM	AB	Cook	Total
4	4	1	1	2	4	2	2	3	4	2	1	26

Study 2: May to August 2015

Ship	Capt	2/O	3/O	C/E	1/E	2/E	Bosun	MM	AB	Total
2	2	3	2	2	1	1	1	2	5	19

What Questions were asked?

Background questionnaire

- BMI
- Working conditions
- Working hours
- Health behaviour
- Sleep habits
- Fatigue
- Sleep problems
- Stress

Weekly diaries

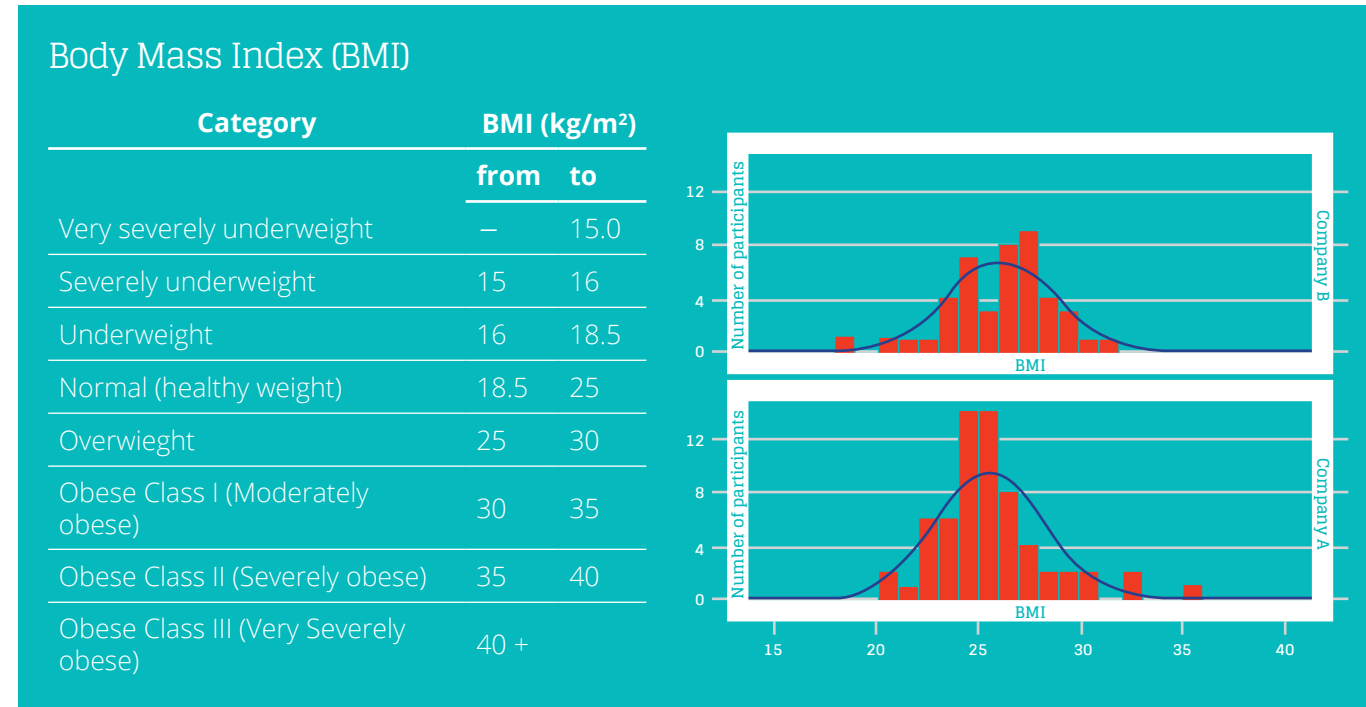
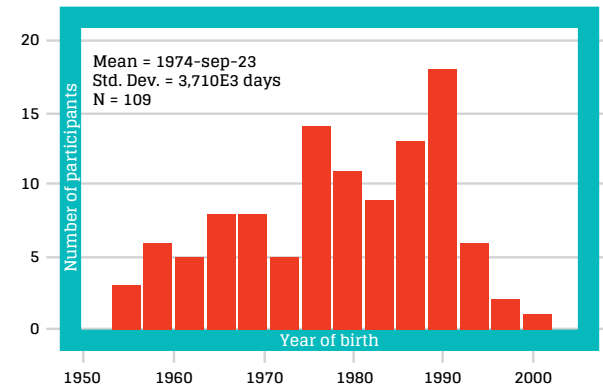
- Sleep (problems)
- Sleep disturbing conditions
- Stress
- Sleepiness
- Fatigue
- Feelings of depression
- General health
- Working conditions

⁶KSS = Karolinska Sleepiness Scale
MFI = Multidimensional Fatigue Inventory

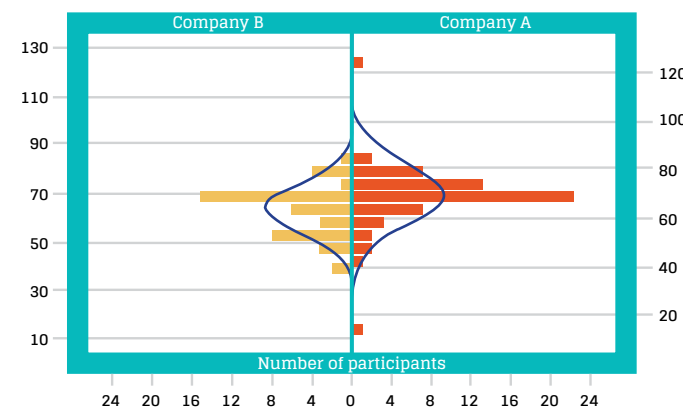
Results from the Background questionnaires

The background questionnaires sought a number of factors which could affect fatigue levels. The graphs below show some of the significant factors:

Age (birth date) of the participants:

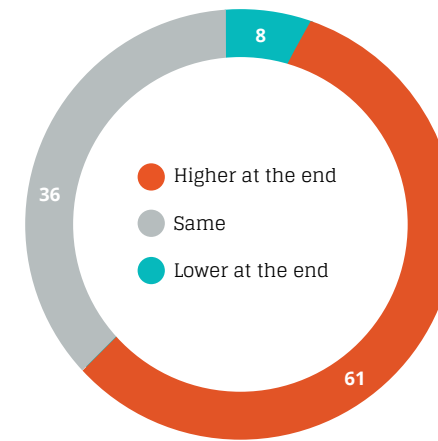


Normal working hours per week



The average number of hours per week which were recorded by all crew onboard is 67 hours per week. There is not a big difference between the two trading companies. It should be noted, however, these figures do not include overtime hours and include all ranks onboard.

Fatigue: is it higher or lower at the end of a voyage?



With regard to all 110 seafarers in the sample, across both shipping companies and including seafarers of all ranks, the majority of seafarers (61%) consider that they are more fatigued at the end of a voyage than at the beginning, irrespective of the actual length of the voyage.

If this result is studied more closely, we find that this perception varies considerably depending on what rank is considered and the types of task carried out onboard.

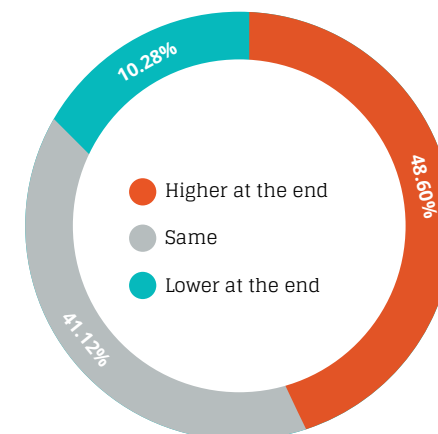
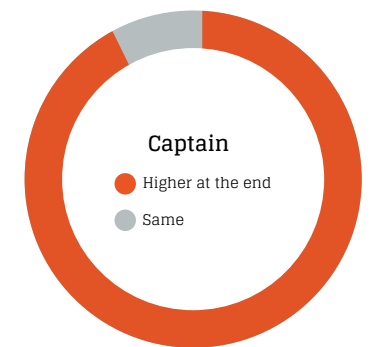
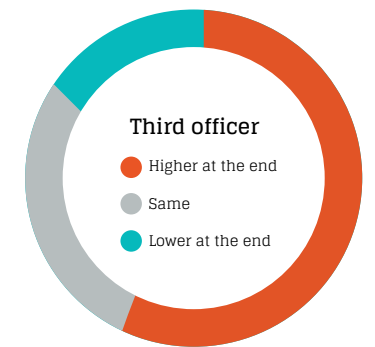
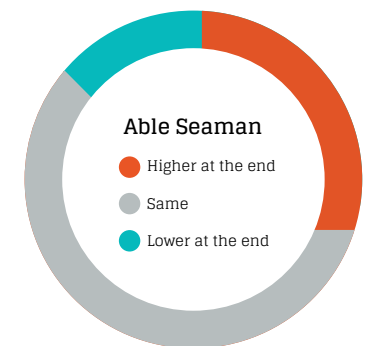
The study considered three groups of crew on the vessel: the Captain; Watch Keeping Officers; and day workers. Each group contained at least 10 members.

The three pie charts (opposite) illustrate the findings.

The group representing day work crews, cooks and engineers experience less fatigue at the end of the voyage than other groups, with a majority of the group being less fatigued or the same by the end of their tour.

The watch keeping group was represented by Second and Third Deck Officers. A small majority of officers reported they felt more fatigued at the end of their tour than at the beginning.

The group representing the Masters presented a very different picture, with a very large majority of the group reporting that their fatigue levels were higher at the end of their tour of duty than at the beginning.

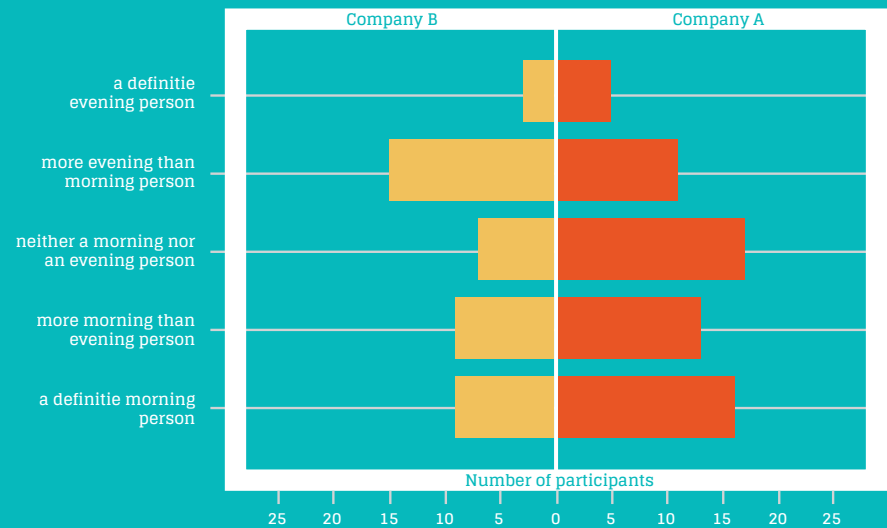


The sample of 110 seafarers asked if crew experienced more stress at the end of the voyage than at the beginning. Taking the group as a whole, nearly half the seafarers did experience higher levels of stress by the end of their tour of duty, as shown in the diagram to the left.

Circadian type

The Circadian type, sometimes also referred to as the 'diurnal type' or 'chronotype', is the propensity of individuals to prefer to sleep in the morning or evening. Although most people are neither extreme morning or evening types, at least 50% of people will recognise themselves as a "lark" or an "owl".

In the sample, a majority of seafarers identified themselves as morning types, which this is unusual among shift workers where most night shift workers are evening types. The reason for this difference is not known, but may be significant if individuals are extreme and are put on watches opposite to their natural inclinations. For example, an extreme morning person on a late evening watch.



⁷Kaida et al (2006) "Validation of the Karolinska sleepiness scale against performance and EEG variables". *Clinical Neurophysiology* Vol117, Issue 7, July 2006, pp 1574-1581

Results from the Weekly Diaries

Participants were asked to complete a weekly diary for each week during their tour of duty. In some cases, the number of diaries was in excess of 10 weeks. The maximum number of returned diaries was for a continuous 17 week period.

The diaries were returned by email on a weekly basis to the Project Manager who could liaise with the Captains about any additional relevant voyage information. In this respect, each Captain was a "champion" for the project, motivating other crew to participate by their own example. This strategy worked well, resulting in a very high return rate of continuous weekly data.

In some cases, the diaries were not started at the commencement of an individual's tour of duty and different periods of time remained after the diaries were stopped until the end of the contract. The periods for data collection were determined by the Captain's time onboard. It was therefore important for "anchoring" the results to the same portion of a voyage, to also know the dates of the start of contract and the end of contract date for each individual.

In addition to general questions about the individual's sleep, two specific and validated measures of

sleepiness and long term fatigue were employed: the Karolinska Sleepiness Scale (KSS) and the Multidimensional Fatigue Index (MFI).

The KSS explores subjective feelings of stress on a scale of 1 to 9. It has been validated against EEG and other variables⁷. Individuals were asked to measure their sleepiness levels for the 24 hour period before completion of the weekly diary.

KSS – The Karolinska Sleepiness Scale

<ol style="list-style-type: none"> 1. Extremely alert 2. Very alert 3. Alert 4. Quite alert 5. Neither alert nor sleepy 6. Some signs of sleepiness 	<ol style="list-style-type: none"> 7. Sleepy, no effort to stay awake 8. Sleepy, some effort to stay awake 9. Very sleepy, great effort to keep awake, fighting sleep.
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The diagram below shows the KSS scores over 7 for all 110 seafarers who completed them at different stages of the voyage. The scores were calculated using an anchoring mechanism, so they show comparable scores at various weeks into a voyage for each individual. Consequently, the

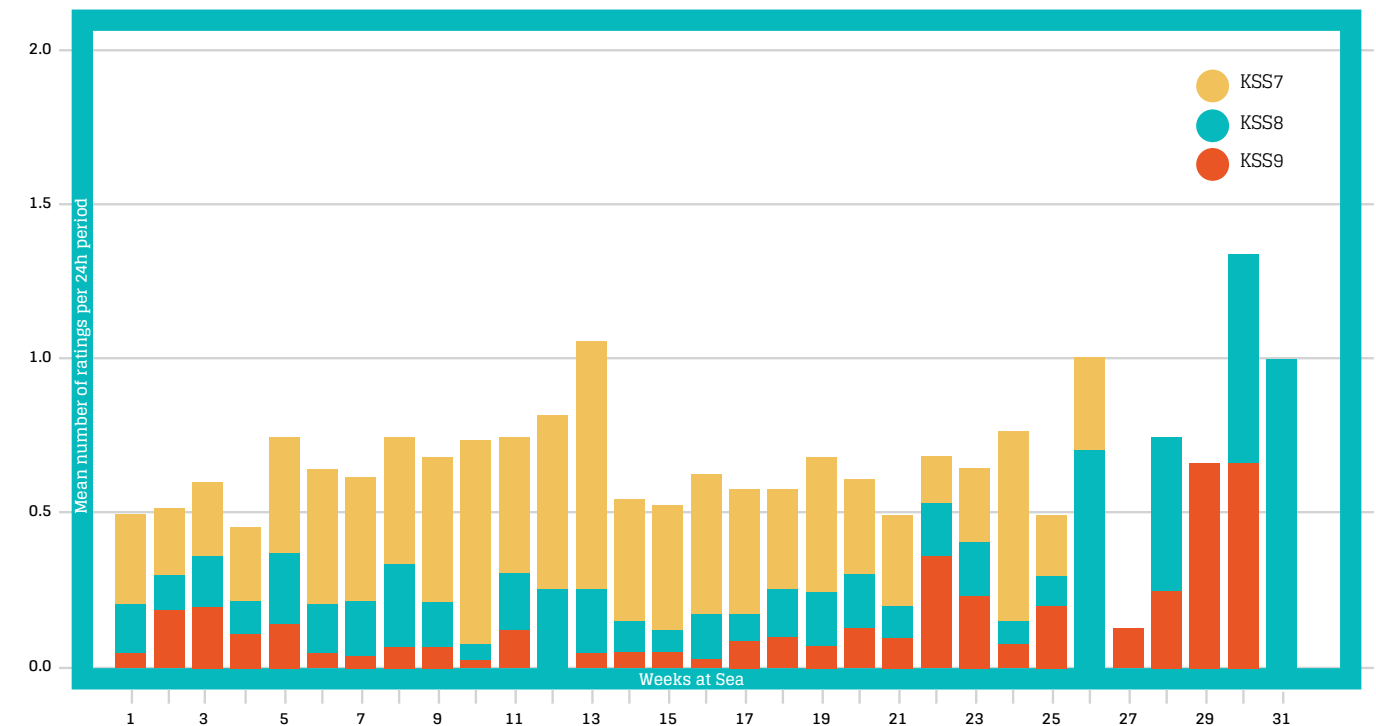
KSS scores cover from week 1 to over 6 months.

From previous research, a KSS score over 7 indicates a high risk of falling asleep. The most significant results, which this diagram illustrates, are:

- The risk of falling asleep through

tiredness is present at **ALL** stages of the voyage, making it a safety risk at all stages of the voyage; and

- Very high levels of sleepiness (KSS of 8 or 9) are apparent and increasing after 6 months onboard.



The Multidimensional Fatigue Inventory (MFI)⁸ measures fatigue using four statements for each of the following dimensions:

- General fatigue
- Physical fatigue
- Mental fatigue
- Reduced activity
- Reduced motivation

⁸Smets, E.A. et al (1995) "The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue" *Journal of Psychosomatic Research* Vol 39, Issue 3, April 1995, pp 315-325

Fatigue dimension	Statements like (positively and negatively formulated)...
General fatigue	I feel fit I feel tired
Physical fatigue	Physically I can take on a lot Physically I feel I am in a bad condition
Mental fatigue	I can concentrate well My thoughts easily wander
Reduced activity	I feel very active I get little done
Reduced motivation	I have a lot of plans I dread having to do things

From the different dimensions of fatigue, the results in this study indicate that it is motivation that decreases with time at sea.

This is a significant finding because it offers an explanation for recent reports of casualties occurring on vessels where the crew, including the Captain, have been onboard for longer than 6 months.

Reduced motivation may lead to complacency, individuals taking short cuts and "work-arounds" and not following the correct procedures.

Results from the Actigraphy

A total of 70 European seafarers took part in the Actiwatch study over the two years of the field study. These included 15 Captains, 19 Watch Keeping Deck Officers, 13 day-working Engineers and 23 Ratings. Although some Chinese officers also took part, logistical problems with transporting the valuable scientific instruments meant that insufficient numbers were collected to make the results statistically significant and so detailed analysis of their data is not included in this report.

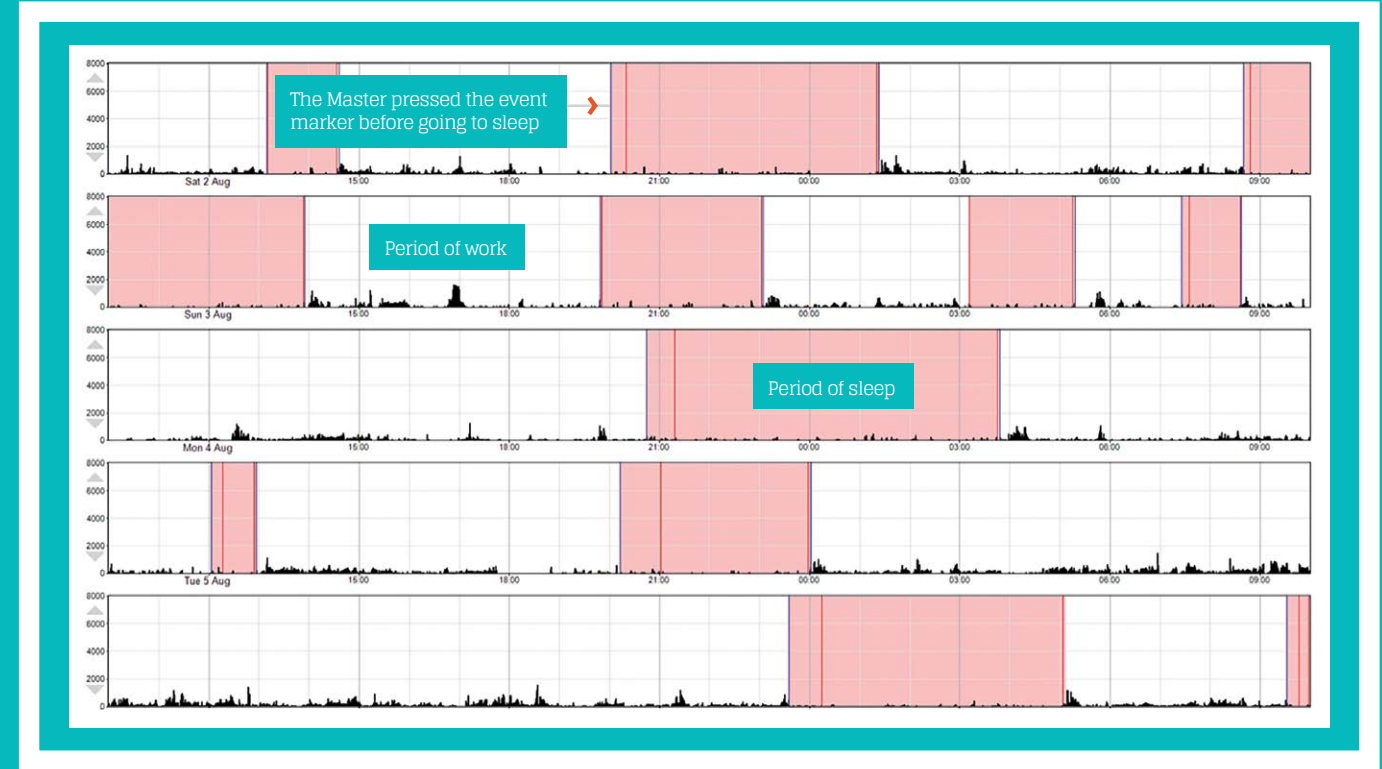
32 Actiwatches were deployed on the 12 participating vessels and volunteers were asked to wear them continuously for two weeks at both the beginning and the end of their tours of duty. Watches were rotated between crew members to optimise data collection.

The watches are accelerometers so they record movement and can indicate the difference between wake periods and sleep periods. To help the analyst, volunteers were requested to press a marker button each time they woke up and before falling asleep to produce a blue line on the graphs to make clearer the different periods of sleep and wakefulness.

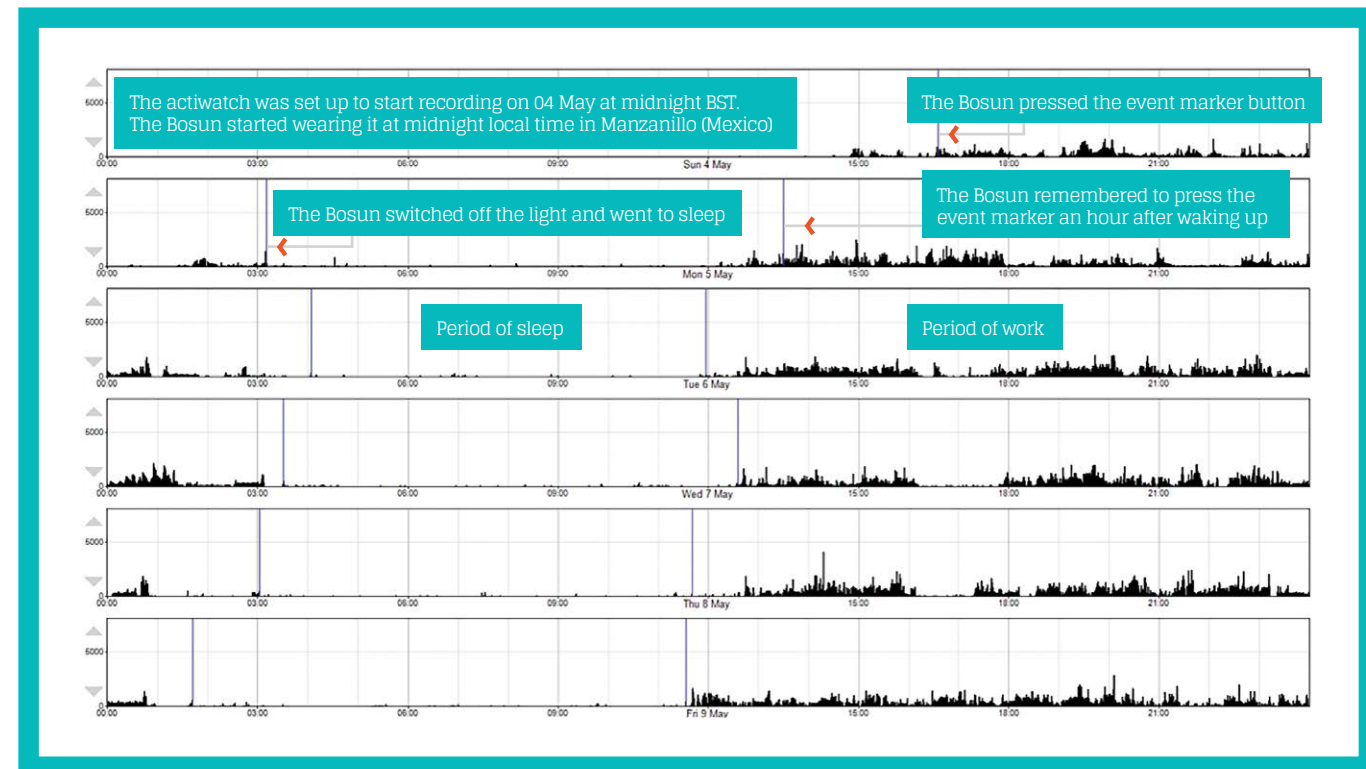
Software is able to analyse various parameters such as total amount of sleep in a 24 hour period and wake bouts during a period of sleep. This latter measure is useful to provide some indication of the quality of sleep obtained.

The graphs illustrated below and opposite show the kind of data which is produced. The first shows a typical day-worker, who is able to get regular and adequate periods of sleep at night. The second graph shows a Captain, with evidence of more disturbed sleep and irregular patterns of sleep.

It is important to remember that Actiwatches measure the amount of sleep obtained, and not how tired someone may feel, nor long term fatigue and stress levels.



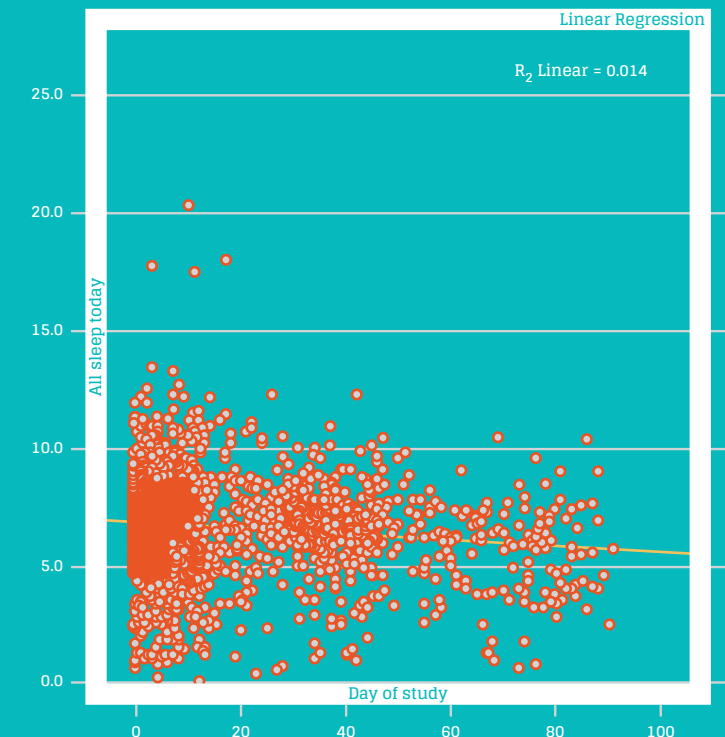
Examples of Actiwatch data: A Bosun on daywork above and below a Captain



The analysis of the actigraphy provides objective data and is a valuable confirmation of the surveys and questionnaires conducted in the field study.

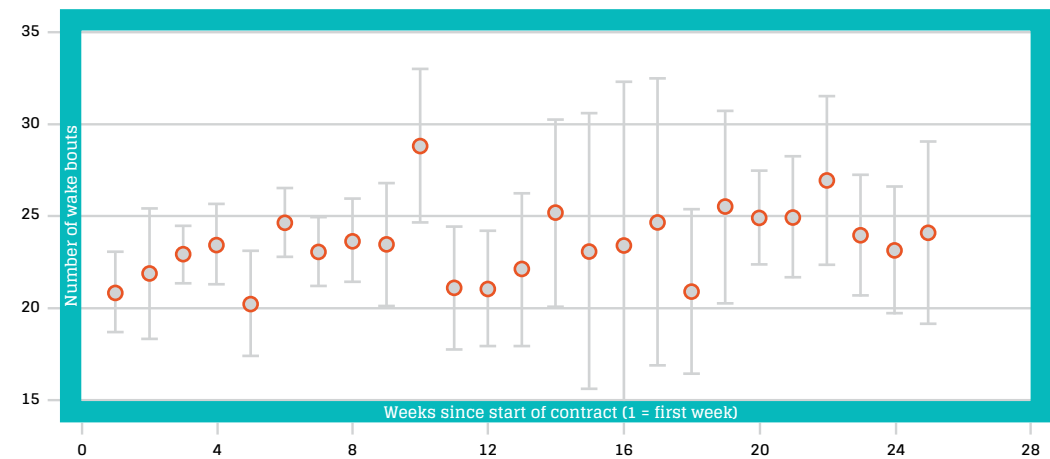
Analysis is ongoing, but some important findings have already been confirmed:

Both the amount of sleep and the quality of sleep (the latter as measured by wake bouts) decreases over time for all crew. This finding supports the KSS numbers showing increasing levels of sleepiness over time.

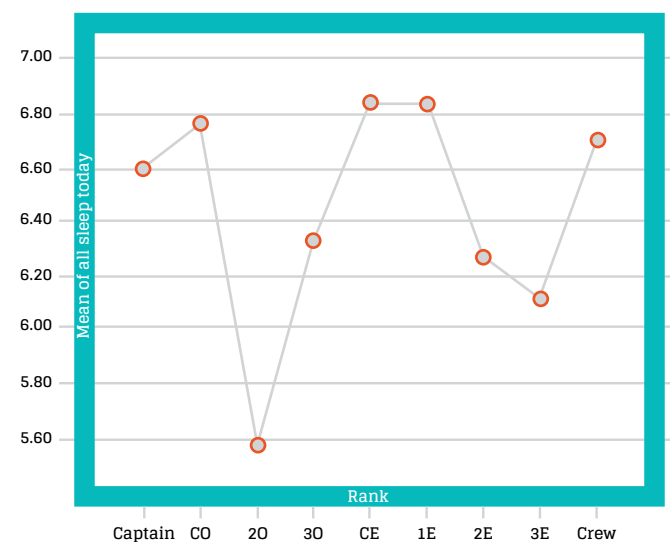


Dissemination activities

The effect of wake bouts is shown in the graph below. It indicates a significant increase, as time (measured in weeks) passes. Increased wake bouts may be seen as an indication of more disturbed sleep as the voyage progresses. The data is “anchored”, so it shows the increase from the start of the contract to at least 24 weeks.



A study of different ranks shows that it is the night time Watch Keeper (typically the Second Officer) who obtains less sleep than colleagues. This is illustrated in the graph below:



In addition to the funding of the project, the TK Foundation also contributed to the funding of two PhD students, registered at the University of Southampton.

Their studies are continuing beyond the completion of the MARTHA project, but their studies will provide a further legacy of the project.

One PhD student is investigating fatigue and distractions in maritime control rooms. The study will explore the relationship between fatigue, attention and safety and investigate the effects of different kinds of distractions on attention, and how fatigue impacts attention. Experimental laboratory work will be conducted with sleep restricted groups.

The second PhD student is examining the effects of stress on attention and visual cognition. Existing research indicates that stress and fatigue can influence each other. This study will examine stress in its ability to both improve and impair attention through the experiments using an Attentional Network Test.⁹

⁹Fan, J., McCandliss, B. D., Sommer, T., Raz, A. & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, 14, 340-347.

The MARTHA partners agreed a publication policy at the start of the project and the following post-project dissemination activities were agreed at the final partner meeting in June 2016. They provide a variety of formats for publishing the results and leaving a legacy for MARTHA in the future.

Publications

- During the course of the project, a number of academic papers, conference presentations and articles for the nautical media were produced.
- Presentations on the MARTHA project have also been given at seminars with both European shipping companies, as well as at several conferences and seminars during the project.
- To date, these outputs have mostly focussed on the questionnaire and interview data, undertaken with the employees of Chinese and European seafarers. Some of these papers have already been translated into Mandarin and vice-versa. Various papers from the field study and the results of the actigraphy analysis will follow in due course.
- In addition to this industry report, it is also planned to provide a written submission on long term fatigue to the IMO. Finally, it is hoped that one legacy of MARTHA will be the provision of a public website for fatigue knowledge transfer.

II-2 Events and Workshops

- A number of workshops were held to obtain feedback on the findings of the project and also to explore the fatigue issues of most concern to seafarers and shore-based managers. Workshops were held in:
 - Athens, June 2016
 - Warsash, June 2016
 - Singapore, October 2016
 - Manila, November 2016

The workshops all proved useful in identifying issues which participants thought might cause fatigue onboard as well as providing some ideas to mitigate the risks of fatigue onboard ships. The format was flexible and interactive and the dialogue focussed on the following two themes:

- What are the most significant causes of lack of sleep and/or

- fatigue onboard the ship?
 - What are the recommendations for mitigating lack of sleep and fatigue and their consequences in the future?

The responses from the workshop delegates can be grouped into three main categories:

- Vessel design and living environment
- Working conditions; and
- Operational issues.

Vessel design and living environment

Participants sought improvements in:

- Noise and Vibration levels
- Temperature
- Quality of Accommodation spaces
- Bedding (eg change of mattresses)
- Exercise facilities onboard

Some of these issues are covered in the Maritime Labour Convention (MLC 2006) to apply to new vessels and measures will need to be evaluated further, as the requirements come into force.

Working conditions

Participants sought improvements in:

- Safe manning levels
- Nutrition and good food aboard
- Hours of work and rest
- Stress onboard through harassment and bullying

Operational issues

Participants sought improvements in:

- Being relieved on time and having a KPI to measure it
- Revision of company reporting requirements in order to reduce bureaucracy
- Communication between ship and shore
- Logistics-port calls to be better organised and discussed with sea staff
- Timings of inspections onboard by external parties
- Time management. For example: the timing of Notices of Readiness

- Recovery time during the voyage. For example, going to anchor.

Participants also recognised that there needs to be a cultural change in the industry's attitude towards fatigue by both seafarers and shore management. The response: "but it's always been like this" was no longer seen as acceptable.

Awareness and cultural change also apply to the agencies ashore who interact with ships and personnel: charterers, agents and port state officials.



Fatigue Risk Management: A Case Study

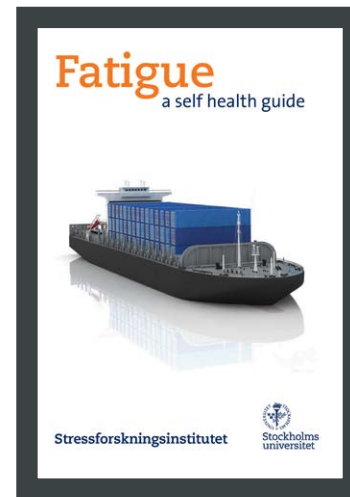
Recent studies¹⁰ in several safety-critical industries reveal a conceptual move away from prescriptive regulations - which seek to mitigate the risk of fatigue through limiting the hours of work, to a more goal-based system - that involves the employment of Fatigue Risk Management Systems (FRMS). The systems approach offers an integrated management of fatigue which covers policies, operational aspects and quality assurance.

FRMS are being adopted in other transport sectors - such as: aviation, road and rail systems - but evidence from recent marine accident investigations indicates that the use of FRMS in the shipping industry is less mature than in other safety-critical transport industries, and less advanced in exploring such concepts in practical operational settings.

¹⁰Gander, P.H.(2015) *Reviews of Human Factors and Ergonomics*, Vol. 10, 2015, pp. 253-271

The core elements of a FRMS are:

1. Fatigue Awareness training and cultural change programmes;
2. A fatigue reporting system within a just culture; and
3. Data-driven analysis for operational fatigue risk assessment, workload management and monitoring of adequate sleep for those onboard.¹¹



Evaluation of the effectiveness of such systems in other industries has highlighted a number of issues to be resolved in the successful implementation, one of the major challenges being the acceptance of these systems by the work force.

Changing the culture in shipping, represents a major challenge, both for individual seafarers and for shore management. The first important step is raising awareness and this can be achieved by simple yet effective messages about managing fatigue through guides and booklets.

Fatigue incident reporting is another important element of the systems approach, and needs to be part of a transparent and "blame-free" culture. Employees will be reluctant to report incidents which may be caused by sleepiness or general fatigue if they think that there will be recriminations.

The third core element – the use of data in assessing the sleepiness and fatigue levels of employees is probably the part most open to misunderstanding. Although in other industries, like aviation, systems have been developed to a high degree. One of the features of FRMS is that it can be part of the continuous improvement cycle of a Safety Management System (SMS).

An example of this approach is the 'maturity model' concept, which allows for different levels of engagement

as the system grows and is accepted by the workforce. The concepts here are similar to that employed in the Tanker Management Self Assessment (TMSA) Code, and may fit well within this kind of approach. Starting with simple messages and guidance can build to a more interactive approach where schedules can be predicted using biomathematical prediction tools.

At a higher level of maturity, seafarers can take more ownership of the system themselves by reporting incidents, and keeping a check on their own and colleagues fatigue levels. The company may also consider periodic reviews of crew fatigue through sleep diaries and other techniques, similar to those used in the MARTHA project. The technology exists now to combine the power of big data and predictive analysis with the science underpinning fatigue, stress, health and wellbeing to provide better health and welfare services to seafarers wherever they may be.

The MARTHA project engaged with both European management companies to explore some of the issues involved in setting up a FRMS. In one of the companies, raising awareness was achieved with presentations on the project at the annual Captain's seminars, where considerable interest in the topic was shown by the participants.

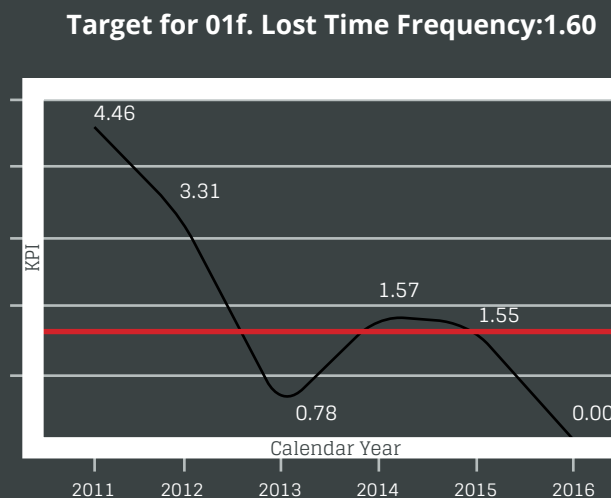
This interest was echoed throughout the project in which seafarers seemed keen to participate and contribute their views on this subject.

After discussions with the management team, a fatigue incident report form was introduced, and changes made to the fleet orders on fatigue. One of the key changes was the introduction of a new Key Performance Indicator (KPI) for work and rest hours.

Although reporting of fatigue is still an issue to be tackled, the following quote from the ship's managers illustrate the engagement with the materials and general success of the initiative.

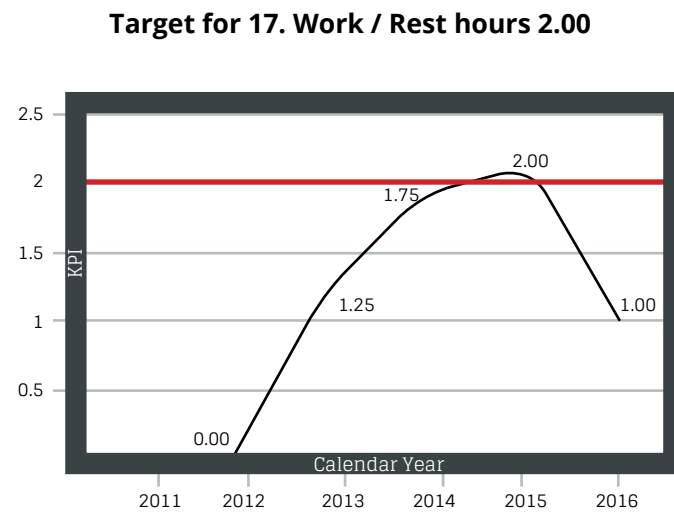
"The publications are very clear and are in use by our seafarers. We have not received any fatigue incident report yet. We are quite happy with our KPI's over 2016 with no incidents and LTIF of zero (which is the first time since 2011). Also recorded observations with regard to work and rest hours shows a considerable decrease since 2013."
12/12/2016

The KPIs on 'Lost Time Injury Frequency' (LTIF) and 'Work and Rest hours Non-conformities' are illustrated below by kind permission of the company. The numbers in the graph below indicate the number of LTIs per quarter, averaged over the year.



¹¹Data collection tools may include sleep diaries and surveys, scientific data, for example, actigraphy, and fatigue prediction models

The number shown in the graph below is the average number of received non-conformity reports per quarter for a given year.



The experience of being involved in a fatigue research project was generally very positive as the quote below from one of the companies illustrates:

“We had several objectives for our participation in the MARTHA project, including wanting to learn more about fatigue and proactive fatigue prevention, to contribute to a scientific project on this important topic, and to engage our crew on a subject that has direct relevance for them. We believe that the project has successfully met our objectives, and we have learnt more about fatigue, its causes and preventative measures. We have shared this knowledge with our crews through a fatigue awareness and prevention initiative as part of

our Occupational Health and Safety Management System (OHSAS 18001). This included sharing some of the materials we received during the MARTHA Project, through onboard training sessions and visits, seminars and onboard discussions. We have also incorporated more beneficial guidance into our management system to ensure that the information remains readily available. We gained a lot from participating in the project and believe the knowledge gained will be beneficial to the shipping industry”.

VI.

Main Findings and Conclusions

The main findings from the three studies are:

- From a search of current research literature, the causes and consequences of both sleepiness and long-term fatigue are now well-established (pages 10-11).
- Sleepiness levels vary a little during the voyage, suggesting there are opportunities for recovery. Overall, there is a small but significant decrease in the amount of sleep in a 24 hour period over the course of time.
- Although European and Chinese seafarers may allocate different priorities to fatigue factors, they do share the same perceptions about the major factors that influence fatigue onboard.
- Captains and day workers get more sleep than watch keepers, but Captains are more at risk of fatigue than other ranks. Night watch keepers (Second Officers) get significantly less sleep than others.
- There is evidence of higher levels of fatigue and stress in seafarers from Chinese-managed companies than European managed ones. This suggests that differences in organisational factors are significant in affecting fatigue mitigation onboard.
- Motivation decreases the longer seafarers are away from home. This has important implications for safety, as it may be a significant underpinning root cause of phenomena such as complacency, short cuts, and not following procedures.
- Long-term fatigue levels are perceived differently depending on the nature of the work onboard. Captains and Watch Keepers appear to fare worse than day workers.
- Although the amount of sleep experienced by seafarers during a voyage may stay the same or decrease slightly, there is evidence that sleep quality becomes more disturbed over time – there are more wake bouts and fragmented sleep.
- Both fatigue and stress levels are perceived as higher at the end of a voyage than the beginning by most crew, and port work is seen as more demanding than work at sea.

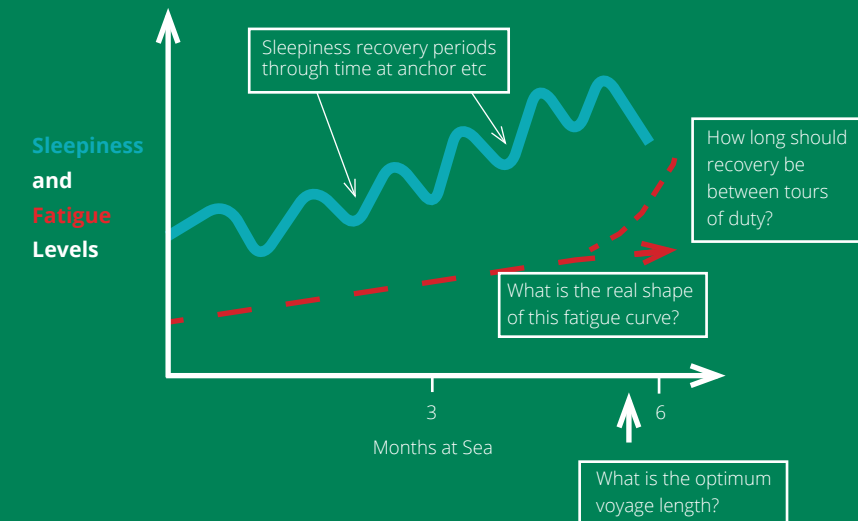
In conclusion, the evidence from three different sources of data: 937 questionnaires, 110 weekly diaries and 70 Actiwatch graphs point in the same direction:

1. Both sleepiness and fatigue are important issues for seafarers and managers: they both have safety and long-term physical and mental health implications;
2. Long tours of duty (over 6 months) may lead to increased sleepiness, loss of sleep quality and reduced motivation. Any of these outcomes could result in 'near-misses' and accidents onboard;
3. Night watch keepers are most at risk from falling asleep on duty;
4. Captains feel stressed and fatigued at the end of their tours of duty and need recovery time.
5. There are simple operational solutions which can ensure sleep is easier for those onboard through fatigue risk management. These solutions should involve seafarers and agencies ashore which impact on shipboard operations.
6. The introduction of Fatigue Risk Management Systems, as already used in other safety-critical transport systems, presents an integrated systems approach to managing the risk of fatigue. It requires ownership by all in the company, changes in culture and can be introduced in a gradual process as the company develops its own approach. The development of new data collection, transmission and analysis techniques will accelerate the process.
7. In the longer term, improved vessel design will make a significant impact in reducing the effects of sleepiness and fatigue.

VII.

Future Research

The diagram below illustrates some of the main findings of the MARTHA project, and also shows some of the new questions raised by this research.



Some of the questions to answer include:

- What is the optimum tour of duty length? Should there be a maximum shorter than the MLC requirement?
- How long should recovery time between voyages be?
- How does cognitive performance deteriorate over time due to fatigue and stress?

- How does "mood" change over time? Does this have a significant effect on the psychological wellbeing of seafarers?

Other areas of research include the further development of FRMS concepts for the shipping industry.

Specific goals are:

- The development of improved fatigue prediction models.
- The development of instruments to survey psychological wellbeing over the long term
- The development of models of how long term fatigue and recovery may be predicted



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