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Exposures and health effects at sea: report on the NIVA course: Maritime Occupational Medicine, Exposures and Health Effects at Sea

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ABSTRACT

The presentations and discussions summarised provide an overview on the current state of knowledge on a wide range of occupational health risks to which seafarers are exposed. The definition of an occupational risk for a seafarer poses problems as their ship provides both their working and their living environment and, because of its mobility, can expose them to diverse climatic and infectious risks. Knowledge about levels of exposure to potential health risks in seafarers is limited when compared to those working ashore while, because of a pattern of working that is often temporary and insecure, there is little valid long-term information on ill-health that can be related to risks at sea and in port. The data that do exist mainly come from developed countries, especially those in North Western Europe and extrapolation from these populations to the Asian seafarers who now crew most ships is of uncertain validity.

This course, run by the NIVA Foundation and supported financially by the Nordic Council of Ministers, provided a first opportunity to draw a wide range of information and experience together to review exposure and health risks in seafarers. As a result it provided both a forum for deciding on future needs for investigation and gave those attending a range of insights that can help inform their own practices.

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Key words: occupational risk, seafarer, exposure, epidemiology, noise, non-ionising radiation, vibration, solar effects, chemicals, infections, cancer, lung disease, skin disease, gastrointestinal disease, cardiovascular disease, sea sickness, venomous marine organisms, fatigue

INTRODUCTION

NIVA is a Nordic foundation specialising in advanced training in occupational health [1]. As part of its programme of workshops it has organised courses in maritime health every 2 years. Between 30 and 40 people, including speakers and organisers, attend. This year's was the first to cover one of the core aspects of occupational health: the effects of exposure to health risks in the maritime workplace. It was decided from the outset not to cover mental health and ergonomic aspects in order to focus the discussions more clearly.

In the event the pattern of presentations demonstrated that, because being a seafarer involves both working and living at sea, the traditional distinctions between a workplace, where about 8 h a day are spent, and the wider community, where the other 16 plus weekends and holidays are taken, was inapplicable.

The other overall impression gained from many of the presenters was the very limited knowledge that exists on the health risks to seafarers, other than naval personnel, arising from their conditions at work when this is compared with the information available on onshore working populations.

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The pattern of work of seafarers and the lack of investigations into their health risks meant that the focus for the workshop was, inevitably, rather wider than originally anticipated. However, it succeeded both creating an opportunity for those familiar with the field to exchange their experiences and for those new to it to gain a series of insights into current knowledge and practice.

This report aims to draw out the main themes covered and to present them in the context of both maritime health practice and that of onshore occupational health.

THE CONTEXTS FOR MARITIME OCCUPATIONAL HEALTH

The complexities of maritime occupational health risks were covered in two contrasting presentations. One was on the methods for investigating health effects and linking them to exposure, and the uses and limitations of each. The other covered the long history of illnesses associated with work at sea. This demonstrated that the definitions of work related diseases used onshore are too simplistic for any discussion of seafarers' occupational health risks.

The available **information** about seafarer occupational health risks and its limitations were reviewed by **Henrik Hansen** (National Board of Health, Denmark). He showed that there was good evidence of a high risk of accidents and of excess mortality from cancer, cirrhosis of the liver and suicide, with increased incidence of cardiovascular disease, infections and gastrointestinal disease among seafarers when compared with the onshore population. However, the studies available reflected levels of risk some decades ago rather than at present, while the populations studied were drawn from developed and mainly Northern European countries and so were unrepresentative of the patterns of the seafarers recruited from Asia, who currently form the majority of those employed on global merchant shipping. Studies were also often of short duration or with short periods of follow up. Those which attempted to assess specific risks on board rarely had access to definitive exposure data and relied on time spent at sea, in particular jobs, or on specific types of ship as a proxy for this. In the course of his presentation he also outlined the available epidemiological methods for the study of seafarer health and reviewed the strengths and weaknesses of each.

A contrasting approach to context came from **Hans Gunnar Øverengen** (Sjömansläkarmottagning, Stockholm, Sweden), who looked at the **history** of seafarer health over the centuries. His presentation ranged widely, from his own extensive experience as a seafarer to examples drawn from all periods of history. These include plague in Europe and the introduction of quarantine; the transfer of diseases such as smallpox and syphilis between continents on the early voyages of exploration from Iberia; the treatment of injury at sea; the challenges of preventing scurvy and beriberi and the changing faces, but constant features, of piracy over the centuries. The historical pattern of disease was then related to the present day shipping industry, where excess calories have replaced vitamin deficiencies and where its globalisation has resulted in major differences in attitudes to seafarer health in different parts of the world.

RISKS FROM PHYSICAL AGENTS

Ambient levels of potentially harmful physical agents can readily be measured, however uncertainties about the relationships of measured levels to damage and to adverse health effects or to subjective complaints were a common feature of several of the contributions on this topic.

Non-ionising radiation (NIR) on board can arise from wiring configurations and also from exposure to beams from sources of emission such as high powered radar installations, particularly on warships. **Kjell Hansson Mild** (Umea University, Sweden) gave an overview of their properties and the sources on board. He then concentrated on a recent study of a brief episode of overexposure that occurred when a warship inadvertently had its high-powered radar on as it sailed by a coastguard ship. This led to the crew on the coastguard ship experiencing a range of symptoms that they attributed to this exposure. He also reviewed subsequent studies aimed at detecting whether there were any reproductive effects that could be associated with exposures to NIR on naval vessels. The studies of risks were essentially negative, but the level of concern engendered by exposures suggests that greater awareness and better information provided for crewmembers would be beneficial [2]. Further investigations of levels on board and their effects have been undertaken [3–5].

The risks from high energy **vibration**, for instance from oscillating hand tools, are well recognised, and hand arm vibration syndrome can be expected to be seen in those seafarers who make extensive use of power tools, for instance to chip off old paint. As described by **Anker Jensen** (Hospital of South West Jutland, Denmark), whole body vibration of the sort that all crewmembers on a ship can be expected to be exposed to and which may occur at high levels in fast craft is a known risk factor for harm to health. There are few relevant studies on seafarers, and in some of those on fishermen the musculoskeletal demands of their work may confound any relationship that could be associated with vibration. Certain parts of the body have characteristic resonant frequencies but these have not been associated with specific problems in seafarers. In the discussion, the high level of vibration on fast craft was raised, and its apparent link to compression fractures of the vertebrae and to other injuries noted. Standards for ships and for exposure levels in occupational settings have been produced, but the approaches adopted are not compatible [6–8].

Exposure to **noise** is a well-recognised risk in seafarers, especially those working in machinery spaces. **Erlend Sunde** (University of Bergen, Norway) summarised the forms of harm arising from noise exposure: hearing damage and tinnitus; non-auditory, emotional, cognitive and cardiovascular effects; interference with communication, and increased accident risk. He then outlined the levels of exposure that were relevant to each type of harm and illustrated this by reference to his recent study on noise levels on board warships. The main noise sources were engines and air handling systems. In the study measured levels of noise were linked to both audiometric measurements and to questionnaire data from those aboard. The prevalence of noise damage, usually sub-clinical, was found to be elevated. The study has led to a series of remedial measures being introduced across the fleet. The measures required differ between ship types, as many of the contributors to high noise levels were specific to particular designs of various types of ships.

The problems of assessing exposure to **ultra-violet** (UV) radiation formed the starting point for the presentation by **Marcus Oldenburg** (Institute for Occupational and Maritime Medicine, Hamburg, Germany) of the results of a recently completed investigation of skin effects of UV exposure in approximately 500 seafarers [9]. Childhood, leave time, holiday and solarium exposures as well as those while working on board needed to be taken into account. In addition, the level of skin pigmentation for each person had to be corrected for. Standardised clinical examinations had been performed on the study group to assess the frequency of changes, from early pigmentation to pre-malignant and malignant lesions. An increased level of skin ageing symptoms and actinic keratosis was found among seafarers, when results were compared with other studies on onshore populations [10]. It was noted that some of the increased exposure in seafarers as compared with other groups ashore could be attributed to the factors noted above that were not linked to job-related UV exposure, in particular there was a higher incidence of actinic keratosis in engine room staff who may also have skin exposure to polycyclic aromatic hydrocarbons. He concluded by emphasising that skin damage was largely preventable if appropriate work related precautions and a lifestyle that limited intentional exposure was adopted.

Thermal exposure risks may arise from either exposure to too high or too low an ambient temperature and will be moderated by a range of factors such as clothing and the presence or absence of water; whether liquid, as in cold immersion, or as water vapour, when working in hot humid conditions. **Henrik Hansen** (National Board of Health, Denmark) reviewed these determinants, presented a series of case studies and used national data on accidents and illness at sea to indicate the situations in which risk arises [11]. Serious harm from overheating, whether presenting as heat cramps, heat collapse or hyperthermia is now relatively rare, as air conditioning systems on ships have improved and as the hot physical work of stoking coal fired boilers is now a thing of the past. However, it may occur when cooling systems are not functioning or during work on deck under extreme conditions. Local cold injury may occur during deck work in cold weather, but the major cause of serious hypothermia and deaths from it is the need to abandon ship and await rescue with inadequate protection from the cold, especially where there is immersion in cold water. The control of risks from heat largely depends on safe working practices, with suitable breaks and access to cool air and water, while most serious cold damage follows ship disasters or falls overboard, both of which are largely preventable by effective safety measures. The risks from cold are a bigger problem in the fishing sector than in maritime transport.

RISKS FROM CHEMICAL EXPOSURES

One of the commonest causes of fatality when entering **enclosed spaces on board ships** is an oxygen deficient atmosphere. **Urban Svedberg** (Sundsvall Hospital, Sweden) noted that there are well-developed precautions aimed at controlling such risks [12]. Reduced oxygen levels may be caused by oxidation processes affecting cargoes, especially organic ones, and from metals, for instance rust development on anchor cables in chain lockers. Some cargoes may produce toxic gasses or vapours, such as carbon dioxide from oxidation by microorganisms and fermentation processes. Carbon monoxide may be generated from partial oxidation, and case studies of the investigation of fatalities and poisoning arising from carbon monoxide generated in wood pellet cargoes were presented [13–15]. Hydrogen sulphide may be released from oils and other sulphur containing materials. Toxic fumigants may be applied to grain and other cargoes subject to infestation and their use can result in potentially dangerous residual concentrations. The risk from such agents will be determined by the concentration present and the duration of exposure and risks are not limited to hold areas but dangerous concentrations may arise in unventilated stairwells and other parts of the ship adjacent to cargo. Quantification of risk is the key to determining appropriate precautions and there are good predictive data for most of the common contaminants. Sealed shipping containers also have the potential to pose risks from fumigants, off-gassing from contents and from oxidative processes. The effectiveness of various ventilation systems in eliminating these was reviewed [16].

The diverse range of **chemical agents** encountered on board ships was reviewed by **Karl Forsell** (University of Gothenburg, Sweden). Many have well known hazards and for these substances regulations about control, supplemented by substance specific data sheets on risks and precautions provide the basis for safe working practices. These practices should include evaluation of exposure where this is not well understood or is poorly controlled, measurement of uptake when possible and health surveillance where a defined medium or long-term risk to health exist. Common situations for exposure include engine spaces, where oil mist may be inhaled and skin contamination with oils and products of combustion can occur. Car decks can have significant levels of exhaust fumes from vehicles, while many marine paints use agents such as epoxides and di-isocyanates with well-known risk of irritancy and sensitisation. Detergents and disinfectants are widely used and these can cause a range of skin problems. Welding produces fume, which can include micro-fine particles of metals and sensitisers. Bulk liquids that are carried as cargo, especially hydrocarbons, solvents and chemical products, are well contained under normal circumstances on modern ships, not least because of environmental concerns, but releases can occur and once cargoes have been discharged tanks may need to be entered for cleaning and inspection. Well-defined precautions are needed to minimise risk.

This presentation was complemented by the showing of an educational video prepared by Seahealth for the Danish Maritime Authority, which aimed to alert seafarers to the importance of safe working practices and to the chemical risks that could be avoided by adopting them [17, 18].

Karl Forsell (University of Gothenburg, Sweden) also reviewed the risks of **cancer** in seafarers. This was on behalf of Ralph Nilsson who was unable to attend, but who was available for discussions by videolink. Several epidemiological studies, the majority performed in the Nordic countries, have shown increased incidence rates of cancer (i.e. lung cancer, mesothelioma, urinary bladder and skin cancer) in seafarers compared to the general population [19–23]. The complexity of the maritime working and living environment makes it difficult to determine the relative contributions of specific occupational exposures and of lifestyle to the incidence of cancers in seafarers; this was a topic that was also covered in Henrik Hansen's presentation on information about seafarer health risks. This difficulty applies particularly to lung cancer, where asbestos, smoking and exposure to the polycyclic aromatic hydrocarbons (PAH), found in heavy fuel oils, in used lubricant oils and in the products of combustion, are all known causes [23, 24]. Mesothelioma is specific to the asbestos exposure risks that arise in seafarers, but even more in shipbuilding and ship repair workers [25–27]. Skin cancer is associated with exposure to the sun (see above: UV). There are also suspicions of an excess of blood malignancies in deck crew on coastal tankers that could be a result of benzene exposure [28]. One of the features of all cancer excesses is that they reflect conditions before the time when the condition arises, rather than the effects of current patterns of exposure, and the lack of historic exposure data means that current risk levels cannot be reliably estimated. Areas of study that are active at present include the measurement of skin absorption of PAH's by biological monitoring. This shows elevated end of shift levels in engineering crew with skin exposure. The evidence of carcinogenicity from diesel exhaust particulates has increased; these are found in flue gasses and also on car decks [29, 30]. Monitoring for exposure to benzene has become more sophisticated and it is now possible to measure a range of metabolites with different time courses for estimation of exposure. Since the results are very dependent on sampling time in relation to exposure time, more research is needed before they can be used to reliably estimate exposure to benzene.

BIOHAZARDS

There is a wide range of **venomous sea creatures**. How to reduce risk and to treat envenomation was described by **Hans Gunnar Øverengen** (Sjömanslakärmottagning, Stockholm, Sweden). Examples discussed included the various species with nematocysts, such as jellyfish and Portuguese men of war, cone shells and spines of organisms varying from sea urchins to sting rays. Toxins that can be ingested with marine creatures may arise from spoiled fish releasing histamine (scombroid); ciguatera from algal blooms, especially when the toxins have been concentrated up the food chain, and the toxic effects of cyanobacteria. The situations in which exposure can occur are diverse: fishing and scientific work with marine organisms bring workers into close contact with organisms. Accidental exposures may occur when swimming, landing ashore and in diving and ship repair and maintenance work. The presentation was illustrated by many examples derived from his experience at sea.

Maritime aspects of **infectious diseases** were reviewed by **Clara Schlaich** (University of Malawi and Hamburg, Germany). Her presentation again illustrated the problems of applying traditional definitions of occupational and work related disease to the maritime setting, as the determinants of risk include: individual immunity, ports visited, duties, living conditions, the places of origin prior to embarkation for others on board, the availability of preventative measures and the extent of travel away from the ship. The review was derived from a literature search covering the period since 1990 that will shortly be published in the "Textbook of Maritime Medicine" [31]. Continuing problems include tuberculosis, skin infections, and vector borne diseases such as malaria. Diagnosis at sea can be lifesaving and for some conditions, such as malaria, suitable tests are available. Challenges include ensuring that seafarers are immunised and, for malaria, use appropriate prophylaxis. All too frequently restrictions that do nothing to control infection and its spread may be imposed either at sea or by port authorities. New and resistant strains of organism can pose sudden threats and there is no systematic surveillance either for these or for the prevalence of existing forms of infection in seafarers. Treatment can also be complicated by inactive counterfeit medicine and poor quality care in many ports.

CLINICAL PERSPECTIVES

Two approaches to the understanding of exposure and its effects became apparent in the workshop. The presentations described above started from particular forms of risk and then considered their health effects. Those summarised in this section take diseases as their starting point and then look at the contributory causes for those that arise during work at sea.

Lung diseases in seafarers were discussed by **Øyvind Omland** (Aalborg University Hospital, Denmark). The main health outcomes reviewed were cancers, including mesothelioma, and asthma. The sources used were mortality and morbidity studies from Scandinavia and Russia [22, 32]. He also considered some case studies on acute effects from exposure to sodium metabisulphite used as a preservative for crustaceans [33–35]. It was not possible to separate out the contributions of lifestyle and occupation for many lung conditions, such as chronic obstructive disease and lung cancer, and studies did not show that risks increase with duration of employment at sea. Few studies have been published addressing lung diseases in seafarers and the scarcity of good longitudinal studies was noted. While it is possible to speculate, for instance about risks of asthma and the contributions of exposure to oil mists and PAHs to lung cancer, there is no clear evidence of excess incidence of asthma and lung cancer attributable to work at sea. Excesses of lung cancer may well be linked to patterns of smoking.

There has been little formal study of **skin diseases** in seafarers. **Marlene Isaksson** (Skåne University Hospital, Malmö, Sweden) presented information on known and likely risks. In particular those with an atopic history are both more likely to develop dermatitis from exposure to irritants and to develop allergic dermatitis from gloves, fish or foodstuffs. She reviewed common causes of allergic dermatitis and the use of patch tests in diagnosis. She also presented a critical appraisal of the allergenic potential and protective value of gloves made from different polymers. Tattooing, often associated with the lifestyle of a seafarer, can lead to allergic sensitisation and this can even happen from temporary tattoos, such as those using 'black henna' which often contain paraphenylene diamine, a sensitiser also found in a wide range of other products. Venomous organisms can be a cause of skin lesions as can infestation such as scabies, historically important among ship crews. Fish catching is a high-risk activity with some specific allergens, such as the marine bryozoan that causes Dogger Bank Itch, as well as allergic responses to bait, to fish and to biological contaminants.

Eilif Dahl (Norwegian Centre for Maritime Medicine, Bergen) summarised the available epidemiological evidence on **gastrointestinal disease** (**GID**) in seafarers [36]. In doing so he emphasised the importance of pre-sea selection as a way of reducing risks, coupled with treatment of remediable risks such as dental problems and hernias. GID has been a major cause of morbidity and death of seafarers and much of it may be related to stress or coping measures such as smoking and alcohol use, although both are now becoming less frequent. There is some evidence that GID is now a less frequent cause of morbidity and death. On cruise ships, gastroenteritis is the commonest cause for crew sick leave and isolation aboard, while dental emergencies lead to most specialist referrals in port and acute abdominal pain and appendicitis are common reasons for medical sign-off and hospitalisation. Among acute conditions, gastro-enteritis is prominent and outbreaks among crew or passengers can be severely disruptive. Controls at embarkation, good hygiene and isolation of cases remain the key aspects of control.

Cardiovascular disease (**CVD**) is the commonest cause of death at sea in seafarers [37, 38]. **Marcus Oldenburg** (Institute for Occupational and Maritime Medicine, Hamburg, Germany) assessed the data on incidence and noted the potential for increased work demands and hence for stress as a contributory factor to CVD. In addition to mortality, CVD is the second commonest cause of serious medical emergencies at sea (after trauma) [39]. However, morbidity studies suggest that while the rates of CVD in Polish seamen are similar to the general population, the prognosis after an event is worse, reflecting inadequate options for medical care on board. Cardiac risk factors, such as raised blood pressure and triglycerides, are common in seafarers and there is scope for risk reduction by their control. Better quality food on board, taking regular exercise and an end to a culture of smoking are all practical preventative measures that need to be adopted at sea. The presence of automatic defibrillators on board can be lifesaving in a small proportion of cardiac events. They can also provide useful information on cardiac rhythm through electrocardiography transmission to telemedical services ashore [40].

Seasickness has a clear causal link to vessel motion. **Hans Gunnar Øverengen** (Sjömansläkarmottagning, Stockholm, Sweden) identified its adverse effects: individual suffering, incapacity to perform duties, impairment of judgement, interference with medication use and mimicry of other conditions where vomiting is a symptom. In addition to the motion of a ship, it may be triggered by anxiety about its development, odours and fatigue. It may present as any blend of vertigo, nausea and vomiting and may sometimes also be a feature of disembarkation on to land. The design of a ship can play a part in risk reduction as slow rolling is less distressing than a rapid return to the ship's equilibrium position, while adaptation of course and speed to weather conditions assist. There have been many attempts to design passenger vessels to minimise seasickness, but few have been effective. However, the use of bilge keels and, more recently, gyroscopic fin stabilisers have both been effective. A wide range of remedies has been promoted from champagne and cocaine to, more recently, antihistamines and anti-muscarinics. The latter two can lead to drowsiness and to impaired vision, respectively. Placebos are free of side effects and some claim that they help. Other adjuncts to prevention include keeping warm and hydrated, avoiding alcohol, tobacco and strong odours and taking light food.

Fatigue is a significant contributor to accidents at sea as well as interfering with the overall performance and wellbeing of seafarers. This is an area of active research, as described by **Wessel van Leeuwen** (Stockholm University, Sweden). The development of fatigue and the commonalities between fatigue and sleepiness need to be considered. A recent international project has investigated fatigue in ship crews using simulators with adjacent accommodation where deck and engine crew worked 4 h on 8 h off or 6 on 6 off patterns over several days. These showed diurnal and in-shift variations in sleepiness, with the highest values towards the end on night time shifts. The level of sleepiness was higher in those on a 6/6 pattern. Short sleeps did occur while on watch, most commonly at night, and these were most frequent in those working 6/6 (c. 40%). More studies are in progress assessing performance and risk management at sea.

DISCUSSION AND CONCLUSIONS

This course provided one of the first opportunities to view the relationships between patterns of exposure to risk and patterns of ill health in seafarers in a holistic way. This enabled a number of important general conclusions to be drawn out and these became apparent in the discussions about individual papers as well as in those at the close of the meeting.

It is far more difficult to define study populations of seafarers and to follow their subsequent patterns of health than is the case for those on land, because they work in a global industry where only a few organisations think in terms of the lifetime risks in those who work for them. This is compounded by a shortage of valid information on exposure to risks and an even greater shortage of measurements to quantify this. It is notable that much of the quantitative data comes from navies, who are both accountable for their performance to national political leaders and who are much more positively concerned about risk management and effective performance in crew members than is the case in commercial shipping, where there is often a rule-following or rule bending attitude coupled with a readiness to dispose of disabled labour and hire new staff rather than to manage long term risks. Many of the best investigations on health risks have been done in the Nordic countries on their own nationals using data linkage to population and healthcare record [41]. However these do not necessarily represent the pattern of illness seen in the majority of the world's seafarers who now come from Asia.

Most population studies use job descriptions as a proxy for patterns of exposure and risk. This can mean that small at risk groups are diluted by those without the relevant exposure. There are also problems in making comparisons between seafarers and other parts of the working and non-working population. Seafarers are selected into employment in-part based on a medical assessment and may also find that they have to leave seafaring employment for medical reasons in addition to the pattern of job change and turnover found in all sectors of employment. Where exposure data are available, as in a number of the studies presented at the workshop, there is often not sufficient follow-up time to assess the late effects of this exposure. Conversely, where current measurements of exposure are taken as indicators of risk it may well be that, as in the crews of tankers carrying hydrocarbons, exposures have been reduced by several orders of magnitude over recent decades in order to comply with environmental emission regulations.

The final important distinctive feature of seafaring, that arose repeatedly in discussions, is that any assessment of the risks of being a seafarer has to take account of the consequences of living in on board with the pattern of restrictions and social interactions that go with it. This is coupled with the risks arising from travel to different climatic zones and to ports where new forms of disease, especially infections, may be encountered.

Thus the associations of work as a seafarer with patterns of exposure and patterns of ill health are markedly different to those ashore. Many of the techniques of exposure assessment, risk management and surveillance for disease are identical, but research questions need to be framed to take account of this unique environment and to recognise the practical limitations to exposure measurement and disease monitoring.

As a consequence of these problems, as well as because merchant shipping is a global profit driven industry that seeks cost reductions wherever possible and which has long used sub-contracting and insurance as ways of mitigating and sharing risk, support for research is hard to find. There is, however, little doubt that seafaring populations remain among the highest risk groups for disease associated with their working and living conditions as well as for accidents. Much more needs to be done to quantify risk and to quantify patterns of illness that could be associated with it. This work is most needed for the large seafaring populations from Asia, but many of these newer crewing countries have a weak research base and lack the registers and skills available in the developed world. This is an area where the use of skills from traditional maritime nations to support studies in the major crewing countries could have benefits, not just for seafarers, but also for the large shipping and insurance companies, most of whom still remain based in the main maritime nations irrespective of where they flag their ships and secure their crews from.

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