JOURNAL OF MARITIME RESEARCH

Vol XXIII. No. II (2026) pp 465–474

ISSN: 1697-4840, www.jmr.unican.es

From Scurvy to Norovirus: A Historical Review of Food-borne Illnesses on Board Ships

S.C. Gómez Correa[1,*], N. Benítez Brito[2], J.A. González-Almeida[3], A.U. Gómez-Correa[4], A. Pacheco Jiménez[5], E. Madariaga Domínguez[6]

ARTICLE INFO

Article history:
Received 23 Jan 2026;
in revised form 12 Feb 2026;
accepted 26 Mar 2026.

Keywords:
scurvy, beriberi, pellagra, maritime nutrition, food security, seafarers, history of naval medicine, ciguatera, norovirus.

ABSTRACT

Life on board has historically been determined by the availability, preservation and quality of food and drinking water. This narrative review traces, in chronological order, the main deficiency diseases and cases of food poisoning/foodborne infections that have affected seafarers from the Age of Discovery to the present day: scurvy (vitamin C deficiency), beriberi (thiamine deficiency), pellagra (niacin deficiency), rickets and osteomalacia (vitamin D deficiency), and infectious and toxic outbreaks associated with the consumption of spoiled food or contaminated water (typhoid fever, norovirus, ciguatera). The course also covers the regulatory framework for food safety on board (HACCP, MLC 2006 Convention) and concludes with an examination of the contemporary nutritional status of seafarers, which is paradoxically characterised by overweight, metabolic syndrome and persistent vitamin deficiencies, particularly vitamin D deficiency.

1. Introduction.

For centuries, the diet on board was organised around an almost exclusively logistical criterion: the ability to preserve food during voyages lasting months, rather than its nutritional value. This priority - ship's biscuits, salted meat, dried pulses and beer or wine as the main source of supposedly safe liquid - gave rise to a pattern of illness characteristic of life at sea that we now recognise as a deficiency disorder, but which for centuries remained shrouded in erroneous medical theories, ranging from 'bodily putrefaction' to miasmas (Hayes, Matthews, Allaire and Holm, 2019). Added to this, in parallel and persistently, the risk posed by contaminated water and food, a problem which-far from having disappeared with the modernisation of the merchant and passenger fleets-continues to manifest itself in the 21st century in new epidemiological forms, ranging from outbreaks of typhoid fever on converted river vessels to norovirus epidemics on large cruise ships (Ooms et al., 2024).

The purpose of this review is twofold. Firstly, to reconstruct the chronology of the main nutritional diseases that affected crews from the 13th century to the present day, showing how scientific understanding of each of them was, in every case, belated compared to the empirical observations of seafarers and naval surgeons. Secondly, to document that the problem of food safety on board - far from being an exclusively historical issue - remains an active public health challenge today, both in terms of infectious risks (microbiological contamination of water and food) and in terms of deficiency and metabolic disorders (spe-

[1]PhD student. Universidad de La Laguna. E-Mail: sgomezco@ull.edu.es.
[2]Universidad de La Laguna. Department of Chemical Engineering and Pharmaceutical Technology. E-Mail: nbenitez@ull.edu.es. ORCID: 0000-0001-6243-4099.
[3]Universidad de La Laguna. Higher Polytechnic School of Engineering. Santa Cruz de Tenerife, Spain. E-Mail: jagonal@ull.edu.es. ORCID: 0000-0002-4544-6028.
[4]Universidad de La Laguna. Higher Polytechnic School of Engineering. Santa Cruz de Tenerife, Spain. E-Mail: agomezco@ull.edu.es.
[5]Universidad de Cantabria. School of Maritime Engineering. Project Management Research Group. Santander, Spain. E-Mail: apj770@alumnos.unican.es. ORCID: 0009-0007-5881-5367.
[6]Universidad de Cantabria. School of Maritime Engineering. Project Management Research Group. Santander, Spain. E-Mail: madariagae@unican.es. ORCID: 0000-0002-0847-1152.
[*]Corresponding author: S.C. Gómez Correa. E-mail Address: sgomezco@ull.edu.es.

cific vitamin deficiencies combined, paradoxically, with obesity and metabolic syndrome).

Figure 1: Ship's biscuit ('hardtack'), a staple food carried on long sea voyages because of its exceptional durability. Its nutritional limitations illustrate how historical shipboard diets prioritised preservation and caloric supply over micronutrient quality.

Source: Wikimedia Commons.

2. Scurvy: the disease that defined ocean-going navigation.

2.1. The scale of the historical problema.

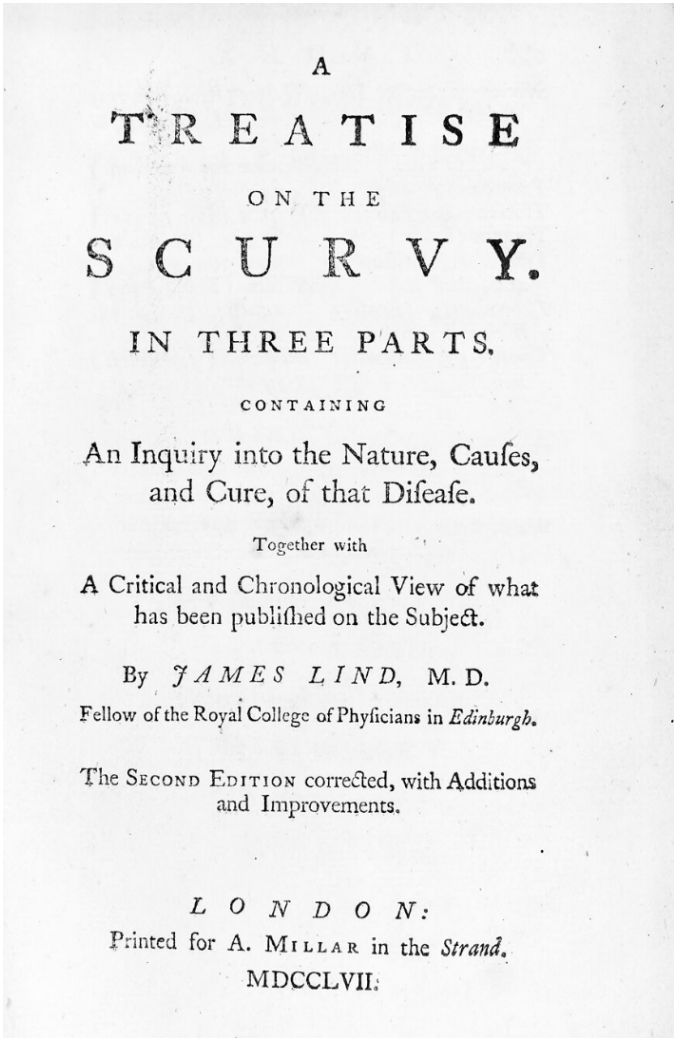
No disease has left such a mark on the history of seafaring nutrition as scurvy. It is estimated that, between 1500 and 1700, up to two million seafarers died from this cause, a figure that far exceeds the casualties of any naval battle of the period. The naval diet of the 16th to 18th centuries - biscuits, salted meat and fish, cheese, butter, dried pulses and up to seven gallons of beer per week per sailor in the Royal Navy - was almost entirely devoid of vitamin C, the body's reserves of which are depleted after ten to twelve weeks without replenishment, with symptoms of deficiency potentially appearing as early as six weeks in sailors who had embarked with reserves already diminished by deficient diets on land (Baron, 2009).

The symptoms followed a well-documented progressive pattern: apathy and general malaise in the first few weeks, followed by spongy, bleeding gums, spontaneous bruising, swelling of the legs, joint pain and, in advanced stages, tooth loss and sudden death from heart failure. Physiologically, the absence of ascorbic acid prevents the adequate synthesis of collagen, an essential structural protein whose deficiency causes the capillary fragility and connective tissue failure characteristic of the disease.

2.2. Lind's trial and the slow uptake of the remedy.

The methodological breakthrough came in 1747, when the naval surgeon James Lind, aboard HMS Salisbury during the War of the Austrian Succession, selected twelve sailors suffering from scurvy with similar symptoms and divided them into six pairs, all housed under the same conditions and on the same basic diet, but assigning each pair a different supplement (cider, vitriolic elixir, vinegar, seawater, a spice paste, or two oranges and one lemon a day). The citrus group showed such a rapid and marked improvement that one of its members was able to return to duty within a few days, constituting one of the first controlled clinical trials in the history of medicine (Baron, 2009).

Figure 2: Title page of James Lind's A Treatise on the Scurvy, one of the landmark works in the history of naval medicine and the scientific investigation of nutritional deficiency.



A

TREATISE

ON THE

SCURVY.

IN THREE PARTS.

CONTAINING

An Inquiry into the Nature, Cauſes, and Cure, of that Diſeaſe.

Together with

A Critical and Chronological View of what has been publiſhed on the Subject.

By JAMES LIND, M. D.

Fellow of the Royal College of Phyſicians in *Edinburgh*.

The Second Edition corrected, with Additions and Improvements.

LONDON:

Printed for A. Millar in the *Strand*.

MDCCLVII.

Source: Wellcome Collection.

However, the translation of this empirical finding into naval policy was extraordinarily slow. Lind himself, still wedded to the humoral theory of disease, devoted only a few paragraphs of his *Treatise on Scurvy* (1753) to his experiment, and even proposed the production of a lemon juice concentrate ('rob'), the boiling process for which destroyed almost all the vitamin C-which explains why subsequent expeditions, such as James Cook's first, observed no benefit whatsoever when they tried it. It was not until 1795-forty-eight years after the original trial, and one year after Lind's death-that the British Admiralty ordered the rationing of lemon juice to the entire fleet, which drastically reduced the incidence of scurvy in the Royal Navy. A full causal understanding of scurvy, however, was not established until well into the 20th century, when ascorbic acid was isolated and synthesised (Baron, 2009).

2.3. Background prior to Lind and geographical scope.

Modern quantitative analysis of 16th-century European naval diets, combining historical provisioning records with contemporary nutritional tables, confirms that a lack of vitamin C was a structural and virtually universal shortcoming across all Western fleets of the period, regardless of the nation: English, Spanish, Dutch and French fleets all exhibited strikingly similar provisioning patterns, determined not by cultural preferences but by the technological limitations of the food preservation methods available (Hayes et al., 2019). This same study documents that fish lost relative importance compared to beef in European naval rations between the 16th and 18th centuries, a change with nutritional implications that has not yet been fully explored.

Much earlier, as far back as the 13th century, the Catalan-Aragonese fleet exhibited dietary patterns that foreshadowed these same structural problems: cheese, meat cooked in a vegetable sauce, biscuits and wine formed the basis of the rowers' diet; they required a high caloric intake to sustain the physical exertion of rowing, but whose diet also lacked reliable sources of vitamin C (Mott, 2018).

2.4. Scurvy did not disappear with the Age of Sail: polar exploration.

Contrary to the widely held belief that the problem of scurvy was resolved following the British Admiralty's reforms of 1795, the disease re-emerged with a vengeance during the so-called 'Heroic Age' of Antarctic exploration (approximately 1897 – 1922), a period in which, paradoxically, the medical community already possessed - or believed it possessed - sufficient knowledge to prevent it. A historical analysis of the medical understanding of scurvy during this period reveals that conflicting and often outright erroneous theories about its origin persisted, including the hypothesis that it was caused by ptomaine poisoning from spoiled tinned food, an idea that led some expedition leaders, such as Robert Falcon Scott, to focus their precautions on the quality of the tins rather than on the supply of citrus fruits or fresh meat (Guly, 2013).

A particularly illustrative case is the comparative analysis of the two branches of Sir Ernest Shackleton's Imperial Trans-Antarctic Expedition (1914–1917). The Ross Sea party, led by Captain Aeneas Mackintosh, suffered from scurvy - including at least one confirmed death, that of A. Spencer-Smith in 1916 - due to a combination of poor leadership, inadequate medical care, overloaded sledges and a sledge diet that was deficient in both energy and vitamin C content. In stark contrast, the Weddell Sea party, under Shackleton's direct leadership, avoided the disease almost entirely despite facing objectively harsher conditions, including the sinking of the Endurance and the subsequent dragging of three lifeboats across the ice until they reached open water.

3. 'Polar anaemia' and beriberi: the other side of the story.

3.1. A retrospective diagnosis a century later.

A second deficiency syndrome, frequently confused with scurvy in contemporary accounts of the period, was what the explorers themselves termed 'polar anaemia': a syndrome of heart failure characterised by dyspnoea (breathing difficulties), abnormal pulse patterns and leg oedema, which affected the majority of members of at least one expedition and caused at least one direct death, as well as six deaths from heart failure throughout the 'heroic age' of Antarctic exploration - excluding Shackleton's own death from coronary heart disease - and at least eight further non-fatal cases.

Guly's (2012) retrospective analysis, carried out almost a century after the events based on expedition medical reports preserved at the Scott Polar Research Institute, concluded that these cases most likely corresponded to wet beriberi caused by a thiamine (vitamin B1) deficiency, often co-existing with scurvy itself in the same individuals, which would have greatly complicated the differential diagnosis for the expedition doctors of the time, who lacked the necessary biochemical knowledge to distinguish between the two conditions.

3.2. Kanehiro Takaki and the eradication of beriberi in the Japanese Navy.

Beriberi, however, has one of the most elegant and best-documented histories of discovery in the entire field of naval medicine, precisely because, in this case, practical intervention completely preceded biochemical understanding. In the Imperial Japanese Navy of the 1880s, the surgeon Kanehiro Takaki observed that the disease - known locally as kakke - disproportionately affected lower-ranking sailors, who were fed almost exclusively on polished white rice, which they received free of charge and which therefore constituted virtually their entire caloric intake, whereas Japanese officers-who had a more varied diet, similar to that of Western navies-hardly suffered from the disease at all, despite eating the same rice.

Takaki had the opportunity to test his dietary hypothesis in an almost experimental manner: during a nine-month training expedition to Hawaii, via New Zealand and South America, undertaken in 1883, 169 out of 376 cadets fell ill and 25 of them died. After requesting and obtaining funding from Emperor Meiji himself to modify the sailors' diet by incorporating barley, meat, milk, bread and vegetables, a virtually

identical voyage undertaken the following year, in 1884, reduced the number of cases to just 16 out of 333 crew members (Itokawa, 1976). Beriberi was virtually eradicated from the Japanese Navy within just six years of the dietary reform beginning, a full decade before Christiaan Eijkman, working independently in Java, identified -through an experimental model of polyneuritis in chickens -the biochemical link between polished rice -devoid of the husk where thiamine is concentrated- and the disease, work that would earn him the Nobel Prize in 1929.

Figure 3: TKanehiro Takaki (1849–1920), Japanese naval surgeon whose dietary reforms dramatically reduced the incidence of beriberi in the Imperial Japanese Navy before the biochemical role of thiamine was understood.

Source: Wikimedia Commons / Jikei University Library Archives.

It is noteworthy that, despite the statistical robustness of Takaki's results, many doctors of the time were reluctant to accept the dietary explanation, attributing the observed improvement to a hypothetical parallel improvement in hygiene conditions on the ships rather than to the change in diet-an episode that illustrates just how deeply entrenched the microbial and hygienist theories were compared to the then-novel idea that a disease might simply be due to the absence of a nutrient.

4. Pellagra, rickets and other, less well-studied deficiencies at sea.

4.1. Pellagra: a primarily land-based problem with maritime implications.

Pellagra - caused by a deficiency of niacin (vitamin B3) and classically characterised by the triad of dermatitis, diarrhoea and dementia, to which a fourth 'D' of death is often added in untreated cases - has been studied considerably less in the specific maritime context than scurvy or beriberi, largely because our understanding of its causes is based primarily on the epidemiological work of Joseph Goldberger in the early 20th century in land-based institutions - orphanages, asylums and prisons in the southern United States - rather than on ships. Nevertheless, there are isolated historical records of documented cases among Italian sailors, reported in New York in 1882 and again in 1902, suggesting that the problem, whilst rare, was not entirely unknown in the maritime context, particularly amongst crews whose diet on land was already deficient in niacin even before they set sail.

Interestingly, some researchers have questioned whether niacin deficiency was ever truly significant amongst seafarers in the 17th and 18th centuries, given the high consumption of beer-a not inconsiderable source of niacin-which formed part of the standard ration; calculations based on laboratory analysis of beer from that period suggest that consuming one gallon a day could provide more than six milligrams of niacin, an amount which, when added to that derived from the meat and fish in the rations, might have partially protected seafarers against this specific deficiency, even whilst scurvy and beriberi were rife.

4.2. Rickets and osteomalacia: evidence from the Mary Rose.

The osteoarchaeological analysis of the remains of the Mary Rose - the flagship of Henry VIII's English fleet, which sank in 1545 and was archaeologically recovered centuries later - provided one of the most direct pieces of physical evidence of nutritional deficiency in a historical crew: several skeletons showed evidence of both healed childhood rickets, visible in the bowing of certain long bones in the leg, and adult osteomalacia, the equivalent form of the disease in the fully formed skeleton. Both conditions are attributable to a sustained vitamin D deficiency, consistent with a diet lacking sufficient quantities of oily fish and with insufficient exposure to sunlight during the long periods of watch duty and confinement on board (Hayes et al., 2019).

4.3. A problem that has not gone away: vitamin D in the modern navy.

Surprisingly, vitamin D deficiency has by no means disappeared from the modern merchant and naval forces, even though one might intuitively expect that a profession carried out outdoors in the sun would be protected against this deficiency. A recent systematic review of vitamin D status among active-duty naval personnel, which analysed thirteen studies published between 1975 and 2022 in navies of the northern hemisphere - primarily the US Navy, but also the British, Israeli, French,

Dutch and Portuguese navies - found an overall prevalence of deficiency of between 29 per cent and 37 per cent, with substantially higher figures among submarine personnel: in a study that followed the same individuals before and after a patrol, the prevalence of deficiency rose from 13 per cent to 30 per cent, and that of insufficiency from 27 per cent to 40 per cent, and the proportion of personnel with sufficient levels halved, from 60 per cent to 30 per cent (Henriques, Rodrigues, Viegas, Serranheira and Sacadura-Leite, 2023).

The authors of this review themselves attribute the phenomenon to a combination of occupational factors specific to naval life: the wearing of protective clothing that covers the skin, shift work patterns - including night shifts, which reverse the cycle of sun exposure -, service in high-latitude regions with low seasonal ultraviolet radiation, and, most notably, confinement in indoor spaces without natural light, such as engine rooms or the interior of a submarine itself, for weeks or months. The authors explicitly recommend the implementation of policies for the fortification of food with vitamin D, the regular assessment of serum levels, and the provision of supplements to those with a deficiency prior to deployment..

5. Contaminated water and food: from typhoid fever to norovirus.

In addition to deficiency diseases of a purely dietary nature, maritime history - and particularly the present day - is marked by infectious and toxic outbreaks directly linked to the contamination of drinking water and food on board, a problem that is far from being merely historical and which continues to cause large-scale incidents well into the 21st century.

5.1. Typhoid fever and cholera: from ballast water to corroded tanks.

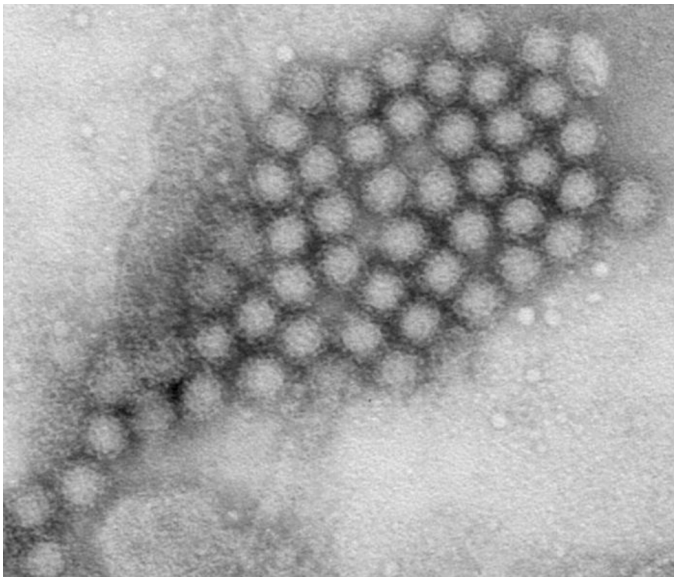
Cholera has historically been associated both with the contamination of fresh water supplies taken on board in port and, in its more modern form, with the unintentional introduction of the bacterium into new regions via ships' ballast water – a recognised transmission mechanism that is difficult to prevent precisely because it does not depend on the awareness of the sick traveller, but on a completely invisible vector carried in the ballast tanks.

A paradigmatic and extraordinarily recent case illustrates that the risk of drinking water contamination on board is far from being merely a thing of the past. In 2022, a Dutch river vessel withdrawn from active service and converted into temporary accommodation for asylum seekers suffered a large-scale outbreak of typhoid fever: within 47 days, 72 confirmed cases were identified - 52 amongst the asylum seekers themselves and 20 amongst the staff - of whom 25 required hospitalisation, although all patients eventually recovered following treatment. A thorough epidemiological investigation determined that the vessel's waste water tank shared a wall with the fresh water tank, and that severe corrosion of that wall had caused perforations which allowed waste water to seep into the drinking water when water levels were high. Salmonella Typhi was cultured directly from the sewage tank, showing an exact genetic match with the isolates obtained from the patients, whilst DNA from the same bacterial species was detected by PCR in the fresh-water tank itself, conclusively confirming the route of contamination (Ooms et al., 2024). The study's authors highlight a lesson of general relevance for any operation accommodating people on floating facilities: strict monitoring of water quality and technical installations is essential, particularly when dealing with populations from countries where certain infections are endemic.

5.2. Norovirus on cruise ships: a structural problem in a confined environment.

Norovirus is currently by far the most common cause of outbreaks of acute gastroenteritis on cruise ships, a phenomenon that can be explained by a combination of high passenger density, semi - enclosed environments and a particularly efficient route of transmission - the faecal-oral route, via both direct person-to-person contact and environmental and food contamination.

Figure 4: Transmission electron micrograph showing a cluster of norovirus virions. Norovirus is currently one of the principal causes of acute gastroenteritis outbreaks aboard cruise ships, where confined spaces and high passenger density facilitate transmission.



Source: CDC Public Health Image Library, Charles D. Humphrey.

One of the best-documented episodes from a molecular perspective affected six consecutive cruises undertaken by the same ship, with the outbreak recurring despite thorough disinfection carried out after the second affected cruise. Epidemiological analysis suggested an initial foodborne origin, followed by secondary person-to-person spread, whilst molecular analysis of the samples provided new insights into the virus's transmission mechanisms, including the detection of a genetically indistinguishable sequence in two patients from an unrelated outbreak at a care home, suggesting that the virus may have been in-

troduced into that care home by a passenger who had been ill during the first cruise in the series.

This pattern is by no means new: as early as 1977, an outbreak of gastroenteritis attributed to an agent then known as the 'Norwalk-like virus' - the precursor to the current norovirus - had affected 64 per cent of the passengers on a cruise ship, with mild to moderate clinical symptoms lasting one to two days, characterised by nausea, vomiting and diarrhoea, with fever present in approximately a quarter of cases. Significantly, a similar gastrointestinal illness recurred on the four subsequent cruises undertaken by the same vessel, albeit in a progressively less severe form and affecting fewer people on each successive voyage, with no common source identified, suggesting once again sustained person-to-person transmission within the confined environment of the ship.

More recently, an outbreak in 2017 aboard a river cruise ship in Chongqing, China, enabled a particularly rigorous epidemiological investigation using a case-control study: of 555 passengers, 101 developed acute gastroenteritis (an attack rate of 18.2 per cent), and statistical analysis independently linked the consumption of four cold dishes served on the same day - including cold vegetables, garlic and cucumber sprouts, amongst others - with a significantly elevated risk of falling ill, with odds ratios of up to 26.1 for the dish most implicated. Fifteen of the samples analysed tested positive for norovirus genogroup GII by PCR, and the investigation concluded that the virus had been transmitted primarily through the consumption of these cold dishes, presumably contaminated by an asymptomatic cook handling food that was not subsequently cooked-a particularly insidious transmission mechanism, given that the handler's lack of symptoms prevents any preventive measures based on self-detection.

These incidents are not isolated cases but rather the recurring manifestation of a structural pattern well characterised by international epidemiological surveillance. The original research identifying norovirus transmission on the six consecutive cruises described above was carried out by a team from the US Centres for Disease Control and Prevention (Isakbaeva et al., 2005). The European surveillance network for foodborne viruses has also documented the emergence of new norovirus variants specifically on spring cruises, which can predict the scale of winter outbreaks on land (Verhoef et al., 2008), and has subsequently developed an integrated approach to identify international foodborne norovirus outbreaks affecting multiple countries via shared cruise routes (Verhoef et al., 2011). A further outbreak, which occurred on a cruise ship sailing around the British Isles, required coordinated multi-agency management across several countries due to its international nature (Vivancos et al., 2010), whilst one of the pioneering cases in recognising this problem, documented as early as 1994, linked an outbreak of Norwalk virus gastroenteritis to the consumption of ice on board a cruise ship in Hawaii (Khan et al., 1994).

5.3. Ciguatera: an occupational hazard specific to seafarers.

Unlike typhoid fever or norovirus, ciguatera poses a relatively specific occupational risk to seafarers, arising directly from a common practice on board: the consumption of reef fish caught by the crew themselves whilst sailing in tropical or subtropical waters, with no control whatsoever over the origin or species of the fish caught.

A particularly well-documented outbreak, published in the *Journal of Travel Medicine* by Schlaich, Hagelstein, Burchard and Schmiedel (2012), affected virtually the entire crew of a refrigerated cargo ship investigated in the port of Hamburg in 2009: fourteen of the fifteen crew members on board fell ill after consuming fish caught two weeks earlier in the Caribbean Sea, subsequently identified as six-banded jack (Caranx sexfasciatus) and red grouper (Cephalopholis miniata); an experimental test confirmed the presence of ciguatoxin in the frozen fish that had been stored. The symptoms, both gastrointestinal and neurological, persisted to varying degrees for at least fourteen days in 93 per cent of the affected crew members, and although no deaths were recorded, two seamen were declared 'unfit for duty' on board due to the severity of their symptoms. The authors conclude that seafarers constitute a specific occupational risk group due to their access to potentially unsafe food sources during international voyages, and recommend three specific preventive measures: the procurement of food in the ports concerned exclusively from safe and certified sources; adequate training for ship's cooks in the identification of high-risk species; and providing seafarers with explicit information on the risks associated with recreational fishing in certain areas.

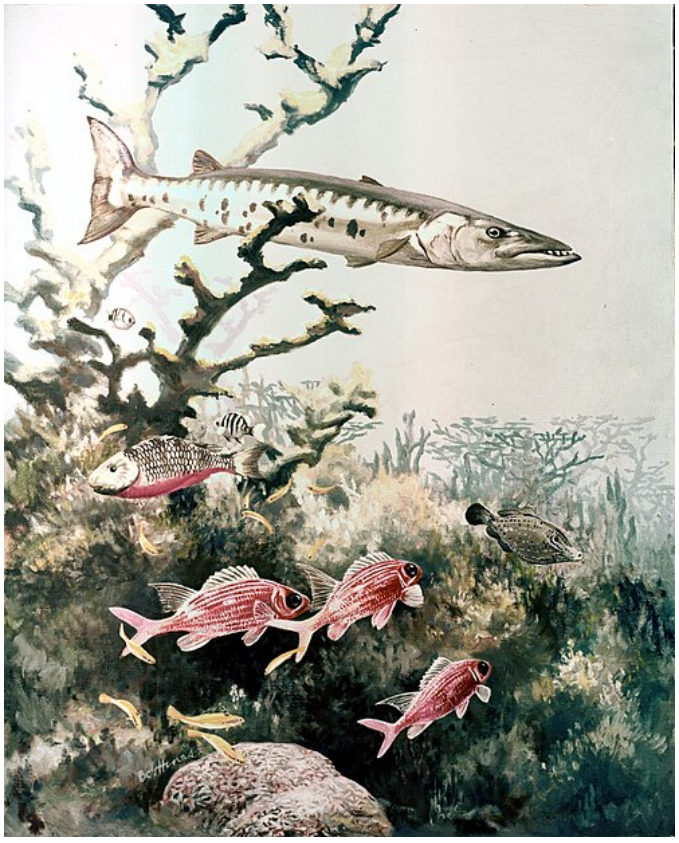
Similar cases have been repeatedly documented in the specialist literature from various regions of the world: a retrospective study of industrial ship crews treated at a port medical clinic in Trinidad and Tobago (Poon-King, Chen and Poon-King, 2004) confirmed that seafarers do indeed constitute an occupational group at high and recurring risk of this form of food poisoning; in 2015, an outbreak affected eight Filipino seafarers on a cargo ship sailing in the Caribbean Sea following the consumption of barracuda; this was investigated upon their return to the Philippines through a case series study (Rebato et al., 2018); and a further case affected an international crew in the port of Saint John, Canada, in 2015 (Muecke, Hamper, Skinner and Osborne, 2015). The geographical recurrence of these incidents - Hamburg, Trinidad and Tobago, the Caribbean, Canada - highlights that this is not a localised problem, but rather a pattern of structural occupational risk wherever trade routes cross tropical waters rich in coral reefs..

6. Food safety, training for catering staff and the regulatory framework on board.

Hygiene in the ship's galley - known in maritime jargon as the 'galley' - and specific training for food-handling staff now form the central preventive measure against food poisoning and foodborne infections, complementing but not entirely replacing the reactive epidemiological surveillance described in the previous section.

A particularly significant study, carried out on 22 ro-ro merchant vessels transporting vehicles with a small number of passengers, used a longitudinal design and objective microbiological analysis to assess the effect of a training course on the principles of Hazard Analysis and Critical Control Points (HACCP)

Figure 5: Barracuda and reef fish in a tropical marine environment. Large predatory reef fish such as barracuda are recognised vectors of ciguatoxins and have been implicated in documented outbreaks of ciguatera poisoning among seafarers.



Source: U.S. Fish and Wildlife Service / Wikimedia Commons.

on the actual hygienic quality of food prepared on board. The study design allowed for a comparison across three time points: before the training, immediately after a refresher training course, and following the regular crew change that takes place on each vessel. The results showed a clear and statistically significant improvement in hygienic quality immediately after the training, but also a subsequent deterioration following the crew change, leading the authors to conclude that continuous education - rather than one-off training - is essential to ensure consistently high food hygiene standards on board (Capunzo, Cavallo, Boccia, Brunetti, Buonomo and Mazza, 2005). This finding has direct practical implications for shipping companies: any investment in training for food handlers that is not systematically repeated with each crew change risks losing its preventive effect within a matter of months.

This framework for continuous training has been reinforced by the Maritime Labour Convention (MLC 2006), which requires that every ship's cook and any other person handling food in the galley hold a recognised qualification in food hygiene or food safety, establishing a minimum level of classroom-based training followed by an examination. The combination of this regulatory framework with the technical principles of HACCP - the identification of biological, chemical and physical hazards at every stage of the process, from the receipt of supplies to the final service - now constitutes the international benchmark for the prevention of outbreaks such as those described in section 5, although the empirical evidence from Capunzo et al. (2005) shows that the mere existence of the regulations does not, in itself, guarantee their sustained compliance in day-to-day practice on board.

Figure 6: Food preparation in the galley of a modern naval vessel. Shipboard catering personnel play a central role in preventing foodborne disease through adequate food handling, hygiene procedures and continuous training.

Source: U.S. Navy / DVIDS.

7. The nutritional paradox of the 21st century: from deficiency to excess.

Whilst for centuries the predominant and almost exclusive problem of seafarers' nutrition was scarcity and acute deficiency of specific micronutrients, contemporary research reveals a partial and complex reversal of this historical pattern: today's seafarers consistently and, as well documented in numerous independent studies, present a markedly elevated risk of being overweight, obese and suffering from metabolic syndrome, without this in any way implying the disappearance of the specific micronutrient deficiencies described in the previous sections - vitamin D being the clearest example of this paradoxical coexistence..

7.1. The scale of the problem of being overweight and obesity.

Previous studies have consistently shown that seafaring is a high-risk occupation in terms of the development of metabolic syndrome, and that, based on their body mass index, almost 50 per cent of all seafarers fall into the overweight or obese categories. A pioneering longitudinal study – the first to use bioimpedance analysis (BIA) to determine the anthropometric changes that occur during several weeks of continuous service on board – followed a group of 63 Croatian professional seafarers with sea-going periods of between eight and twelve weeks, comparing them with a control group of 36 people in non-seafaring occupations. The results confirmed that Croatian

seafarers are in line with global trends observed in the general maritime population, with the following distribution by BMI categories: 0 per cent underweight, 42.86 per cent of normal weight, 39.68 per cent overweight and 17.46 per cent obese. More significantly, the study demonstrated that seafarers' anthropometric status changes significantly during the period of embarkation itself: after eleven weeks of continuous service on board, seafarers lost an average of 0.41 kilograms of muscle mass whilst their total fat mass increased by 1.93 kilograms, an unfavourable pattern of body recomposition - loss of muscle combined with fat gain - which the authors themselves point to as indicative of a general deterioration in health status specifically associated with service on board, and not merely with the passage of time (Russo, Mulić, Kolčić, Maleš, Jerončić Tomić and Pezelj, 2023)..

7.2. Attitudes, perceptions and cultural differences.

A large-scale European research project, carried out as part of the 'e-healthy ship' project funded by the European Union, surveyed 810 seafarers and 62 ship's cooks using two different questionnaires. These seafarers were spread across 68 vessels belonging to two German shipping companies with multinational crews. The results confirmed that, although 98.8 per cent of the seafarers surveyed consider a healthy diet important for their general well-being and job satisfaction, and 88.4 per cent say they are open to changing their eating habits, there remain numerous structural barriers that make it difficult to translate this positive attitude into genuinely healthy eating practices on board. Significantly, the study found differences between European seafarers and those from South-East Asia in terms of their stated willingness to reduce their consumption of certain foods, suggesting a need for culturally sensitive interventions rather than one-size-fits-all solutions (study published in the *Journal of Occupational Medicine and Toxicology*).

This cultural dimension has been explored in greater depth through the so-called Seafarer Nutrition Study (SeaNut), which compared dietary factors between 48 seafarers from Kiribati - a Pacific island nation with a high representation among the crews of certain German shipping companies - and 33 seafarers of European origin, recruited from four container ships belonging to the same shipping company during Atlantic crossings undertaken between April and August 2014. The study, which had a participation rate of 90.9 per cent amongst eligible crew members, found that 35.4 per cent of the Kiribati seafarers, compared with 16.7 per cent of the Europeans, could be classified as being at high cardiovascular risk based on the number of established risk factors present, a finding which the authors attribute to culturally determined differences in attitudes towards food and body shape, as well as a reported greater tendency to overeat amongst Pacific crew members (von Katzler, Zyriax, Jagemann, Westenhoefer, Jensen, Harth and Oldenburg, 2019).

7.3. Structural factors in the maritime environment.

The specialist literature is unanimous in pointing out that the situation on board a merchant vessel involves structural conditions that inherently make it difficult to maintain a balanced diet, regardless of the crew's nationality or individual preferences: individual influence over the quality and variety of the diet is extremely limited, given that crew members remain on board for months at a time with scarce and brief shore leave, which severely restricts the possibility of supplementing their diet with their own purchases; nutrition is thus almost entirely confined to what is actually served in the ship's mess. Similarly, leisure-time physical activity is also restricted to the spaces and equipment available on board - typically a small fitness room - as activities as simple as walking or cycling long distances are simply impossible within the confined space of a vessel at sea.

This paradox has been the subject of a specific systematic review on dietary outcomes and methods for assessing food intake in maritime environments, which analysed 26 studies from an initial total of 4,449 identified references, systematically confirming that access to meat, processed meats, eggs, frozen and tinned foods, sugary drinks, alcohol and fatty or salty products is high on board, whilst the consumption of fruit, vegetables, dairy products and cereals falls below recommended levels (Baygi et al., 2021). These dietary findings form part of a broader occupational context of risks and stress factors characteristic of the maritime profession - prolonged separation from family, social isolation, a heavy workload and environmental stressors specific to life on board - which may interact with dietary habits and exacerbate the cardiometabolic risk already described (Slišković and Penezić, 2015; Oldenburg, Baur and Schlaich, 2010). In response to this situation, research has begun into health promotion interventions based on mobile applications tailored to the specific characteristics of the maritime environment (Arslan et al., 2023) and specific nutritional improvement programmes developed from a joint perspective involving crews and ship's cooks (Neumann et al., 2024).

8. Conclusions.

The history of food on board can, in short, be seen as a series of epidemiological transitions that reflect both advances in scientific knowledge and the technological and organisational limitations of each era. From scurvy and beriberi in the Age of Sail - diseases that literally cost millions of lives before their dietary causes were understood and accepted by the medical community - through to the surprising rediscovery of these very same vitamin deficiencies during polar exploration in the early 20th century, to the very contemporary infectious and toxic outbreaks - typhoid fever caused by corroded water tanks, norovirus on large cruise ships, ciguatera from recreational fishing in tropical waters-which demonstrate that water and food contamination on board remains a pressing threat despite the significant regulatory advances embodied in HACCP and the MLC 2006 Convention.

At the same time, and in a less intuitive way, 21st-century maritime nutrition faces a challenge that is, in a sense, the opposite of the historical one: not the widespread calorie deficiency that characterised the centuries of sailing, but chronic calorie excess-with its associated obesity and metabolic syndrome - combined, paradoxically, with specific micronutrient deficiencies that persist despite the general abundance of food, with

vitamin D being the best-documented example of this seemingly contradictory coexistence. This picture suggests that public health and occupational wellbeing policy on board must necessarily evolve from the historical model centred on the prevention of acute deficiency-the paradigm that prevailed from Lind to Takaki-towards a comprehensive, culturally sensitive and sustainable model for managing the diets of increasingly multinational crews during prolonged voyages, without, however, neglecting active epidemiological surveillance of infectious and toxic risks which, as demonstrated by the most recent cases reviewed in this article, are far from having been eradicated..

References.

Arslan, L. C., Dengler, D., Belz, L., Neumann, F. A., Zyriax, B.-C., Harth, V., & Oldenburg, M. (2023). Exploration of seafarers' mobile proficiency as a prerequisite for possible health app-based health promotion on board. *INQUIRY, 60*, 00469580231206264. https://doi.org/10.1177/00469580231206264.

Baron, J. H. (2009). Sailors' scurvy before and after James Lind-A reassessment. *Nutrition Reviews, 67*(6), 315–332. https://doi.org/10.1111/j.1753-4887.2009.00205.x.

Baxby, D. (1997). Lind's clinical trial and the control of scurvy. *Journal of the Royal Society of Medicine, 90*(9), 526–527. https://doi.org/10.1177/014107689709000926.

Baygi, F., Mohammadi-Nasrabadi, F., Zyriax, B.-C., Jensen, O. C., Bygvraa, D. A., Oldenburg, M., & Nielsen, J. B. (2021). Global overview of dietary outcomes and dietary intake assessment methods in maritime settings: A systematic review. *BMC Public Health, 21*, 1579. https://doi.org/10.1186/s12889-021-11593-z.

Capunzo, M., Cavallo, P., Boccia, G., Brunetti, L., Buonomo, R., & Mazza, G. (2005). Food hygiene on merchant ships: The importance of food handlers' training. *Food Control, 16*(2), 183–188. https://doi.org/10.1016/j.foodcont.2004.01.010.

Guly, H. R. (2012). 'Polar anaemia': Cardiac failure during the heroic age of Antarctic exploration. *Polar Record, 48*(2), 157–164. https://doi.org/10.1017/S0032247411000222.

Guly, H. R. (2013). The understanding of scurvy during the heroic age of Antarctic exploration. *Polar Record, 49*(1), 26–32. https://doi.org/10.1017/S0032247411000428.

Hayes, P. W., Matthews, J. A., Allaire, B., & Holm, P. (2019). European naval diets in the sixteenth century: A quantitative method for comparative and nutritional analysis. *Historical Methods: A Journal of Quantitative and Interdisciplinary History, 52*(4), 195–212. https://doi.org/10.1080/01615440.2019.1580170.

Henriques, M., Rodrigues, D., Viegas, S., Serranheira, F., & Sacadura-Leite, E. (2023). Vitamin D status in active duty Navy military personnel: A systematic review. *Occupational and Environmental Medicine, 80*(6), 353–360. https://doi.org/10.1136/oemed-2022-108710.

Hughes, R. E. (1975). James Lind and the cure of scurvy: An experimental approach. *Medical History, 19*(4), 342–351. https://doi.org/10.1017/S0025727300020469.

Isakbaeva, E. T., Widdowson, M.-A., Beard, R. S., Bulens, S. N., Mullins, J., Monroe, S. S., Bresee, J., Sassano, P., Cramer, E. H., & Glass, R. I. (2005). Norovirus transmission on cruise ship. *Emerging Infectious Diseases, 11*(1), 154–157. https://doi.org/10.3201/eid1101.040434.

Itokawa, Y. (1976). Kanehiro Takaki (1849–1920): A biographical sketch. *The Journal of Nutrition, 106*(5), 581–588. https://doi.org/10.1093/jn/106.5.581.

Khan, A. S., Moe, C. L., Glass, R. I., Monroe, S. S., Estes, M. K., & Chapman, L. E. (1994). Norwalk virus-associated gastroenteritis traced to ice consumption aboard a cruise ship in Hawaii: Comparison and application of molecular method-based assays. *Journal of Clinical Microbiology, 32*(2), 318–322. https://doi.org/10.1128/JCM.32.2.318-322.1994.

Morrow, J. D., Margolies, G. R., Rowland, J., & Roberts, L. J., II. (1991). Evidence that histamine is the causative toxin of scombroid-fish poisoning. *The New England Journal of Medicine, 324*(11), 716–720. https://doi.org/10.1056/NEJM199103143241102.

Mott, L. V. (2018). Feeding Neptune: Food and nutrition in the Catalan-Aragonese fleet, 1282–1302. *International Journal of Maritime History, 30*(1), 131–138. https://doi.org/10.1177/0843871417745510.

Muecke, C., Hamper, L., Skinner, A. L., & Osborne, C. (2015). Ciguatera fish poisoning in an international ship crew in Saint John, Canada: 2015. *Canada Communicable Disease Report, 41*(11), 285–288. https://doi.org/10.14745/ccdr.v41i11a04.

Neumann, F. A., Belz, L., Dengler, D., Harth, V., Reck, C., Oldenburg, M., & Zyriax, B.-C. (2024). Seafarers' attitudes and chances to improve the nutrition on merchant ships from the crews' and cooks' perspective. *Journal of Occupational Medicine and Toxicology, 19*, 13. https://doi.org/10.1186/s12995-024-00412-x.

Oldenburg, M., Baur, X., & Schlaich, C. (2010). Occupational risks and challenges of seafaring. *Journal of Occupational Health, 52*(5), 249–256. https://doi.org/10.1539/joh.K10004.

Ooms, D., de Vries, A., Koedijk, F. D. H., Generaal, E., Friesema, I. H. M., Rouvroye, M., van Lelyveld, S. F. L., van den Beld, M. J. C., Notermans, D. W., van Schelven, P., van den Brink, J. F. H., Hartog, T., Veenstra, T., Slavenburg, S., Sinnige, J. C., & Ruijs, W. L. M. (2024). Large outbreak of typhoid fever on a river cruise ship used as accommodation for asylum seekers, the Netherlands, 2022. *Eurosurveillance, 29*(5), 2300211. https://doi.org/10.2807/1560-7917.ES.2024.29.5.2300211.

Poon-King, C. M., Chen, A., & Poon-King, T. (2004). Ciguatera fish poisoning in industrial ship crewmembers: A retrospective study in a seaport general practice in Trinidad and Tobago. *West Indian Medical Journal, 53*(4), 220–226.

Rebato, N., de los Reyes, V. C., Sucaldito, M. N., Gallardo, F. D., Ballera, J. E., Asuncion, I., & Hartigan-Go, K. (2018). Consumption of barracuda in the Caribbean Sea linked to ciguatera fish poisoning among Filipino seafarers. *Western Pacific Surveillance and Response Journal, 9*(4), 12–15. https://doi.org/10.5365/wpsar.2016.7.2.004.

Russo, A., Mulić, R., Kolčić, I., Maleš, M., Jerončić Tomić, I., & Pezelj, L. (2023). Longitudinal study on the effect of on-

board service on seafarers' health statuses. *International Journal of Environmental Research and Public Health, 20*(5), 4497. https://doi.org/10.3390/ijerph20054497.

Schlaich, C., Hagelstein, J.-G., Burchard, G.-D., & Schmiedel, S. (2012). Outbreak of ciguatera fish poisoning on a cargo ship in the port of Hamburg. *Journal of Travel Medicine, 19*(4), 238–242. https://doi.org/10.1111/j.1708-8305.2012.00619.x.

Slišković, A., & Penezić, Z. (2015). Occupational stressors, risks and health in the seafaring population. *Review of Psychology, 22*(1–2), 29–40.

Verhoef, L., Depoortere, E., Boxman, I., Duizer, E., van Duynhoven, Y., Harris, J., Johnsen, C., Kroneman, A., Le Guyader, S., Lim, W., Maunula, L., Meldal, H., Ratcliff, R., Reuter, G., Schreier, E., Siebenga, J., Vainio, K., Varela, C., Vennema, H., & Koopmans, M. (2008). Emergence of new norovirus variants on spring cruise ships and prediction of winter epidemics. *Emerging Infectious Diseases, 14*(2), 238–243. https://doi.org/-10.3201/eid1402.061567.

Verhoef, L., Kouyos, R. D., Vennema, H., Kroneman, A., Siebenga, J., van Pelt, W., & Koopmans, M. (2011). An integrated approach to identifying international foodborne norovirus outbreaks. *Emerging Infectious Diseases, 17*(3), 412 – 418. https://doi.org/10.3201/eid1703.100979.

Vivancos, R., Keenan, A., Sopwith, W., Smith, K., Quigley, C., Mutton, K., Dardamissis, E., Nichols, G., Harris, J., Gallimore, C., Verhoef, L., Syed, Q., & Reid, J. (2010). Norovirus outbreak in a cruise ship sailing around the British Isles: Investigation and multi-agency management of an international outbreak. *Journal of Infection, 60*(6), 478–485. https://doi.org/10-.1016/j.jinf.2010.03.018.

von Katzler, R., Zyriax, B.-C., Jagemann, B., Westenhoefer, J., Jensen, H. J., Harth, V., & Oldenburg, M. (2019). Lifestyle behaviour and prevalence of cardiovascular risk factors-A pilot study comparing Kiribati and European seafarers. *BMC Public Health, 19*, 855. https://doi.org/10.1186/s12889-019-7186-2.