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To link to this article: https://doi.org/10.1080/03468755.2018.1479914

Published online: 13 Jun 2018.
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In this article the author analyses how scientific ideas about anthropogenic nutrient load in the sea changed in Finland and Sweden from the 1950s to the early 1970s. In the 1950s, marine scientists considered an artificial increase in the volume of nutrients beneficial to the oligotrophic Baltic Sea. This conception was challenged in the late 1960s by the Swedish hydrologist Stig Fonselius. He theorized that nutrient discharge from municipalities and factories had set in motion a vicious cycle: the growth in biomass consumed oxygen in the depths of the sea, which in turn fed the accumulation of nutrients in the productive surface layer. This process led to eutrophication, which is now widely considered to be the most serious environmental problem in the Baltic Sea. However, Finnish marine scientists divided into two camps vis-à-vis Fonselius’ theory of anthropogenic eutrophication. So-called alarmist scientists argued that the Baltic Sea was a victim of industrial development and demanded stricter wastewater treatment. Conversely, eutrophication sceptics insisted that the observed environmental changes originated from natural cycles. The author argues that this division stemmed from the different perceptions of the scientists in regard to the role of the marine environment for the benefit of human society.

Keywords environmental history, Baltic Sea, Finland, Sweden, eutrophication, marine science, nutrient pollution

Introduction

There is nothing unnatural or intrinsically anthropogenic in cyanobacterial blooms. In the Baltic Sea, cyanobacteria proliferate every year during the high summer, when they exploit free nutrients in the seawater. They sometimes reproduce in great quantity in aquatic environments, which can turn the water into a slimy, green mush. They have
probably done this for thousands of years. Human action, however, has created ideal conditions for cyanobacteria to surge by supplying seawater with increased nutrient loads from the land and the air. The Baltic Sea is a semi-enclosed and shallow sea with a small water mass, in comparison to the great oceans, which makes it vulnerable to hydrographical changes based on nutrient discharges.

Cyanobacterial blooms have been the most well-known and notorious indicator for the public in regard to anthropogenic eutrophication in the Baltic Sea. Besides making the water repugnant, the problem is exacerbated by the fact that some species of cyanobacteria are toxic and harmful for humans and animals alike. Today, eutrophication, or the increased growth of biomass, is widely considered to be the most serious environmental problem in the Baltic Sea. The visible effects of eutrophication became obvious in the 1980s, when cyanobacterial blooms proliferated and consequently fishing nets and water-line constructions became noticeably more covered in greenish slime.

Both Sweden and Finland have a long Baltic Sea coastline, with the most populous cities located along the shore. Most of the nutrient discharges into the Baltic Sea also came from Sweden and Finland (as well as from the Soviet Union). In addition, the effects of anthropogenic nutrients were felt most severely in the northern Baltic Sea, where water exchange with the Atlantic Ocean was much more limited than nearer to the Danish Straits. These reasons partly explain why the scientific discussion about the problem first gained ground in Sweden and Finland in the late 1960s. The main focus of the article is on Finland, where scientists ended up occupying conflicting positions regarding the effects of nutrients. However, it should be noted that scientific theory about nutrients as a possible cause of eutrophication was formulated and first endorsed by Swedish scientists. Hydrographical findings in Sweden will therefore provide a necessary context and background for understanding the Finnish scientific context.

The debate over the impact of nutrients in the marine environment arose during the first wave of the global environmental crisis. In the early 1960s, Rachel Carson published her remarkably influential book *Silent Spring*, in which she warned against the incautious use of pesticides. The book galvanized the environmental movement, particularly in the United States, and helped to instigate extensive studies on environmental pollution throughout the Western world, including Sweden and Finland. At the turn of the 1970s, discussion regarding the human impact on the environment extended to include a wide range of topics, from resource scarcity and population explosion to the pollution of the land, water and air. This was also the first time in history that scientists began to seriously worry about the negative impact of humans on marine ecosystems.

However, there were no prior experiences on our planet of an entire sea becoming polluted by anthropogenic nutrient load. Thus, the case of the Baltic Sea also has global importance at a present time when the marine ecosystems around the world have become threatened by climate change, overfishing and pollution. In the 1970s, the Baltic Sea was already being used as an example by the governments of Mediterranean countries when they were seeking to build a system to prevent their sea from being polluted.

When the new theory regarding the harmful effects of nutrients was introduced into Finland, Finnish marine scientists divided into two conflicting schools of thought. In this article these schools will be called alarmists and sceptics. The same concepts have been widely used by scientists representing opposite views in the debate over the
human impact on climate change during the early 21st century. This is no coincidence. Similarly to the debate over climate change, the arguments for and against more pronounced action to protect the Baltic Sea originated from opposing views about the role of humans in environmental change.

In their overview of Finnish scientific ideas about nutrients during the 20th century, Simo Laakkonen and Antti Parpola noted the change that took place in the 1960s and early 1970s. By referring to it as a transition from a ‘paradigm of use’ to a ‘paradigm of vulnerability’, they reveal how scientists started to conceive of nutrients as a contaminant in the marine environment. However, in this article it will be shown that the new ideas about nutrients in the seawater were not discovered, let alone accepted, overnight. Far from a straightforward process, the paradigmatic shift required years of basic oceanographic research. Moreover, when new conceptions about nutrients were finally published in scientific reports, they faced fierce criticism from many marine scientists. The ensuing debate lasted for several years and was characterized by conflicting views and the formulation of conflicting scientific theories in order to explain certain indisputable findings.

This is, of course, the way science works. What is interesting, however, is how extra-scientific motives, such as the interest of industry, interfered and sometimes even trumped scientific argumentation vis-à-vis nutrient discharges. The schism between Finnish scientists clearly demonstrates, although many contemporary scientists still find it difficult to admit, how science is not disconnected from a scientist’s subjective worldview and attitudes. It will be argued that scientific discourse on nutrients was warped by deliberate attempts to muddy the line between science and politics. In so doing, this article highlights the scientists’ attitudes towards the environment, which profoundly influenced their work: how they viewed the role of the sea for human societies and how they valued the marine environment.

Environmental issues seem to be prone to this kind of entanglement between science and politics. In a manner similar to the case studied in this article, the scientific discourse on toxic chemicals since the 1960s and, more recently, climate change, for example, have turned into battlefields for scientists sympathetic to the chemical industry and the carbon-intensive energy system, respectively, as well as scientists attuned to political ecology. This article will therefore contribute to the analyses on the dynamics of environmental sciences regarding environmental problems, in which major economic interests are at stake and in which anthropogenic environmental changes threaten the legitimacy of exploiting the natural environment for human purposes.

As environmental historians Jeffrey Bolster and J. Donald Hughes, among others, have pointed out, marine environmental history is a virtually non-existent field of study, with the exception of certain histories of marine fisheries. In regard to the environmental history of the Baltic Sea, the situation is even grimmer. The existing studies concerning environmental changes in the Baltic Sea mainly examine pollution in the urban waters near Baltic cities. In addition, there are some articles by veteran marine scientists, which, while reviewing the development of their own field, demonstrate the emergence of pollution studies from the 1960s onwards. The abovementioned article by Laakkonen and Parpola, although highly cursory in its empirical analysis, is a rare exception in addressing the discussion regarding the impact of nutrients in the open Baltic Sea areas.
By using scientific reports and popular essays by Finnish and Swedish marine scientists, most of which have thus far not been used in scholarly studies, this article will examine the debate surrounding nutrients in the Baltic marine environment in the 1960s and 1970s. It will analyse how scientific conceptions changed and theories were developed, as well as their intellectual roots. At the heart of the debate studied will be the theory on the phosphorus balance in the Baltic Sea, formulated by the Swedish hydrographer Stig H. Fonselius in his tripartite study, *Hydrography of the Baltic Deep Basins*. This theory was and is virtually unknown outside the community of marine scientists. Yet it was a revolutionary approach on the human role in shaping the marine environment, and as such is a fundamental text in the history of marine sciences in the Baltic Sea area and beyond. Indeed, our current understanding of the relationship between land-based nutrients and the Baltic Sea marine environment is greatly indebted to Fonselius and his study.

**Beneficial nutrients**

In his oft-cited ‘1950s syndrome’ theorem, the Swiss environmental historian Christian Pfister has shown that almost all indices related to anthropogenic environmental change and the consumption of natural resources accelerated in the 1950s.\[^9\] Indeed, this was also the case vis-à-vis the nutrient loads present in the Baltic Sea. In Finland, for example, 3.7 times more water was pumped into the sewage system in 1969 than in 1950. The increase in nutrient discharge was probably even higher, since detergents containing phosphates became common during the same period. Most municipal and industrial wastewater from Baltic Sea countries flowed into waterways through rudimentary filters or without any purification. This was also a period when farms began to replace manure with synthetic fertilizers. Often farmers used many times more fertilizer than instructed by the producers in the hope of increasing their crop yield. Nutrients were also spread in forests. In the Finnish forestry industry, clear-cutting replaced traditional light selection felling. Consequently, the ground began to suffer increased water erosion and nutrients were washed into the waterways. Furthermore, marshes became parched, with similar consequences. Combustion engines became ubiquitous, which increased industrial production and helped human beings to move from place to place, but also released nitrogen into the air. Some of this gas found its way into the sea via precipitation.\[^10\] Taken together, it has been calculated that the nutrient load into the Baltic Sea in the 20th century increased by as much as eightfold, with the lion’s share of this growth occurring between 1950 and 1980.\[^11\]

Nutrient accumulation in open sea areas was widely considered as being beneficial to the marine environment and its human users in the 1950s, although it was already known to be a considerable problem in inland lake areas and coastal regions near cities.\[^12\] The Baltic Sea is an oligotrophic sea, which means that its biological productivity is limited due to a lack of nutrients. Thus, the growth of nutrient content, the logic went, would increase phytoplankton production and consequently fisheries. This was by no means an anomalous concept only held by marine scientists around the Baltic Sea. In her study on the history of the International Council for the Exploration of the Sea, Helen Rozwadowski tells us that fishery science all over the industrial world moved away from a traditional hunting model, which focused merely on finding
the best possible catch, to a cultivation model. This latter approach entailed scientists actively seeking to produce methods that would boost fish stocks. A central element of the new cultivation model was to increase nutrient content in barren sea areas. The detonation of nuclear devices in the sea was among the most radical suggestions for triggering a welling of nutrients to the surface water and thus bringing about an improvement in the sea’s productivity.\textsuperscript{13}

The fact that the Baltic Sea was largely akin to a large lake did not prevent Finnish scientists from proposing similar goals, albeit with less extreme methods. They advocated a similar cultivation model and even used argumentation that was analogous to farming techniques. In 1961, Ilmo Hela, the head of the Finnish Institute of Marine Research, pondered how artificial fertilization could be used in the Baltic Sea and other ‘unfavourable sea areas [. . .] if one can guarantee that fertilizers stay in one’s own fields and invigorate one’s own fisheries’.\textsuperscript{14} In so doing, Hela joined the timely discussion in the 1950s and 1960s among Western oceanographers regarding the social applicability of marine sciences. The improvement of fisheries was not only targeted to ensure the strengthening of the national economy; scientists also saw themselves as being on the front line in the fight against poverty and hunger. For them, the sea provided a largely untapped source of food for a rapidly growing global population.\textsuperscript{15}

In a similar vein, Aarno Voipio, a leading oceanographer in Finland and later Hela’s successor as the director of the Finnish Institute of Marine Research, went even further by pointing to the marked benefits of wastewater:

The dirt that comes with domestic wastewater degrades swiftly, when aptly diluted, and, at the same time, releases useful nutrients, such as phosphorus and nitrogen compounds [. . .] Perhaps the greatest indirect advantage that marine science can bring about will in one day be the knowledge of the best ways to increase the basic nutrients in the sea, that is, how we can fertilize the sea. For a farmer does not just fertilize ditches and the edges of fields.\textsuperscript{16}

Up to this point Baltic Sea countries had only ‘fertilized’ coastal waters, the ditches and edges of their watery fields, with the result that water had become eutrophic in many places. Voipio clearly indicated that nutrient-rich wastewater should be conveyed into the open sea in the future, where it would be diluted and could be used within marine food chains. In short, it could potentially benefit fisheries. This required careful scientific planning about where the nutrients should be discharged and in what form and ratio.\textsuperscript{17} The link to contemporary odumian ecology, with its objective to exploit ecosystems more efficiently by measuring their energy balances, was clear.\textsuperscript{18} The arguments advanced by both Hela and Voipio indicate an unwavering belief in the ability of science to accurately quantify the world for the benefit of human societies. As Hela states: ‘Science was moving to another era, when [predicting fish catches] is far closer to become reality than ever before.’\textsuperscript{19} Elsewhere, he boldly claimed that ‘the eventual objective of [marine sciences] is to find out how much the Baltic Sea produces organic matter in a given year.’\textsuperscript{20}

Voipio’s implicit proposal of conveying wastewater into the open sea was to be put to the test in the late 1960s. Alarmed by the deterioration of coastal waters, several coastal cities in Finland, which had previously discharged their waste into inner bays and archipelagos, planned to build longer pipes, through which wastewater would be
funneled to the edge of the open sea. Espoo, for example, which was the fourth largest city in Finland at the time, planned only to purify its wastewater by mechanical means, since a better water exchange in the open sea area would guarantee that no harm was inflicted on the environment or on human comfort. The most prestigious Finnish marine scientists and their host organization, the Finnish Institute of Marine Research, did not see any problems with these plans. 21 Retrospectively, it is not difficult to see the similarity between these plans and the 19th-century practice of building taller chimneys for factories, which it was believed would help to disperse the smoke away from cities, but which in reality regionalized this local problem. 22 Longer wastewater pipes would have eased the stress on coastal waters, but would have exacerbated the accumulation of nutrients in the Baltic Sea as a whole.

These plans, alongside the willingness of scientists to back them, reveal how the sea was not considered as a unified whole. Instead, coastal waters and the open sea belonged to different ontological realms, with the former being a space of life and recreation for humans, while the latter was merely a commodifiable resource space. The open sea provided humans with a trade route, fish and minerals. A number of marine scientists prophesied that in the future the sea would provide another important resource, which human society would be able to utilize. With this in mind, Voipio states: ‘The capacity of the sea to accept waste may become an extremely precious capital.’ 23 Industrial and urban development inevitably meant more waste. Voipio and his likeminded fellow scientists saw this as an opportunity to aid society and thus widen the social applicability of their work.

The vicious circle theory

The prevailing theory of hydrography in the Baltic Sea in the 1960s assumed that the nutrient content in the productive near-surface layer remained in a state of constant balance. When phosphorus accumulated in the productive layer, as either a result of riverine run-off or influx from the Atlantic Ocean, it fleetingly increased the primary biological production in the marine environment. However, after the production peak, phosphorus sank to the bottom and was finally buried into the sediment. It was a known fact that water near the bottom of the sea contained a far greater quantity of nutrients than the surface water. However, the stratification of the water column prevented nutrients from feeding primary production. 24 According to contemporary understanding, there was no correlation between the open sea and freshwater ecosystems or coastal waters, due to stratification and the sheer size of the water mass in the sea. 25 The sea was perceived as an eternally static system, an immense mass of water, which human chemistry could never alter. 26 The separation of the open sea from other aquatic environments was dressed up as science. However, it also echoed the cultural construction of the sea during the modern capitalist era of the 19th century and early 20th century, according to which inland lakes and coastal sea areas belonged to the human environment, while the open sea was a great void between human civilizations. 27

A few times every century the Baltic Sea receives a giant influx of ocean water through the Danish Straits. One of these massive influxes occurred in 1951, after which Swedish marine scientists launched a lengthy research programme in order to study the influence of saline and nutrient-rich ocean water on the chemistry of the sea’s
deep basins. One participant in the Swedish research programme was Stig H. Fonselius, a doctoral student at the University of Gothenburg.

At the very beginning of his research, Fonselius formulated his study against the prevailing theory of the incompatibility of marine and lake systems. He took anthropogenic changes in freshwater ecosystems as his starting point. Furthermore, contrary to his contemporaries, who had studied nutrients in the Baltic Sea as ahistorical parameters (a logical premise for a research subject that was considered unchangeable), Fonselius historicized the sea. He focused on the long-term changes in the hydrography of the Baltic Sea by incorporating findings from previous decades into his research.

The two most important plant nutrients in aquatic ecosystems are phosphorus and nitrogen. In the 1960s, it was thought that phosphorus was the main limiting factor in the Baltic ecosystem, thus regulating the degree of biological production. Fonselius’ principal findings also concerned phosphorus. In particular, he examined the dynamics of phosphorus in the seawater and its relation to oxygen content on the sea floor. The fact that the water at the bottom of the sea contained little or no oxygen had been known for years, but it had been considered as a natural phenomenon that had no implications on humans. Fonselius undermined this perception in his three-volume treatise, entitled *Hydrography of the Baltic Deep Basins I–III* (published in 1962, 1967 and 1969 respectively). The study was targeted at his colleagues and for this reason it has remained virtually unknown to anyone outside the community of oceanographers. His theory of phosphorus accumulation, nonetheless, became the bedrock stance for Baltic marine scientists, who mediated his main arguments to a wider public, thereby changing the way ordinary people perceived the sea.

In sum, Fonselius made his first crucial discovery that would lead to his theory while working on the first part of his tripartite study: in anoxic circumstances the accumulation of phosphorus in the depths of the sea was much greater than in any other well-studied marine environment in the world. Much of his later work – and the basis of his whole theory – concentrated on explaining this anomaly. The traditional explanation suggested that phosphorus was transferred to water from decaying biomass. Fonselius calculated that this was insufficient in explaining why so much phosphorus was found in the depths of the sea, since the decaying process would have required an enormous amount of oxygen. Yet, there was almost none. The only possibility, Fonselius reasoned, was that some amount of phosphates are released from the sediments. The theory about the release of oxygen from sediments was not completely new. Since the 1950s, some scientists had studied whether this phenomenon occurred in some other sea areas, as well as in laboratories, though never in the Baltic Sea. However, no correlation between the two had been found in the marine environment. Laboratory experiments, in contrast, had indicated that the release of phosphorus depended on the pH level in the water. Fonselius realized that this was also the case with the Baltic Sea. The key factor was hydrogen sulphide, which was formed in anoxic conditions and which reduced the pH level in water. Hence the disparity between the Baltic Sea and other sea areas and the release of phosphorus.

Comparisons between contemporary values and historical data revealed to Fonselius that oxygen content in the depths of the sea had starkly diminished throughout the century. Moreover, contrary to previous thinking, plenty of phosphorus welled to the productive surface layer, especially in wintertime. His prediction was dire: 'If this development continues in the Baltic deep water, the whole water
mass below the halocline will soon turn into a lifeless “oceanic desert” such as is found in the Black Sea.\textsuperscript{35} We will return to the comparison between the Baltic Sea and Black Sea later. More important at this point is his second conclusion: ‘It is quite obvious that the enormous load of urban and industrial wastewater discharge into the Baltic has enforced oxygen utilisation.’\textsuperscript{36} In other words, there was a positive feedback mechanism between phosphorus and oxygen content. Wastewater increased the production of biomass. As biomass decayed, it consumed a vast quantity of oxygen up to anoxic levels. In anoxic conditions, phosphorus was released from sediments to the body of water, from where it also welled up to the productive layer. More phosphorus meant more biological production and thus more decaying organic matter. The vicious circle of oxygen deficit and eutrophication had been set in place.

\textbf{Theories in conflict}

Even before Fonselius’ third volume was published, there had been discussion in both Sweden and Finland regarding how human waste might be aggravating the oxygen deficit in the depths of the Baltic. At this point, no one referred to anthropogenic eutrophication. When Fonselius presented his theory in full, many leading scientists in Sweden aligned themselves with him. Fonselius approximated that wastewater was only a partial reason for the deoxygenation tendency, while increased salinization from natural causes was potentially the principal factor.\textsuperscript{37} Bernd Dybern, a distinguished marine scientist from the Swedish Institute of Marine Research, soon became convinced that it was the other way round: the rise of salinity may have added to the tendency, but the real culprits were humans and their wastewater.\textsuperscript{38} Lennart Hannerz, a research director from the Swedish Environmental Protection Agency, prophesied that without immediate action, the outcome would lead to eutrophication, that is, the ‘unpleasant dyeing of water, prolific algae growth in rocks and constructions, the encroachment of reeds and other phenomena, that people do not tolerate in their summery milieu’.

In Finland the reception was quite different. Instead of unanimously praising the new theory for resolving the conundrum of diminishing oxygen, the Finnish community of marine scientists divided into opposing parties. Some scientists, most of whom belonged to the younger generation, expressed real concern over the marine environment. Others responded to Fonselius’ theory with suspicion and resistance, among them the leading figures of Finnish marine science, such as the above-mentioned Ilmo Hela and Aarno Voipio. The critical evaluation of novel theses is, of course, an elemental part of the philosophy of science. However, scientific argumentation only partially explains this dispute.

In 1968, Hans Luther, an esteemed professor of botany at the University of Helsinki and the head of the Tvärminne Zoological Station, voiced alarmist fears when he denounced the notion of using the sea as dumping place for human waste. Instead, he demanded that the best possible purification methods should be introduced in every municipality and in all industrial facilities. He saw that plans to build longer pipes for wastewater were nothing but acts of stupidity:

On the outer edge of the archipelago – and in open shores – the Baltic Sea opens up before us. We feel like we have arrived at an infinite and boundless sea. This is
our sea, and as long as we convey wastewater, so problematic in inland areas, through pipes and tunnels a little farther from the shore, there they will handily disappear . . . it is as if no one sees beyond his own shore.  

In reality, he predicted that the consequence of such short-sighted operations would be the ever increasing degradation of the quality of the sea’s surface water.  

Soon afterwards, a group of young marine scientists began to speak out against unpurified wastewater discharges. Åke Niemi and Lauri Pesonen proclaimed how ‘the nutrient load had grown to such an extent that the open sea was on its way to eutrophication.’ In another article, Niemi and Julius Lassig, referring specifically to the Baltic Sea, hoped that humans would ‘become wiser and could learn from the mistakes made by the current generation and avoid repeating them in the future’.  

Pauli Bagge stated that the Baltic Sea was already ‘polluted in different ways and that there [were] signs of a continuous deterioration of the situation’. Paavo Tulkki, while separating himself from environmentalists, accused technocrats and economic circles of propagating ‘propaganda, according to which the need for the protection of the sea was exaggerated, and instead, the self-purification capacity of the sea could be exploited to a much greater extent’.  

Tulkki did not mention any names, but rather aimed his accusations at certain general social forces. However, he also highlighted how these propagandists had compared the Baltic Sea to the Black Sea, in which the depths were permanently in an anoxic state without inflicting harm on human beings. It is highly unlikely that anyone from the ‘economic elite’ would have known the specifics about Black Sea hydrography. Aarno Voipio, on the contrary, had made exactly the same claims. Therefore, this can be read as almost an insult to Aarno Voipio. Voipio, though, was not the only person who felt confident that the sea had the self-purification capacity to absorb all human waste. Ilmo Hela stated that eutrophication would probably always only be a problem in coastal and archipelagic environments. According to Folke Koroleff, another prominent marine scientist, ‘it [was] hard to believe . . . that wastewater discharges into the Baltic Sea would significantly affect the birth of stagnant conditions,’ by which he meant the oxygen deficit.  

In terms of persistence and passion, Aarno Voipio best exemplified a sceptical outlook. At this time he had been nominated to be the leader of environmental studies at the Finnish Institute of Marine Research. The Canadian political scientist Thomas Homer-Dixon has suggested that denial of environmental problems often proceeds through three stages. In the first phase, the existence of a problem is refuted, hence the name ‘existential denial’ in Homer-Dixon’s vocabulary. In the next stage, which he calls ‘consequential denial’, the problem is acknowledged, but its implications are downplayed. This legitimizes inaction. Finally, in the fatalistic stage, when the evidence becomes insurmountable, action is avoided by claiming that nothing can be done. The time was not ripe for ‘fatalistic denial’ in the early 1970s, since eutrophication was merely a prediction. In Voipio’s stance, however, we find the first two stages of denial, albeit often simultaneously. On numerous occasions he contended that there was no problem, since he argued that the oxygen deficit was purely of natural origin. According to him, there had always been periods of stagnation in the depths of the sea, and this will always be so. The sea follows its own rhythm, which is regulated by wind patterns and the currents of the Atlantic Ocean. In Voipio’s
opinion, the current phase of stagnation would be a passing moment, and the aquatic environment would be healed with the next pulse of saline water from the Atlantic. For several years he also opposed Fonselius’ claim about the release of oxygen from sediments. As regards consequential denial, he did not see anything to be worried about, whilst admitting that the current stagnant period was exceptionally severe in terms of space and time. Anoxic conditions and the subsequent formation of hydrogen sulfide affected organisms on the sea floor. However, these organisms would bounce back after the next pulse of saline and oxygen-rich water. Thus, oxygen deficit would have no effect on water at the surface layer. He compared the situation to years of crop failures in agriculture, which sometimes lasted for several years but always recuperated. In sum, Voipio felt that there was no problem, and even if there were, it was not having any impact on humans.

By 1972, with evidence mounting, Voipio had somewhat changed his mind and accepted that phosphorus was indeed released from the sediments. However, instead of accepting Fonselius’ theory, he came up with his own, which continued to deny the validity of the feedback mechanism between oxygen deficit and eutrophication. This refined attempt to downplay the human impact on the Baltic Sea was based on the notion of stratified sediments. He argued that the release of oxygen only occurred from the thin top layer of sediment, which formed during the period of stagnation. Another layer was under this top strata, which was formed when water contained rich supplies of oxygen. This plentiful supply of oxygen prevented the release of phosphorus from deeper layers. Thus, Voipio could maintain that the huge phosphorus storage found in the depths of the Baltic must have developed through natural forces. More importantly, Voipio posited that wastewater did not pose risks, since the amount of phosphorus released would be moderate and its effects insignificant. In this respect, Voipio’s theory stood in stark contrast to that of Fonselius, who had specifically argued that phosphorus remained in a suitable form for release, due to periodic fluctuation between oxygen-rich and anoxic phases. Therefore, the Baltic Sea was not comparable to the Black Sea, as Voipio suggested. In the Black Sea, where anoxic conditions were permanent, the release did not take place.

Years passed, but Voipio found it hard to change his stance. In the late 1970s, he was forced to admit that the levels of phosphorus had increased in open sea areas. Consequently, he started to speak in terms of vigilance with regard to the future development of the quality of the sea water in the Baltic. Furthermore, he came to terms with the need for more efficient wastewater purification. Yet he continued to downplay the risk of anthropogenic eutrophication and assured the public that there was no need to be worried about the fate of open sea areas. He also cast doubt on the role of humans. Instead, he continued to point to natural long-term fluctuations as the most likely reason to explain the oxygen deficit in the Baltic’s depths. His thinking still relied on a belief in the sedimentation of nutrients, without mentioning the release of phosphorus in anoxic conditions. He correctly presented the notion that anthropogenic eutrophication was still disputed among scientists, but falsely claimed that the voices of alarm were marginal and that the majority of Baltic marine scientists argued that the human role in the Baltic’s plight was exaggerated. In short, he supported purification, but gave little scientific reason for this stance and thus rather encouraged inaction.

The tide had turned by the late 1970s, as factories and municipalities in Finland and elsewhere in the Baltic Sea area were already building modern wastewater
treatment plants. Yet, Voipio’s denialism was still far from irrelevant in the Finnish context. After Ilmo Hela’s death in 1975, he was a leading figure in Finnish marine science, a position in which he remained an influential environmental decision-maker. Had he and fellow-minded scientists expressed more concern for the Baltic Sea, marine issues might have become a top priority in Finnish environmental politics, which had briefly occurred in the early 1970s. This would have possibly meant more resources for research, as well as more innovations vis-à-vis the protection of the marine environment. Instead, the Baltic Sea slid away from the spotlight until the late 1980s and 1990s, when massive cyanobacterial blooms once again energized researchers and brought nutrient pollution to the public’s attention. Only then were the claims about the strictly natural origins of the oxygen deficit and cyanobacterial blooms finally buried.

In between two worlds
Since the divide between marine scientists, in the case of nutrient load, largely followed neat generational lines, one cannot help but recognize a confluence with Karl Mannheim’s theory of generations and his formulation of generational locations. In his 1923 essay *The Problem of Generations*, Mannerheim postulated that particular geographical and cultural locations produced generations through formative experiences that were shared by the members of the same age group. These shared experiences shaped particular modes of behaviour, feelings and thoughts. Underpinning statements by alarmist scientists stood the firm belief in the need for a change in the trajectories of societal development. This younger generation of marine scientists had come of age during the Cold War and the ever present threat of all-out nuclear catastrophe. When they graduated from universities in the 1960s and started their professional careers, in Finland, as elsewhere in the Western world, an unprecedented amount of literature on environmental threats was published. Moreover, societal discussion was dominated by concerns over the global environmental crisis. The degradation of the Baltic Sea was one among many manifestations of this global crisis. For the alarmists, progress not only entailed economic growth, but also the quality of the human environment. Emblematic to their stance was the fact that not once in dozens of articles did they refer to the economic value of the sea or the economic cost of its protection. There was no uncertainty in their minds vis-à-vis how human action had degraded the Baltic Sea. Now it was up to society to guarantee that human mistakes be rectified, no matter what the economic cost. In short, they embodied the shift in values that emphasized the fulfilment of post-material needs, as famously laid out by Ronald Inglehart.

As for Hans Luther, who was the only senior scientist in the alarmist camp, he was a long-time member of the Finnish Association for Nature Conservation (FANC), which was by far the largest and most influential environmental organization in Finland. His affiliation to the FANC doubtless made him inclined to share its ideological commitment to restricting human impact on the environment. The scientific ideas of the alarmists regarding nutrients were heavily influenced by the discourse of environmental crisis. Therefore, they were more prepared than their older colleagues to accept a theory that pointed to the negative effects of modern industrial society on the marine environment.
It is worth stressing, however, that the older generation of marine scientists were not all entirely hostile to protecting the environment. Finnish marine scientists were unanimous, for example, in viewing toxic chemicals as a serious threat to marine life and human health. The case of nutrient load and its entanglements with the oxygen deficit and eutrophication, however, was different to toxic chemicals in two decisive ways. First, by the early 1970s anthropogenic eutrophication was merely a scientific theory, without real-life evidence. Yet, the occurrence of toxic chemicals and their effect on birds and fish was a proven fact. Second, unlike toxic chemicals, nutrient discharges had until the recent past been perceived as being beneficial to marine life. This standpoint had relied on the exceptionality and otherness of the sea, to which regularities in terrestrial ecosystems did not apply. Freshwater ecosystems could be spoiled by excess nutrients, but not the unchangeable sea.

This notion of the otherness of the nature of the sea persisted, although in a modified and less bold form. No one spoke anymore about fertilizing the sea. Yet, exploitation was given a new face, which relied on the immensity of the sea. The maritime waters now represented an economic asset: a place in which society could dump its wastewater, as nutrient sceptics in their writings often emphasized. Although acknowledging the need for caution, Hela saw the ability of the sea to absorb human waste as one of its main purposes for society. Voipio spoke frankly about the necessity of economic development, which impelled ‘every company, in the pressure of tightening competition, to keep watch on their profits’. Therefore, they must retain the option of discharging waste into the sea. Instead of repeating the cry for ‘radical measures “everything must be purified”’, he asked for more time for scientists to properly study the sea, before any protective actions were implemented.

The members of the older generation of marine scientists were born at a time when Finland was still a developing country. They had experienced the war economy and they entered their profession during the scarcity of the age of restoration (both of which their Swedish colleagues had not had to endure). It is also worth noting that their employee, the Finnish Institute of Marine Research, functioned under the tutelage of the Ministry of Trade and Industry. Thus, the older generation of scientists was far from alone in placing more value on economic development than on costly environmental protection. As responsible leaders in the institute, they also fulfilled their official duties by promoting the national economy, whether by means of improving fisheries, producing knowledge for shipping companies or by helping cities and factories to get rid of their waste. They embodied a worldview that conceived of the open sea as a great void: an anti-civilization between civilized landmasses. According to this viewpoint, the only purpose of the sea was to function as a resource that could be exploited. In this respect they differed from their younger colleagues, who viewed the sea as a vital part of the human environment. To the younger generation, the sea was increasingly becoming a vulnerable space at the mercy of humans: an indictment of the pervasive environmental crisis.

Conclusions
The Baltic Sea degraded into a state of eutrophy because of natural and cultural factors. During the last (or current) Ice Age, enormous continental ice shelves repeatedly tore and compressed the earth’s crust and created huge depressions in present-day
Northern Europe. The melting ice cap carried sand and moraine to its southern edge, that is, into an area that is today called Denmark. Post-glacial rebound accomplished the rest and left the Baltic Sea almost isolated from the Atlantic Ocean. As a result, the Baltic Sea resembles a giant estuary in many ways rather than a proper sea. In the latter part of the 20th century the Baltic Sea had been surrounded by almost 90 million people, who lived in highly industrial societies. When acting in tandem, these factors—poor water exchange, a relatively modest size and water mass and affluent societies in the surrounding region—made the Baltic Sea both susceptible to chemical changes and a victim of ever increasing environmental stress.

The situation was only made worse by the prevailing attitudes towards the sea, which de-emphasized its vulnerability. During the two decades after the Second World War, in particular, marine scientists sought ways to increase the harvests of marine resources. Nutrient run-off was viewed as a means to improve fisheries and thereby were beneficial for national economies and the wider human race. The first signs of anthropogenic changes were dismissed by pointing to natural cycles and the capacity of the sea to self-purify. Irrespective of the process of eutrophication of lakes and coastal waters, the immense sea could not be altered by human action: not even the not-so-immense Baltic Sea.

Scientific use of nutrients proved largely to be an ineffective fantasy. As the Swedish marine scientist Stig Fonselius noted, the phosphorus content in the Baltic Sea had ballooned. Before anyone really realized what was going on, the amount of phosphorus had surpassed the threshold level. Thereafter it set in motion the self-regulating feedback mechanism, which resulted in a vicious circle of oxygen deficit and eutrophication. As the famous oceanographer Sylvia Earle put it: 'The sea, like a great vat of milk, can tolerate many drops of vinegar, but there comes a time—no one can predict just when—when the system goes sour.'

New ideas about the marine environment, however, became entangled with other contemporary currents. While nutrient alarmists saw the pollution of the sea as symptomatic of the ongoing environmental crisis and demanded restrictions to the degree of nutrient pollution, sceptics continued to argue that changes in the sea were simply due to the work of nature. For them, the sea was an economic asset to be utilized by a well-functioning industrial society.

Scientists are in a position whereby they can have a concrete impact on the course of events, which is why scholars have in recent years paid increasing attention to attitudes within science. In the case of discussion in Finland, the sad fact is that those who were in the best possible positions to influence decision-making expressed little concern vis-à-vis the problem of nutrient pollution. Thus, many projects that were harmful to the sea received scientific approval.

The Baltic Sea was the first such body of water to be severely affected by anthropogenic eutrophication. This should have been a warning sign for scientists, politicians and the wider public in every corner of the Earth to stop using the sea as a place for waste disposal. Sadly only a few even noticed. There have been many people who have worried about the fate of oceanic ecosystems since the late 1960s. Yet, too little has been done to save the sea from contamination and the destruction of marine life. Too often warnings by alarmist scientists have been ignored and the management of the sea has been dominated by the blasé attitude of environmental sceptics. The day comes when indifference and maltreatment backfires, such as occurred in the final decades of the 20th century in regard to the Baltic Sea.
Disclosure statement
No potential conflict of interest was reported by the author.

Notes
1. For cyanobacterial blooms as a natural phenomenon in the Baltic Sea, see Furman and Niemi, ‘Itämeren suojelutarve kasvaa’, 67–8; and, Myrberg, Leppäranta, and Kuosa, Itämeren fysiikka, tila ja tulevaisuus, 183.
2. For Carson’s role in launching environmental studies in Sweden and Finland, see Räsänen, ‘Converging Environmental Knowledge’, 159–81.
3. For the human impact on oceans, see for example, Matthews, Smith, and Goldberg, Man’s Impact on Terrestrial and Oceanic Ecosystems.
4. For the allusion to the Mediterranean case, see Haas, Saving the Mediterranean, 111.
5. Laakkonen and Parpola, ‘Reheväytymiskäsitysten historiaa’, 86–91. Laakkonen and Parpola’s article is one of the very few historical studies that addresses the discussion regarding the impact of nutrients in open Baltic Sea areas.
6. Bolster, ‘Opportunities in Marine Environmental History’; and Hughes, What is Environmental History?, 111–12.
15. Hela, ‘Meritietteen kehitys ja nykyiset tehtävät’, 63–4; Hela, ‘Talassologeista ja heidän työmaastaan merestä’. For international discussion among oceanographers, see Hamblin, Oceanographers and the Cold War, 112–13, 121.
21. Voipio, ‘Itämeren likaantumistutkimukset’. This manuscript was most likely written in 1966 or 1967, since the text closely resembles his published works written in these years. A similar argument was put forward by Ilmo Hela. See Hela, ‘Merien käyttö ja suojetu’, 66.
22. Voipio, ‘On the Total Phosphorus Content in the Northern Baltic Sea’; Voipio and Särkkä, ‘Kokonaisfosforin taso Suomen rannikkovesissä’, 2–4. Stratification is produced by salinity. Water with a greater quantity of salinity is also denser. Consequently, it sinks to the bottom. The so-called halocline zone lies between the more saline bottom water and less saline surface water. The halocline zone prevents much of the water exchange between the two layers, and was also thought to prevent nutrient welling from the deeps.
24. In subsequent decades it was demonstrated that the role of nitrogen in regulating biological production in the sea had been underestimated. On the role of nitrogen in the Baltic Sea, see Elmgren, ‘Understanding Human Impact’, 227; Jouko, *Haafeilua ja vedenpesua*, 232–3. On the general discussion, see, for example, National Research Council, *Clean Coastal Waters*, 67–70.
27. Ibid., 26–8.
28. Ibid., 50.
29. Ibid., 91.
39. Voipio and Hannerz, ‘Östersjön försämras när den förbättras’, 11–16. It should not confuse the reader that Voipio and Hannerz, who embodied the opposite sides in the discussion on the human impact on the marine environment, appeared as authors in the same article. This was not a joint article, but a feature in the magazine, in which both scientists had an opportunity to present their own stand in separate section.


41. Ibid. See also, Luther, ‘Östersjön – Lortsjön?’, 14–15.


43. Lassig and Niemi, ‘Meribiologian nykisyiä suuntauksiä’.


55. For Mannheim’s theory of generations, see, for example, Pilcher, ‘Mannheim’s Sociology of Generations’, 481–95.

56. For a wider discussion on the Finnish environmentalism in the late 1960s and early 1970s, see Räsänen, ‘Converging Environmental Knowledge’.

57. Inglehart, Silent Revolution, 45, 48–50. Interestingly, in Inglehart’s study, many older respondents valued the environment more than younger cotemporaries. This may be due to the phrasing of questions, which in Inglehart’s enquiry emphasized aesthetic experiences. Since the publication of this research it has been demonstrated in numerous studies that modern environmentalism appealed specifically to educated young adults.


60. Voipio, ‘Itämeren pilaantumisen ongelmat’, 6; Voipio, ‘Miten Itämeren pilaantumisastetta voidaan arvioida’, 7–9; Voipio, ‘Suomenlahden pilaantumisongelma’;
Voipio, ‘Meren saastuminen’; Voipio and Hannerz, ‘Östersjön försämras när den förbättras’, 11; and Voipio, ‘Pollution and Hydrographic Features’.


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