The Ocean turns more acidic – is sustainable development at risk?

Earth seen from space appears as a blue dot surrounded by darkness. It holds 1.386 billion km^3 of water, from which around 96.5% belong to oceans, seas, or bays (USGS, n.d.). The Ocean has played a crucial role in the development of human society. For millenniums it was the base for trading, transfer of knowledge, and exploration. Nowadays, more than ever, it is essential for global food security, the well-being of humankind and contributes significantly to coastal community' prosperity. In the last century, the world's oceans mitigated CO^2 concentrations and, therefore, climate change. But through the absorption of the atmospheric CO^2, its chemical composition is changing. CO^2 reacts with seawater and leads to a reduction in pH. This process is known as ocean acidification (OA). Such a rapid change in pH values gives the marine ecosystems little time to adapt. Adverse effects on marine life are recognized and reported. (Doney, 2020). Considerably quiet is the discussion about the implications on humankind, the threat of global food security, the negative impact on fisheries, and the global economy. In this paper, we want to focus on how ocean acidification influences sustainable development, increases socio-economic risks, and what humanity could do to solve this problem. (Shi et al., 2016).

Fisheries

The most direct way acidification threatens humanity's development is through the fishing industry. Fisheries are crucial for food security, especially in less developed parts of the world (Smith et. al., 2009). In 2013, over 3.1 billion people relied on seafood for at least 20% of their animal protein intake (Guillen et. al., 2019). Additionally, fisheries and aquaculture provided jobs to 59 million people worldwide in 2018 (Shahbandeh, 2020). The species threatened the most by acidification are calcifies, such as mollusks, crustaceans, and corals, who struggle to maintain their calcareous structures in the more acidic water (Doney et. al., 2020). The threat also extends to species that prey on calcifies or live-in coral reefs (Doney et. al., 2020). This means acidification has consequences for entire marine ecosystems and marine industries. For example, US fisheries made 73% of their revenue from calcifies and their direct predators in 2007 (Denman et. al., 2011).

The most immediately threatened group of species is mollusks, which currently represent 9% of the global fishing industry's revenue (Doney et. al., 2020). It is difficult to tell exactly how impactful the decreased mollusk harvest will be, but an assessment from 2012 predicts global losses of around $100 billion (Narita et. al., 2012). The most strongly affected regions are Europe, North America, and Asia (Narita et. al., 2012). Specifically, the highest impact is expected in the USA and China.

Mollusks are not the only species threatened by OA. Crustacean harvests have not changed much yet but are expected to decline substantially as OA worsens (Mangi et. al., 2018). In many marine ecosystems, mollusks and crustaceans are an important part of the bottom and middle trophic levels (Cooley and Downey, 2009). Any threat to these species will permeate these ecosystems, causing issues on higher trophic levels as well.

Lastly, OA threatens a rather unique group of species: corals. These ecosystem engineers currently face many monumental threats, and acidification is one of them. Today, coral reefs provide around 500 million humans with numerous ecosystem services, such as coastal protection, fishing opportunities, and recreational and tourism opportunities (Doney et. al., 2020). It's very difficult to assess how much these services are worth, with estimates ranging from $29.8 billion/year to $376 billion/year (Doney et. al., 2020).

Human health and well-being

The connection between human health and OA is not widely discussed. A reason for that might be because those two areas seem barely connected. That is not the case. OA has direct and indirect effects on the well-being of human beings through potentially destabilizing food security, losing coastal protection mechanisms, increasing mental health issues, and decreasing the possibility to obtain medical resources due to the loss of biodiversity.

First, OA, CO^2 acidified seawater, can lead to toxic metal accumulation such as Cadmium (Cd). It is comparable soluble, and therefore organisms like bivalve can accumulate it. Mostly it can enter the cells of mammalian and marine organisms through the Ca2+ channel. Research from Wei Shi (2016) shows that a decrease in pH increases Cadmium and decreases Calcium concentrations significantly. For the poorest 1 billion people on earth, marine bivalves constitute the number one source of specific vitamins and proteins (Shi et al., 2016). Marine bivalves can accumulate high toxic-metal concentrations. In extreme situations, they could become a threat to the health of the most vulnerable (Shi et al., 2016).

Coral reefs play an essential role in human well-being because they provide food, important nutrition, protection against extreme weather, and income. To grow, their ability to calcify must outdo bioerosion. OA leads to a decrease in calcification rates of corals and coralline algae. Therefore, it leads to low resilience and more vulnerability towards coral bleaching and environmental changes (DeCarlo et al., 2015).

Not only the destruction of habitat can lead to a forced diet change through the disappearance of affordable nutrient sources, but there is evidence that OA can also lower the nutritional qualities of some seafood. Cultured whelk species, for example, show a reduction of proteins and lipids through OA . (Falkenberg, 2020). That is problematic as polyunsaturated fatty acids have highly beneficial properties for human health, from inflammatory effects to reducing the risk of heart disease.

Barely recognized and discussed is the impact of habitat loss on our mental health even though higher biodiversity is coupled to stress reduction, “nature-consciousness” benefits social interaction and physical activity and increases well-being. (Falkenberg, 2020). Livelihoods, recreational activities, and social connections affect our mental health significantly. Economic independence supports livelihoods, and oceans provide many jobs, around 300 million from which 90% are associated with small-scale, artisanal fisheries (Falkenberg, 2020). Also, our physical and mental health is interlinked. Current research indicates that malnutrition may increase the risk of developing mental health disorders (Cheng Huang et al., 2013). In summary, the adverse effect of OA on the fishing industry and biodiversity, and the possibility that it can lead to a decrease in the nutritional value of marine food pressures human mental health stability (Falkenberg, 2020).

The adverse impact of OA on biodiversity can limit us in discovering new medications. The potential of finding new molecules of high medical value through ocean-based organisms is high. By the destruction of species-rich habitat, we lose this opportunity. That effect shouldn’t be underestimated, as undiscovered medical applications can be crucial for tackling malnutrition, poisoning, and mental health issues (Falkenberg, 2020).

Economy

The socio-economic impact OA has on welfare is difficult to research, precisely because there is a huge knowledge gap. Complete data on the impact of OA on, for example, fisheries, aquaculture, and tourism are quite limited. It is important to mention that the time span for different scenarios plays a crucial role in economic analyses. Both cost and benefits need to be measured with each other. The data needed also depends on the scale of the analysis, and the data available can influence the analysis. Lastly, the final data needs to include uncertainty in various scenarios. That can make it possible to estimate potential risks. In other words, there is a lot of variables that need to be included while talking about the economic aspects (Hilmi et al., 2013).

OA make maintenance more expensive, energetically speaking, because of organisms that make trad-offs between growth and calcification. Within aquaculture, it is logical to assume that feeding costs are likely to increase if growth is to be maintained, to compensate for the increase of energy demand. To ensure the right quality in waters and a continued supply of spat, hatcheries might be needed. They ensure that the water pH is at high levels. The costs of coastal protection may also increase if such coastal protections are dependent on, for example, coral reefs that are susceptible to OA (Hilmi et al., 2013).

Future solutions

We have discussed the threat of OA for global ecosystems and the adverse effects on fisheries, human health, and the economy. That raises the question of what we can do to secure the positive trend of human development and achieve the UN SDGs? The most effective way to stop OA is by reducing atmospheric CO2 emissions. But since the efforts to mitigate global warming have been unsuccessful until now, there is a growing interest in climate engineering (CE) to prevent various consequences of anthropogenic climate change. ”Artificial Ocean Alkalinization” (AOA), which modifies ocean alkalinity, is one of them. Several studies have simulated the use of alkalizing agents, such as olivine, calcium carbonate, or calcium hydroxide, to elevate the ocean's alkalinity, increase CO^2 uptake, and mitigate OA. These simulations suggest that AOA could mitigate global warming and OA to some degree (Feng (冯玉铭) et al., 2016).

Another approach to counteract OA is seagrass and kelp, a local management tool that recently gained popularity in California (Nielsen, 2018). Seagrasses and kelps use dissolved forms of inorganic carbon for photosynthesis and therefore directly affect the aquatic carbonate system. That is a valuable characteristic as other coastal vegetations consume CO^2 gas from the atmosphere for that process. Furthermore, seagrass and kelp provide a range of valuable ecosystem functions, including providing refuge and nursery habitat for commercially and recreationally important species, improving water quality, and protecting coastal zones from storm surge, erosion, sea-level rise, and ecotourism. Thus, significant alternative benefits of restoring these ecosystems have already been observed and quantified (Nielsen, 2018).

Conclusion

Fisheries, human health, and economy are all important factors to consider while elaborating on OA and how it affects sustainable development. The risk of OA is neglected in today's discussion on climate action. Fisheries is one marine resource that has been highly affected by the increased OA, mostly the mollusks and crustaceans, both comprise the bottom or middle trophic level of the ocean. Substantial revenue declines, job losses, indirect economic costs, and negative effects on human health are just some of the many ripple effects. The scale of these risks is unclear, precisely because of the lack of research done until now. By considering the UN sustainable development goals we can say that OA adversely affects sustainable development, especially SDG2 (zero hunger), SDG3 (well-being), SDG8 (economic growth), and SDG13 (climate action). It threatens food security, human health, the fishery sector, and ecosystems like coral reefs. Many future potential solutions and technologies have been expressed. ”Artificial Ocean Alkalinization” and seagrass and kelp as local management tools are two examples of future potential solutions. But we want to point out that the most effective way to solve the problem is reducing CO^2 emission on a global level.

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