Summary

In this thesis, the abundances of *Asterias rubens (L.*) in the Kieler Meeresfarm during the summer of 2021 are evaluated and related to topics such as the pollution caused by fishmeal in aquaculture, the utilization of the common sea star as well as the ecological situation of the Baltic Sea.

Aquaculture has been one of the fastest-growing food sectors in recent years. It poses potential to offer a less impactful protein source compared to some terrestrial animal protein but, conversely, has issues with sustainability. One major contributing factor is feed. Feed is necessary for many different aquacultures; however, its production can be controversial, and its use can be polluting.

Due to the industry's rapid growth, the need for fish feed and its main ingredient, fishmeal, rose. Fishmeal production, which relied mostly on scraps from commercial fishing, could no longer supply quantities large enough—forcing increased fishing explicitly for fishmeal. When used in water-based systems, fish feed can also introduce excess pollution, either through uneaten feed or through effluent from the cultivated species. More sustainable alternatives seek to alleviate these issues while remaining economically viable and delivering a similar level of nutrients. Sea stars are one, which recently gained traction to substitute to fishmeal partially. Their local removal and use in nearby aquaculture could also decrease the nutrient overload present in the Baltic Sea by encouraging recirculation.

The common sea star, *Asterias rubens*, has a wide distribution. It is native to the sub and intertidal regions of the Atlantic, reaching as far as the brackish waters of the western Baltic Sea. It is a voracious predator, which feeds mainly on slow-moving or sessile benthic invertebrates. It can be especially detrimental to on-bottom oyster or blue mussel cultivation. The sea star sporadically forms enormous swarms, sometimes reaching tens of thousands of individuals. These swarms can decimate a mussel bed in a matter of days, destroying the entire harvest. For decades mussel-fishers have used various techniques to rid themselves of such invasions. Yet beyond extermination, little valorisation of the sea stars was ever attempted. Up until recently, when the world's first sea star processing plant for use in pig feed opened in Denmark.

The Baltic Sea is the world's largest brackish sea and an essential resource for bordering countries. Yet its ecological situation is mostly poor, suffering extensively from eutrophication. This process must be halted at its origins to improve the situation, removing inputs from agriculture and heavy industry. Extractive aquaculture, the practice of raising aquatic organisms without additional feed, can not alleviate the current pollution of the Baltic Sea. It can, however, promote more sustainable aquaculture practices and counterbalance some of the anthropogenic stresses on the environment of the Baltic Sea.

The Kieler Meeresfarm (KMF) is blue mussel, *Mytilus edulis*, longline farm situated in the Kieler Förde. They practice extractive aquaculture and sell their produce locally. Naturally, some cultivated mussels are lost and sink to the bottom due to natural phenomena like adverse weather. There the mussels accumulate, forming what will hereafter be referred to as mussel mounds underneath the lines. There they are exposed to predators, like the common sea star *Asterias rubens*, which can accumulate on these mussels in great abundance.

In this work, the abundance of the common sea star was counted during three samplings in the late summer of 2021. In addition to this, the abundance of blue mussels and the environmental variables: temperature, depth, salinity, oxygen content and oxygen saturation were recorded. This was achieved using a water-proof camera and probes measuring the environmental variables. The samplings were carried out at the Kieler Meeresfarm and a reference area, plausibly outside of the influence of the KMF. Using a boat, 24 measurements were carried out on each site resulting in 144 measurements total. This work wants to answer the question of whether the sea star is more abundant on the KMF compared to a reference site and if the measured environmental variables appear to have any influence on sea star presence or distribution. Furthermore, the abundance of sea stars in both sites was to be extrapolated using the data from each sampling. These extrapolated sea stars should then be evaluated on their potential as a fishmeal substitute and what quantities of fish could be produced with it.

The gathered data were evaluated using statistical analysis in the software R-Studio. The U-Test by Mann-Whitney and the Kendall-tau correlation were primarily utilised to assess the data. The U-test compares two sites on similarity. Not only was the KMF was compared to the reference area, but a subdivision of the KMF was also undertaken. Therein the parts of the KMF containing mussel mounds and those that did not were also compared to the reference. This aimed to highlight the differences in sea star abundances in both sub-sites. The correlation compared the species and environmental variables to each other. Lastly, the extrapolation of the sea star count was calculated. The reference was assumed to contain a homogenous distribution of sea stars. The KMF, however, was assumed to be heterogeneous due to the mussel mounds. The extrapolation of both sites was undertaken, and a difference was calculated. The difference was further multiplied by the average sea star weight to achieve a possible mass for the extrapolated sea stars.

Both the sea stars and the blue mussels were calculated to be more abundant on the KMF. These results were amplified when comparing only the mussel mounds to the reference site. Both species also displayed a discordant correlation to depth, only in the reference area, while in the KMF, only sea stars and blue mussels correlate. The extrapolation resulted in 11294 sea stars more in the KMF compared to the reference area. The extrapolated amount would roughly equate to 63 kilograms of dried sea star meal.

The results indicate that mussel mounds mainly influence sea star distribution in the KMF. The results of the U-test and the correlation suggest as such. Salinity was the only environmental variable that appeared to influence sea star distribution. No meaningful difference in environmental variables was measured between both sites.

Utilising the 63 kilograms of dried sea star meal, when replacing 80% of the fishmeal in shrimp feed, 523 kilograms of shrimp feed could be sustained. Assuming an average FCR, this feed could produce 312,12 kilograms of Shrimp. Similarly, when substituting 50% of fishmeal in salmon trout feed, 849 kilograms of trout feed could be produced, resulting in 738 kilograms of trout. This accounts for roughly one percent of salmon trout production in Schleswig-Holstein. Although this appears to be minimal, the extrapolated results are only made up of 3 samplings in late summer. Six similar harvests could already sustain almost 10% of production. It should also be noted that the weight used to calculate is from a winter sampling and included smaller individuals. Schleswig-Holstein also has more bivalve producers, where the harvest could theoretically be expanded.

Harvesting sea stars, attracted by blue mussel longline farms, and utilizing them as feed in local mariculture could lead to a recirculation of nutrients and positively impact the

Baltic Sea's ecological situation while simultaneously offering a more sustainable fishmeal alternative.

To better understand the annual variation and ideal harvest periods for sea stars in the Kieler Förde, as well as their relationship to long-line mussel farms, an improved measurement procedure is recommended. The current measurements were of limited significance as they only included a small timeframe, the late summer of 2021, and only investigated the older longlines. Monthly samplings, combined with weight samplings in both the old and new longlines as well as the reference site, would give greater insight into the distribution and density of sea stars in the Kieler Förde. The harvest itself is still challenging. Which methods are the most suitable to harvest large quantities of sea stars underneath longlines without damaging them? How often could such a harvested be performed while maintaining an ecologically sustainable population of sea stars? How would the sea stars be processed while remaining economically viable? Simultaneously further feeding and palatability trials should be conducted, including more aquatic species beyond shrimp.

There is great potential in sea star meal, but the research into its use in aquaculture is still in the early days, and more needs to be achieved for sea star meal to be utilized as a legitimate fishmeal substitute.