Assessing bottlenecks within the lifecycle of Atlantic herring encountered within the Wadden Sea

Introduction:
Due to the recent decline in many fish populations within the Wadden Sea, Danish, Dutch and German fish experts have proposed that changes need to be made to reverse current trends in fish diminutions. As a result, conservation objectives for herring (named the Triental Fish Targets) were developed by project Swimway, which are aimed at preserving or increasing the suitability of the Wadden Sea area for different species of fish. However, at the basis of successful management, knowledge is required on the exact lifecycle of the species in question. Therefore, during the first year of the Swimway Project, research has been conducted on all the lifecycle stages of Atlantic herring. This project has contributed to the knowledge of the lifecycle of the species in the Wadden Sea and has identified both the lifecycle of Atlantic herring encountered within the Wadden Sea area and potential bottlenecks encountered within, with the objective to funnel the bulk of information into one singular source. Since Atlantic Herring is the flagship species of Pelagic marine juvenile species, which is one of five Swimway categories based on lifecycle and behavior, this information may prove valuable to the Swimway Program and its objectives.

Lifecyle (fig 1):
1. Of the four main spawning stocks in the North Sea area, only the Banks stock and the Downs stock utilize the Wadden Sea during their spawning (Dixey-Colly et al., 2010; Hendon & Pride, 2010). Herring spawning in the North Sea begins in September in the North, ceasing in the South at the end of January. The timing of spawning is fixed, occurring at the same time every year (ICES, 2002; Payne, et al., 2005; Rozenzame et al., 2000; Sinclair & Power, 2015). After hatching, Downs and Banks herring larvae passively drift towards the southern North Sea, including the Wadden Sea. (Kellnreitner & Peck, 2015). Fisheries have seen, and been within the Fässler et al., 2005). Other bottlenecks on the need of high NAO during the period from 1988 to 1990, a northern distribution of herring was not only linked with high water temperatures but also with low abundance of copepod C. finmarchicus in the Wadden Sea (Rijnsdorp, 2000, Climate: Fish Migration, Fishery Management, Ecology & Marine Research)

Fisheries and other human activities:
Herring plays a key economic role with ~0.3 to 0.4 million tons landed yearly between 2007 to 2012 (Van der Veer, et al., 2015). Fishermen have witnessed which years have been part of, long and short term fluctuations within the herring stock over the years. There have been times in which the Wadden Sea has suffered because of large-scale blooms (Corten, 2000; Corten et al., 1994; Corten, 2015). The timing of phytoplankton blooms shows yearly variation, mainly related to other or total year population survival (Sinclair & Tramblay, 2014). After herring larvae reach the nurseries during the winter, they take advantage of plankton blooms which commonly occur in coastal waters during this part of the year. Research has shown that seasonal egg and larval production is often determined by interannual variations in phytoplankton blooms that occur during the summer months (Sinclair et al., 2001b; Seier, 2007). This results in something called the match-mismatch theory in which herring has fixed spawning periods while the timing of phytoplankton blooms shows yearly variation, resulting in either terrible or non-beneficial conditions. Researchers have noticed that the herring stock size thrived and periods in which the herring stock size declined coincide with periods in which the herring stock size decreased. It is likely that autumn increased in North Sea begins in September in the North, seizing in the South at the end of January. The timing of spawning is fixed, occurring at the same time every year (ICES, 2002; Payne, et al., 2005; Rozenzame et al., 2000; Sinclair & Power, 2015). After hatching, Downs and Banks herring larvae passively drift towards the southern North Sea, including the Wadden Sea. (Kellnreitner & Peck, 2015). Fisheries have seen, and been within the Fässler et al., 2005). Other bottlenecks on the need of high NAO during the period from 1988 to 1990, a northern distribution of herring was not only linked with high water temperatures but also with low abundance of copepod C. finmarchicus in the Wadden Sea (Rijnsdorp, 2000, Climate: Fish Migration, Fishery Management, Ecology & Marine Research)

While changing salinity was also researched as a potential bottleneck, salinity has not been of high NAO in the Wadden Sea, which resulted in long timespans of above average sea water temperature. While it might affect recruitment through the matching of phytoplankton blooms and herring larvae, this phenomenon is not yet fully understood. Researchers concluded that reduced larval survival during different time periods were caused by either unusual hydrological conditions or by temperature changes (Collas et al., 2006; Kallmariner et al., 2012; Rijke Waddense, 2010; Payne et al., 2005). Some past changes in pelagic fish stocks in the North Sea (including herring) could be explained by a reduced influence of Atlantic water and changes to the circulation of the North Sea area. Specific periods of exceptionally low and high NAO-index, which resulted in long timespans of above average sea water temperature, are expected to be a direct consequence of global warming (Edwards et al., 2002; Reid & Edwards, 2002).

While changing salinity was also researched as a potential bottleneck, salinity has not been of high NAO in the Wadden Sea, which resulted in long timespans of above average sea water temperature. While it might affect recruitment through the matching of phytoplankton blooms and herring larvae, this phenomenon is not yet fully understood. Researchers concluded that reduced larval survival during different time periods were caused by either unusual hydrological conditions or by temperature changes (Collas et al., 2006; Kallmariner et al., 2012; Rijke Waddense, 2010; Payne et al., 2005). Some past changes in pelagic fish stocks in the North Sea (including herring) could be explained by a reduced influence of Atlantic water and changes to the circulation of the North Sea area. Specific periods of exceptionally low and high NAO-index, which resulted in long timespans of above average sea water temperature, are expected to be a direct consequence of global warming (Edwards et al., 2002; Reid & Edwards, 2002).

Acknowledgments:
Since bottlenecks discovered in the lifecycle of herring are primarily driven by climate change, the problem is mostly cut out of Swimway’s hands. Right now it is mostly speculation on the future situation increase since models show varying results which are often location specific. While it might be near impossible to reverse the warming of the North Sea, especially since the warming and cooling of seas and oceans are a natural phenomenon, it will be possible to reduce climate change on herring. The activity of adding and removing is therefore essential to herring’s survival. Herring recruitment though the match-mismatch theory (Sinclair et al., 2001b; Seier, 2007). As a result, fishing pressure is not the threat it used to be and does not pose direct danger to the survival of herring stocks as it did in the generation prior.

Other human activities encountered by juvenile herring consist of oil exploitation, construction and use of wind turbines, military activity, dredging and metal-induced eutrophication. Of the first two activities, scientists indicate that the effect on herring is negotiable or even absent, often due to mitigating measures taken (Herdson, 2010). However, military activity and dredging are common in the Dutch part of the Wadden Sea and research on these activities in the area is lacking. Continuous shipping can contaminate the surrounding waters with lead and other heavy metals which are toxic to many marine species (Collas et al., 2005). Nonetheless, due to the small scale of the military activities in the Wadden Sea, the effect on the ecosystem is expected to be negotiable (Bennett et al., 2013). As for dredging, the Wadden Sea is an area in which turbidity is already high, which makes matters naturally resistant to turbidity, at least temporarily. Additional research is needed regarding these two activities within the desktop law as dredging might release trapped heavy metals, introduced by military activity, or might increase the threat of eutrophication in a way that is not yet clear. To date, research has been made on a regular basis since current chlorophyll levels in the Northern Wadden Sea are among the highest in the whole of the European Sea Water Framework Directive (Van Beusekom et al., 2017). While eutrophication does not pose a direct threat to Atlantic herring populations, it might have a more indirect effect on herring. This is because eutrophication results in an increased biomass of phytoplankton blooms, which potentially threatens the survival of juvenile herring in the Wadden Sea area. Considering the importance of the Wadden Sea as an important nursery and feeding area in the Wadden Sea, it is therefore crucial to understand the effects of eutrophication on herring. For the other Atlantic herring species, a similar approach can be used to define bottlenecks and knowledge gaps in the lifecycle of these species. While the temperature increase in the Wadden Sea might affect all fish species, it might have little or no effect on the other Atlantic herring species. On the other hand, found bottlenecks might affect other Swimey species even more. Future recommendations should go towards performing similar (successive) research on other Swimey species, to aid the Swimway Action Programme in achieving the Triental Fish Targets in the Wadden Sea.