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Evaluation of the Common teal and Twaite shad model: comparison between predictions based on actual data and input derived from the modelling train

Report in the framework of the Integrated plan of the Upper Sea Scheldt

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EVALUATION OF THE COMMON TEAL AND TWAITE SHAD MODEL: COMPARISON BETWEEN PREDICTIONS BASED ON ACTUAL DATA AND INPUT DERIVED FROM THE MODELLING TRAIN

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1 INTRODUCTION

The Integrated Plan of the Upper Sea Scheldt describes a set of morphological adjustments designed to improve the sustainability of the river functioning by 2050. The intended improvements encompass, among others, aspects of ecology, flood control, shipping and maintenance efforts. Within this context a number of alternative morphological designs have been proposed with different degrees of impact on the current morphology. To evaluate the expected impact of alternative morphological designs on hydrodynamics, sediment transport, water quality and pelagic ecosystem, habitat quality and fauna and flora, a series of modelling tools have been developed to predict the effects of the alternatives on each of these components (the modelling train; see 'Model instruments for the Integrated Plan Upper Seascheldt' (IMDC et al. 2015).

The models for the higher trophic levels include a model to predict the numbers of Common Teal on the mudflats in the Upper Sea Scheldt (Vanoverbeke et al. 2019a) and a model to predict habitat suitability for spawning and larval development of Twaite shad in the Sea Scheldt (Vanoverbeke et al. 2019b). These models take input from other models in the modelling train with respect to hydrodynamics, sediment transport, habitat quality and the pelagic ecosystem (see IMDC et al. 2015). In the present report we evaluate the performance of both these models by comparing the predictions when taking input from actual data for the present situation (2009 - 2012) to predictions based on input from the modelling train for the present situation (ACT_2013; for the same years: 2009-2012). We also evaluate the sensitivity of the model outcomes to variation in individual predictors.

2 PREDICTIONS FOR COMMON TEAL

Input of the modelling tool for predicting the numbers of Common Teal on the mudflats of the Upper Sea Scheldt relies on ecotope maps and raster grids (GIS) capturing the width, slope and spread in exposure time (SpD) of the mudflats (only taking into account areas with soft sediment) (Vanoverbeke et al. 2019a). Results for the ecotopes of 2010 (Van Braeckel, 2013) based on measured hydrodynamic data and bathymetry are compared with the ecotopes for ACT_2013 (Van Braeckel et al. 2019) based on the bathymetry of 2013 and output of the modelling train for hydrodynamics (Smolders et al., 2016).

Figure 2-1 shows the characteristics of the mudflats along the Upper Sea Scheldt based on the ecotopes of 2010 and of ACT_2013. For the width of the mudflats, estimated values are comparable downstream of Dendermonde (30 km from Merelbeke), but there is a considerable overestimation of the area of soft sediments on the mudflats in ACT_2013 for the more upstream parts (between Merelbeke and Dendermonde). This is mainly caused by higher modelled high water levels in ACT_2013 than the true, observed water levels. In general, the average slopes for ACT_2013 tend to be steeper than for the ecotope 2010, and again the differences are larger for the upstream parts between Merelbeke and Dendermonde than for the downstream area. The differences in slopes can partly be explained by the larger estimated area of soft sediments in ACT_2013, which also captures areas with higher slopes (for example the often steep transition from tidal flat to marsh). Spread in exposure time of the mudflats (SpD) tends to be lower for the ACT_2013 estimates than for ecotope 2010 downstream of Dendermonde and higher upstream of Dendermonde.

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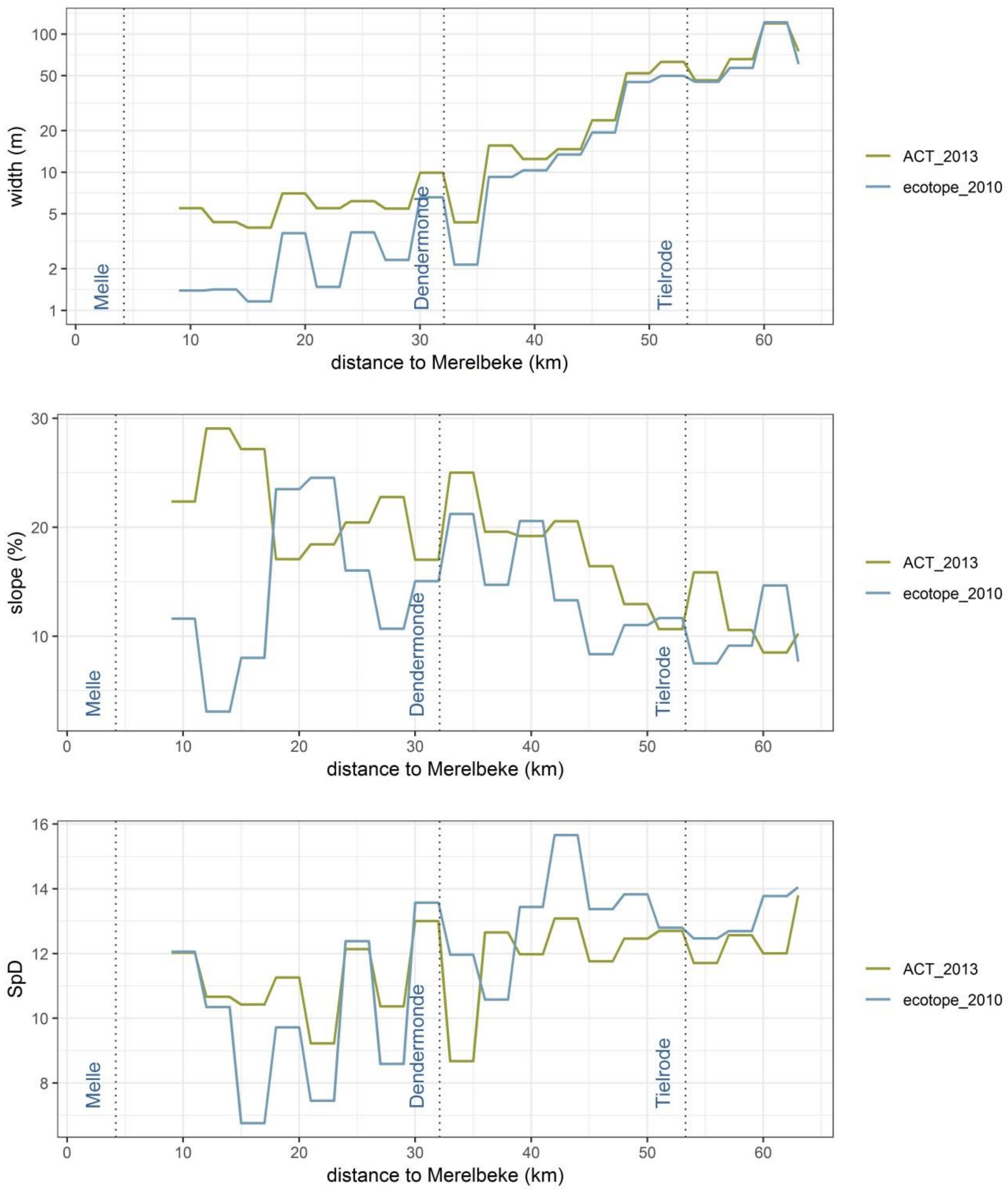

Figure 2-1: estimated values of width, slope and spread in exposure time (SpD) of the mudflats with soft sediment, based on ecotope 2010 mapping and on the output of the modelling train for ACT_2013.

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Despite the differences in morphological parameters between the observed (ecotope 2010) and modelled (ACT_2013) bathymetry, the predicted bird number is very comparable, and align well with the data of the observed numbers of birds in the winter of 2012-2013 downstream of Dendermonde (Figure 2-2, 'full model'). In ACT_2013, however, there is a clear overestimation in areas upstream of Dendermonde, compared to ecotope_2010 and the actual counts for 2012-2013, especially in the area around 20 km from Merelbeke. Based on the sensitivity analysis (Figure 2-2), the most important factor determining differences in numbers of birds between ACT_2013 and ecotope 2010 and the overestimation in the upstream areas in ACT_2013 is the width of the mudflats. The fact that the width of the mudflats mainly determines the predictions is in agreement with the higher estimated coefficient (β = 1.16) from the linear model compared to coefficients for slope (β = -0.26) and SpD (β = 0.39) (see Vanoverbeke et al. 2019a). The overestimation of bird numbers in ACT_2013 in the upstream part can in turn be ascribed to the higher estimated area (width) of mudflats with soft sediment (see Figure 2-1). Steeper slopes and lower (downstream) or higher (upstream) SpD in ACT_2013 are also reflected in the predicted numbers of birds but with lower impact than the width of the mudflats. Steeper slopes and lower SpD result in lower estimated numbers of birds while higher SpD results in higher numbers (see Vanoverbeke et al. 2019a).

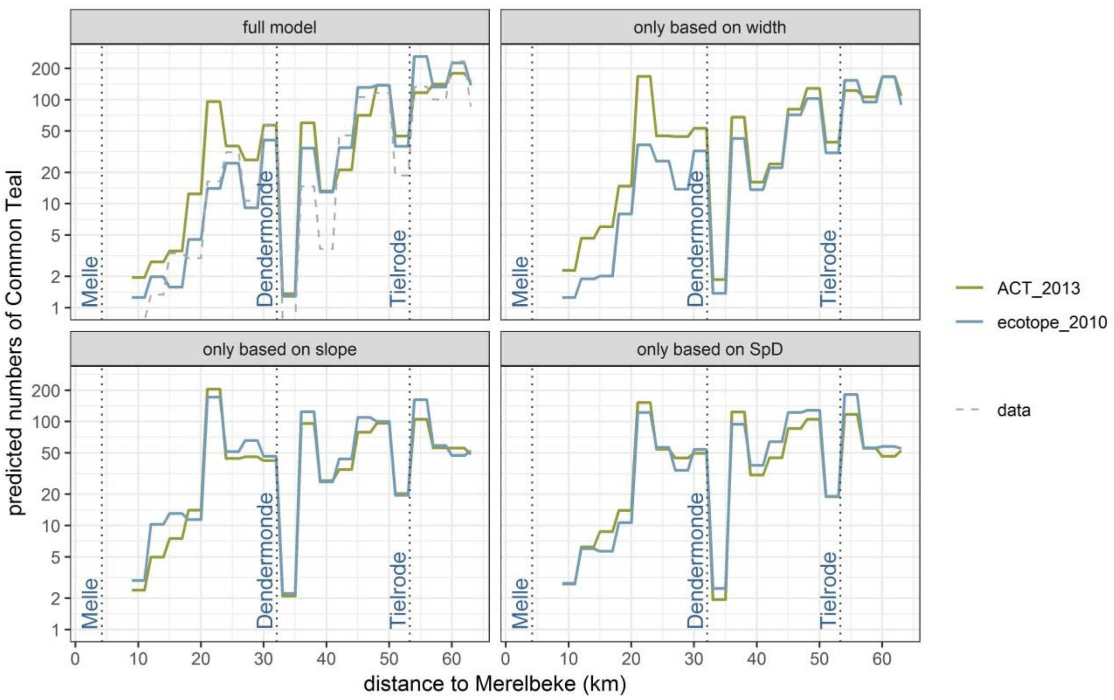

Figure 2-2: comparison of the predicted numbers of Common teal based on input from ecotopes 2010 and from the modelling output of ACT_2013. The dashed line represents the actual counts for the winter of 2009-2010. Predictions are shown for the full model including variation in all three predictive variables, and for prediction where the non-focal input variables are fixed to the mean.

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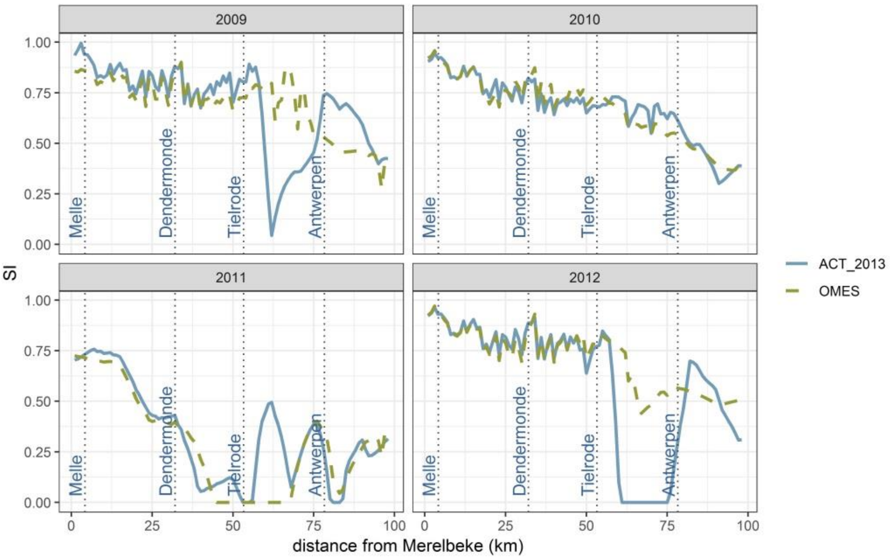
3 PREDICTIONS FOR TWAITE SHAD

The suitability index (SI) for spawning and for development of larval Twaite shad is based on a fuzzy logic model (Vanoverbeke et al. 2019b) and relies on bathymetric (depth), hydrodynamic (maximum water velocity, turbidity) and water quality (temperature, salinity, oxygen, zooplankton) predictor variables. For the period 2009-2012, a comparison can be made between predictions based on OMES monitoring data and the outcome of the modelling train on water quality (UA, Van Engeland et al., 2018), while the bathymetry and hydrodynamic predictors (WL, Smolders et al., 2016) remain fixed.

3.1 SUITABILITY FOR LARVAL DEVELOPMENT

For the model with respect to larval development, the results based on OMES data and on ACT_2013 are very similar upstream of Tielrode (around 50 km downstream of Merelbeke) (Figure 3-1A). Downstream of Antwerpen (75 km from Merelbeke), there are visible differences in the suitability index for 2009 and 2012 (Figure 3-1A), driven by the balance between the positive effect of higher estimated zooplankton levels in ACT_2013 and the negative effect of higher salinity levels in ACT_2013 in that area (Figure 3-1B, Figure 3-2). The area downstream of Antwerp, however, is less important for early development of larval Twaite shad, which predominantly reside in the oligohaline and freshwater areas of the Sea Scheldt. Moreover, the modelling outcome of the pelagic model (UA) for ACT_2013 (and other alternatives) is less confident on the biomass of zooplankton (Van Engeland et al., 2018), which is not at the focus of this model and its evaluation. The most important differences in SI between OMES and ACT_2013, are in the stretch between Tielrode and Antwerpen (between 50 and 75 km from Merelbeke), with strong deterioration of SI in 2009 and 2012 for ACT_2013 and strong improvement of SI in 2011. In 2011, SI for larval development based on OMES data is generally low because of high values of SPM in that year. The improvement between Tielrode and Antwerpen for ACT_2013 is caused by a dip in SPM in that region, which is not observed in the OMES data. The deterioration in SI in 2009 and 2012 on the other hand, is caused by strong declines in the oxygen levels calculated in ACT_2013 between Tielrode and Antwerpen. When oxygen levels fall below 4 mg/l, viability and thus suitability quickly decline toward zero.

A



B

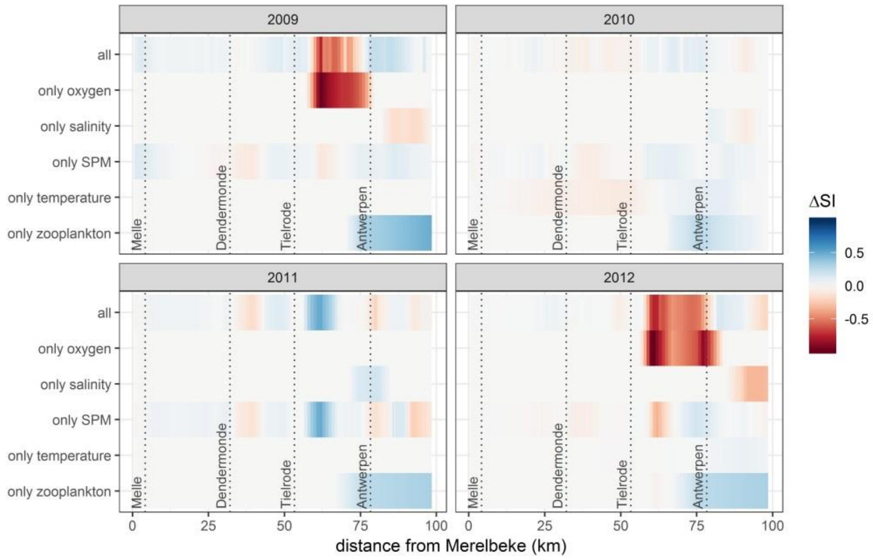


Figure 3-1: **A)** Comparison of the predicted suitability index (SI) for larval development between input from OMES data and from the modeling results of the pelagic model for ACT_2013. **B)** Sensitivity analysis, comparing the output of the full model with the output when taking only one of the predictor variables into account. $\Delta SI = SI_{OMES} - SI_{ACT\_2013}$

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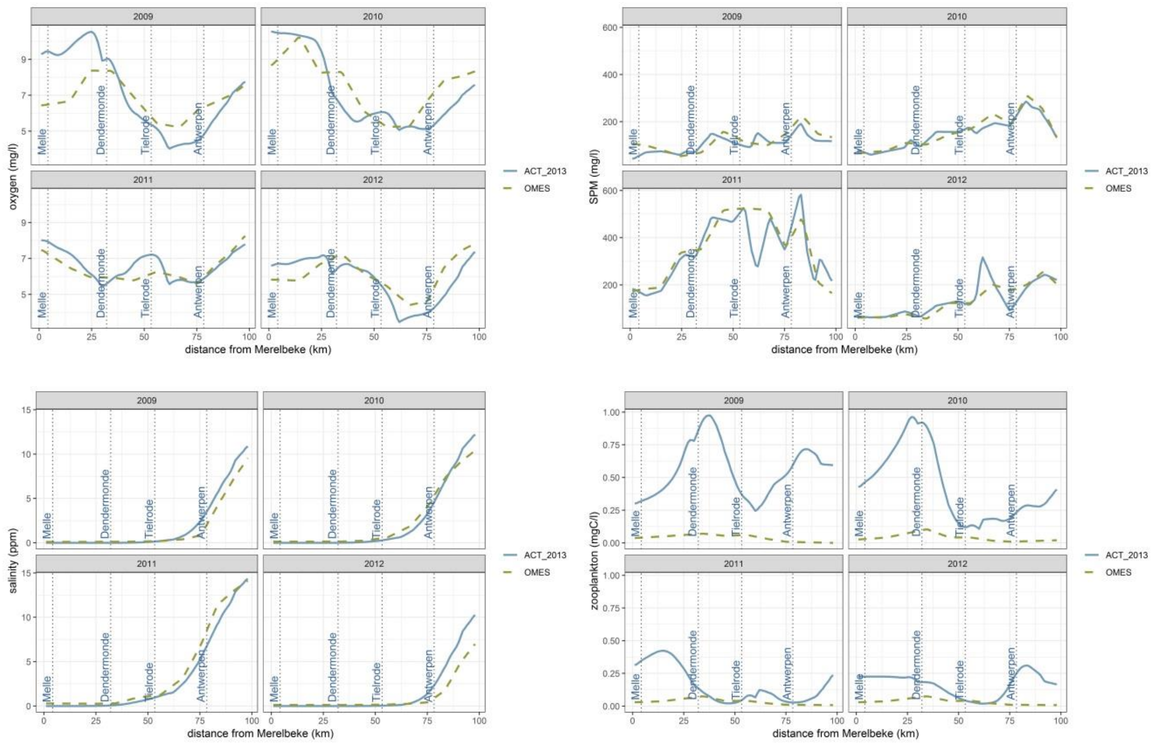
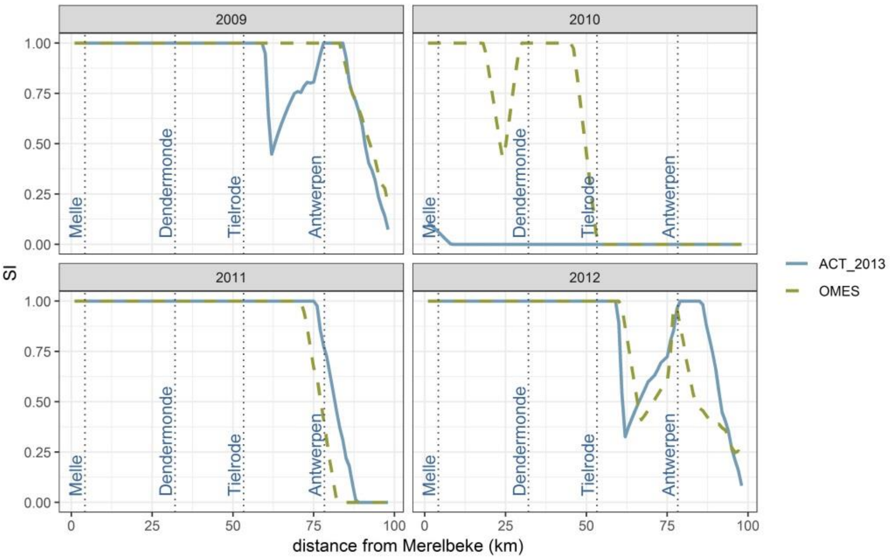


Figure 3-2: Comparison between the predictor variables for larval develoment obtained from OMES data and from ACT_2013. Only for zooplankton large differences between OMES and modelled values are observed.

3.2 SUITABILITY FOR SPAWNING

For spawning of Twaite shad, the most relevant area is upstream of Antwerpen. The predicted SI for ACT_2013 in 2009 shows a clear decline between Tielrode and Antwerpen (Figure 3-3A), due to lower oxygen values (Figure 3-3B, Figure 3-4) compared to the OMES data. The most obvious difference between the data sets, however, is the reduction of the SI to zero upstream of Tielrode in 2010 for ACT_2013 (Figure 3-3A). This is caused by temperature estimates below the threshold for spawning (15 °C) over almost the entire modelled strech (Figure 3-3B, Figure 3-4).

A



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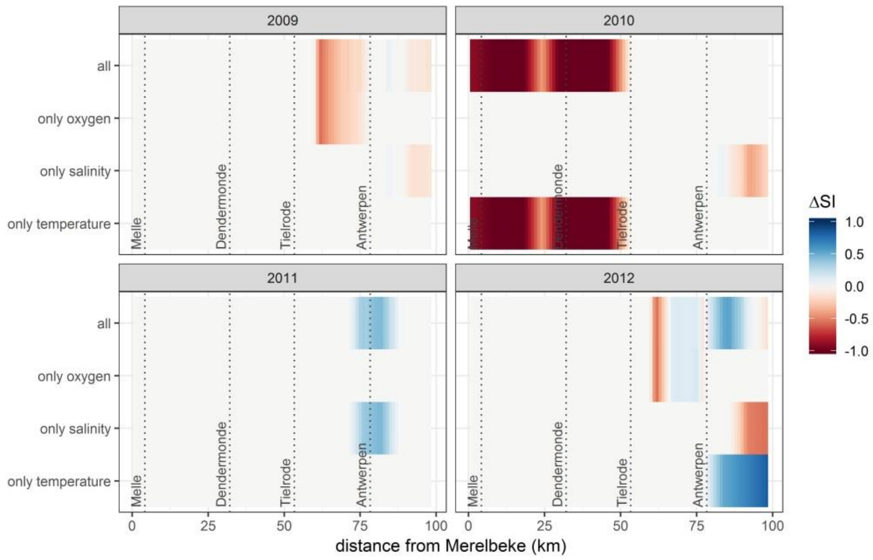

Figure 3-3: **A)** Comparison of the predicted suitability index (SI) for adult spawning between input from OMES data and from the modeling results of the pelagic model for ACT_2013. **B)** Sensitivity analysis, comparing the output of the full model with the output when taking only one of the predictor variables into account. $\Delta SI = SI_{OMES} - SI_{ACT\_2013}$

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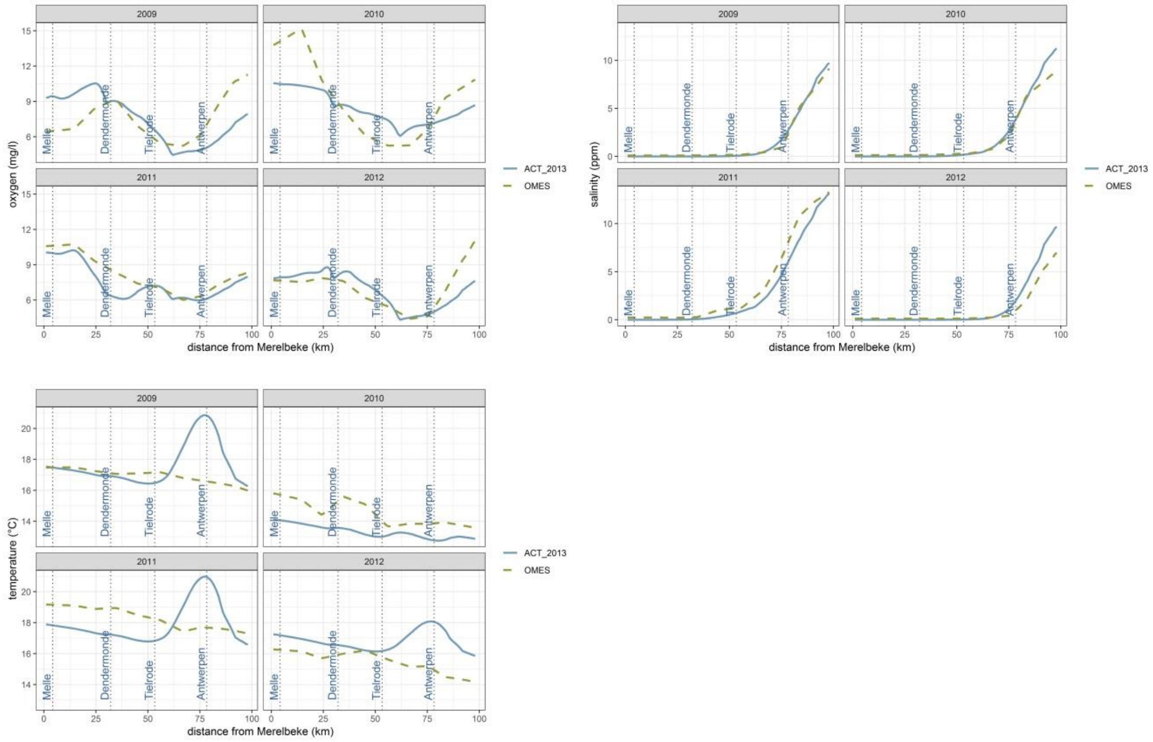

Figure 3-4: Comparison between the predictor variables for adult spawning obtained from OMES data and from ACT_2013. Only variables where the differences between OMES data and ACT_2013 have an important effect on the suitability index are shown.

4 CONCLUSIONS

For Common Teal, comparison between predictor variables derived from ecotope 2010 and from the output of ACT_2013 shows that the model is most sensitive to variation in the width of the mudflats. Changes in the slope of the mudflats or spread in exposure time, even when considerable, do not affect the predictions that strongly. The higher estimated width of the mudflats in the upstream parts of the Sea Scheldt (upstream of Dendermonde) for ACT_2013, results in an overestimation of the numbers of Common teal in that area for ACT_2013. This overestimation, however, will also be present in the outcome for alternative bathymetries, and comparison of relative changes in numbers of Common teal between alternatives is still possible.

Development of larval Twaite shad predominantly occurs in the freshwater and oligohaline stretches of the Sea Scheldt. In this area, attention should be paid to changes in SPM and oxygen levels. A decline in oxygen levels below 4-5 mg/l renders the Sea Scheldt unviable for Twaite shad and many other organisms. Likewise, an increase in SPM reduces suitability for larval development and is an indication of deteriorating viability in general in the Sea Scheldt.

The model predicting suitability for spawning of adult Twaite shad strongly deteriorates in response to temperatures below the threshold for spawning (15 °C) in ACT_2013. Temperature, however, is a forcing variable in the modelling train which does not change between the alternative bathymetries. Because strong temperature effects are thus not very informative within the context of comparing alternative bathymetries and might mask the impact of other drivers of habitat suitability, temperature will be excluded from further comparison and evaluation of the alternatives and scenarios.

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