Supplementary Material

The Effect of Optical Properties on Secchi Depth and Implications for Eutrophication Management

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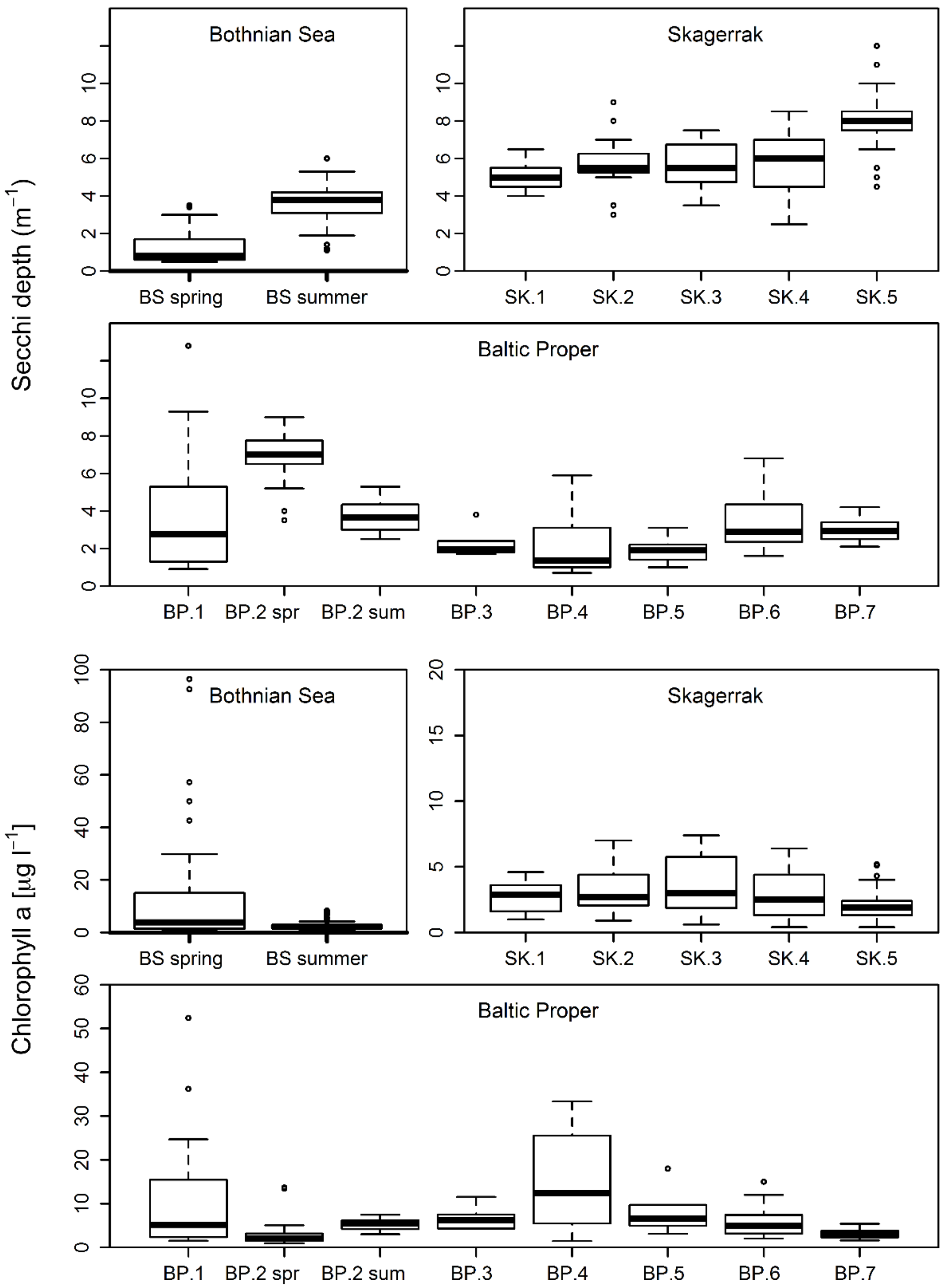
RANGES OF SECCHI DEPTH, CHL-A, CDOM AND SPM

The measurement ranges for Z_{SD} and other optical parameters for each sub-area in the three regions are given in Figure S1-3. The boxplots in Figure S1-3 displays the ranges of the optical variables per sub-area and in the Bothnian Sea per season. Horizontal lines in the boxplots show the median values, horizontal edges of the boxes the 25th and 75th percentiles, the whiskers the minimum and maximum observations within 10th and 90th percentiles, open circles represent outliers.

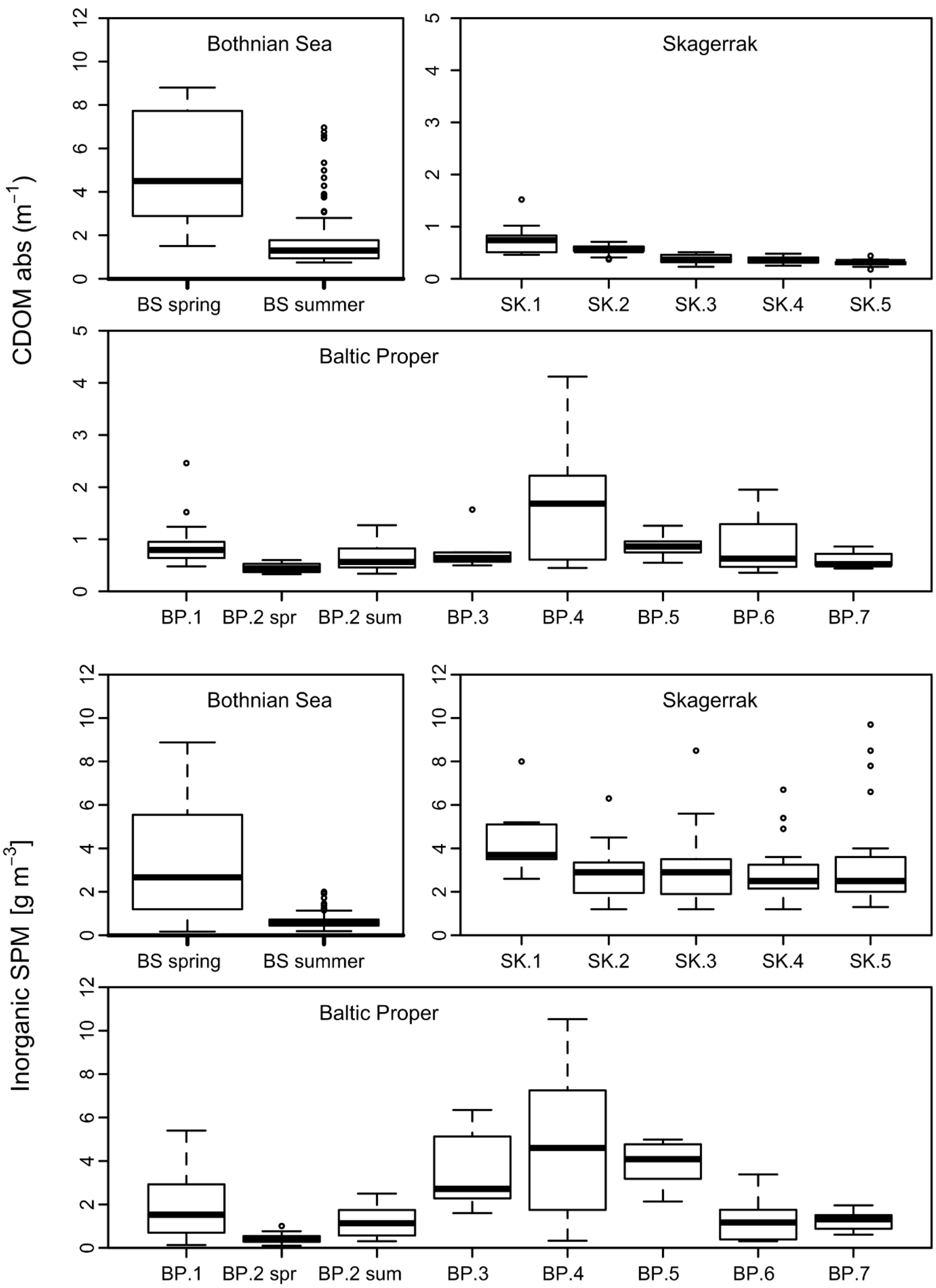
The Z_{SD} varied greatly between sub-areas in the Baltic Proper. In Himmerfjärden, BP.2, water clarity and Z_{SD} were greater in spring than in summer. In contrast, the Bothnian Sea had lower Z_{SD} in spring than in summer, due to a large run-off. In the Skagerrak region, sub-area SK.5 had high but quite variable Z_{SD}, explained by the proximity to the open sea and lower terrestrial influence (Figure S1). The Z_{SD} was above both the G/M and ref thresholds (6.3 and 2.8 m) during summer in the Bothnian Sea. In the Baltic Proper the thresholds vary with salinity and the ref levels were between 5.8 and 11.6 m and the G/M levels between 4 and 8 m. The observed Z_{SD} were often below the G/M thresholds. In the Skagerrak region many of the observations were above the Z_{SD} thresholds of 5 m for the G/M level and 8 m for the ref level. Sub-area SK.5 has higher thresholds, of 8 and 12 m, respectively as it is a more open sea area.

Some Chl-a concentrations in the Bothnian Sea in spring were extremely high, reaching nearly 100 μg l^{-1}, with a median of about 5 μg l^{-1}, but the summer median was lower (~3 μg l^{-1}). In the Baltic Proper sub-areas BP.1 and BP.4, the Chl-a concentration reached about 50 and 40 μg l^{-1}, but the medians were much lower. Chl-a variability was low in the Skagerrak region, with the lowest values at the more open sea station, SK.5 (Figure S1). However, the Skagerrak region usually has high Chl-a concentrations during the spring bloom.



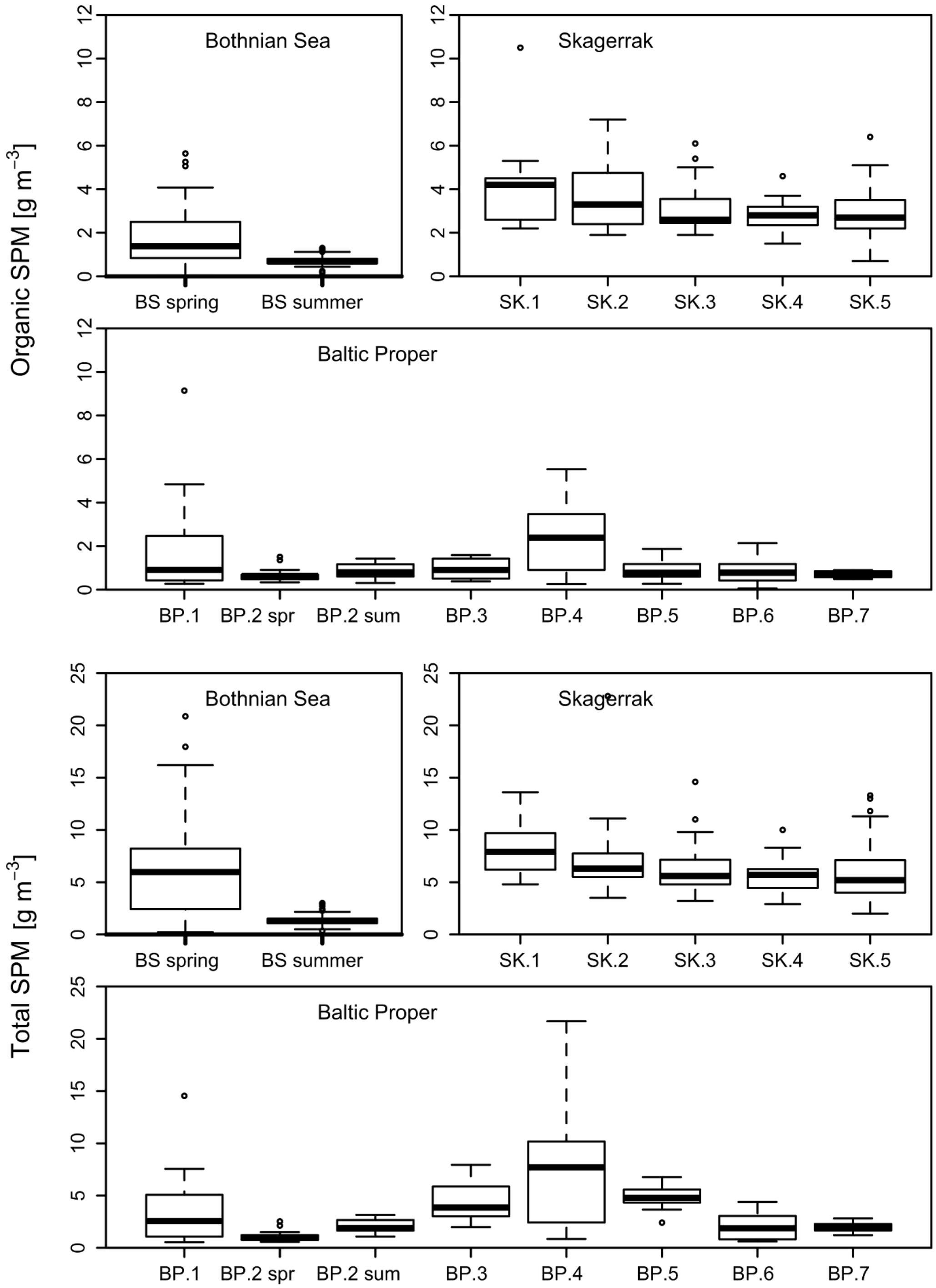
SUPPLEMENTARY FIGURE S1 | Boxplots of Z_{SD} (m^{-1}) and Chl-a [µg l^{-1}] for each region and sub-area. For the Bothnian Sea (BS) and Himmerfjärden (BP. 2) in the Baltic Proper, the data is separated for spring and summer. Note that the scales for Chl-a concentration on the y-axis differ between regions.

The highest CDOM observations were, as expected found in the Bothnian Sea, and the lowest in the Skagerrak. The highest CDOM values in the Baltic Proper were found in in sub-area BP.4, which has a large freshwater inflow (Figure S2).



SUPPLEMENTARY FIGURE S2 | Boxplots of CDOM absorption (m^{-1}) and inorganic SPM (SPIM) [g m^{-3}] for each region and sub-area. For the Bothnian Sea (BS) and Himmerfjärden (BP.2) in the Baltic Proper, the data is separated for spring and summer. Note that the scales for CDOM absorption on the y-axis differ between regions.

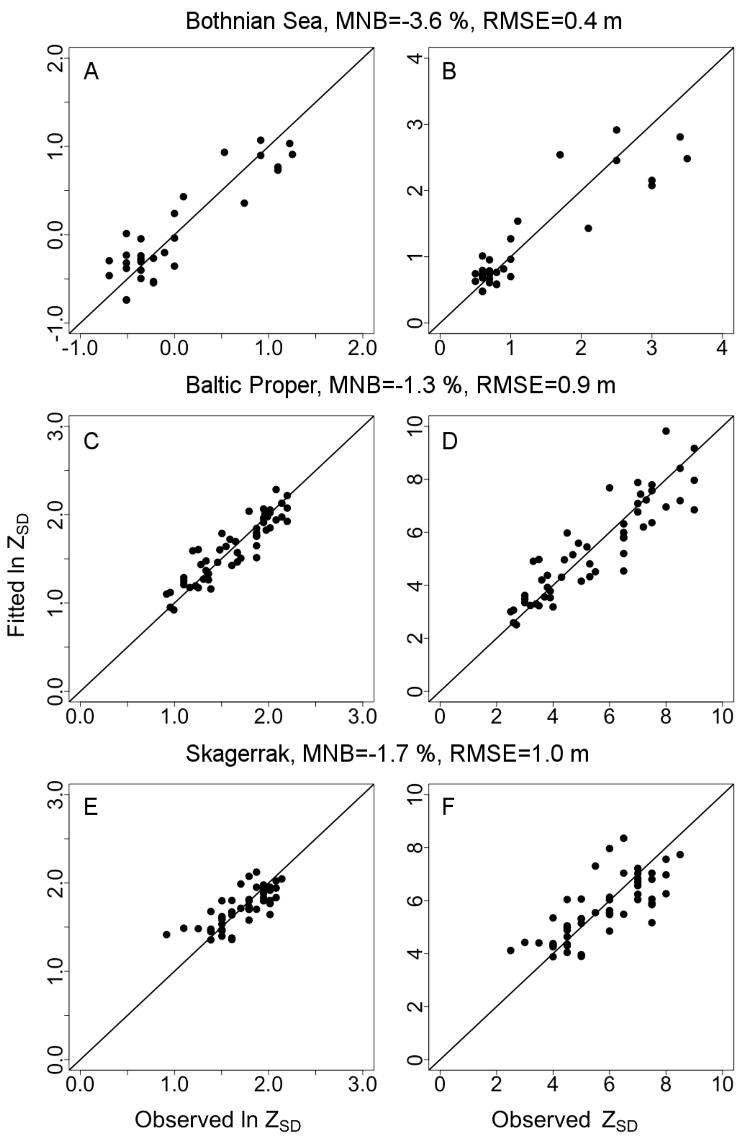
In the Skagerrak, the concentration was higher for SPOM (Figure S2) than for SPIM (Figure S3) but with less variability. In the Bothnian Sea, the concentration was lower and less variable for SPOM than for SPIM, in both cases with lower concentrations in summer. The variability of SPIM in the Baltic Proper was high within the areas BP.1 and BP.4, corresponding to also high CDOM, Chl-a and SPOM concentrations. The total SPM followed the same pattern as the most abundant sub-fraction.



SUPPLEMENTARY FIGURE S3 | Boxplots of SPOM [mg l^{-1}] and total SPM [mg l^{-1}] for each region and sub-area. For the Bothnian Sea (BS) and Himmerfjärden (BP. 2) in the Baltic Proper, the data is separated for spring and summer.

ASSESSMENT OF THE ADDITIONAL MODELS

Z_{SD} was predicted well also by the additional models with R^2_{adj} between 0.53 - 0.84 with a high precision (i.e. an RMSE of 0.4-1 m, equivalent to a NRMSE of only 9-16%) and a similar accuracy as the main models with a small negative bias, i.e. MNB of 1.3-3.6 % (Table 3). The graphs in Figure S4 shows the relationship between the observed and fitted Z_{SD} values. The spring model of the Bothnian Sea (Figure S4a & b) has a show a good prediction but was not further used when applying the refence and G/M Chl-a values, as the summer period was of interest. The other models were used for the applications of the EU Directive Secchi depth targets where the Baltic Proper model here represents data for the Himmerfjärden Bay (Figure S4c & d) and was overall performing very well with a R^2_{adj} of 0.82, low bias (MNB=-1.3%) and high accuracy RMSE=0.9 m). The Skagerrak model (Figure S4e & f) also captured the full range of Z_{SD}, with low errors (RMSE=1.0 m) and bias (MNB= -1.7%) but slightly lower predicting power with a regression coefficient, R^2_{adj} = 0.53.



SUPPLEMENTARY FIGURE S4 |

Graphs showing the observed Z_{SD} (m) on the x- axis vs. fitted Z_{SD} on the y-axis for the additional models per region. The left panel (**A, C** and **E**) shows the values in natural log scale and the right panel (**B, D** and **F**) in back-transformed normal scale. The Mean normalized bias; MNB and Root mean square errors; RMSE are indicated for each model.