Re:Hess-2012-42

Reply to reviewer #1, Dr. Dirk-Ingmar Müller-Wohlfeil

We are grateful for the thorough and constructive review, which we have acknowledged in the new revised version of the manuscript.

The review is in two parts. The first part is a general part with three bullets/paragraphs and the second part is an annotated version of the manuscript with comments and corrections written directly in the text.

In the following we consider every comment/correction in the order provided by the reviewer:

GENERAL COMMENTS

1) We have conducted an assessment of the precision of the model estimates for both gauged and ungauged areas and e.g. inserted the paragraphs below in sect. 3.2.1 and sect. 4.1, respectively, in the revised manuscript. Moreover, the calculation of the precision and bias for the N load estimate to the estuary (combined gauged and ungauged) is included in Appendix A:

   "The precision and bias of the estimated N-loading from the gauged catchments is assessed to amount to 10% and 0%, respectively, based on Monte Carlo evaluations of sampling frequencies and load estimates (Kronvang and Bruhn, 1996)."

.."The mean precision and bias from the validation of the model for total N at the two gauged stream stations are calculated to amount to 15.2% and 10.5%, respectively. Combining the uncertainty of the total N loading from both gauged and ungauged catchment areas to the Horsens estuary reveals a mean precision and bias amounting to 9% and 5%, respectively…"

2) We have moved the following paragraph from sect. 4.3.3 to sect. 3.2.2

…"Nutrient limitations is assumed to occur at 14 µg DIN L^{-1} and 6.2 µg DIP L^{-1}. These values are equivalent to K_m-values for growth in a Michaelis-Menten expression of 1 µmol L^{-1} for DIN and 0.2 µmol L^{-1} for DIP based on values given by MacIsaac and Dugdale (1969), Eppley et al. (1969), Falkowski (1975) and Quile et al. (2011)"...

We do not think the manuscript will benefit from moving other paragraphs in the paper.

3) We do agree that it is a rather large and transdisciplinary paper. However, we already refer to previous papers quite extensively without providing many details. We are afraid that it will be too difficult to follow the derivation of threshold values and understand the implications and possibilities for water management if we reduce explanations and discussions any further.

SPECIFIC OR GENERAL COMMENTS WRITTEN DIRECTLY IN MANUSCRIPT.

p2, l18: corrected

p3, l5-6: revised as suggested

p3, l19: We have not changed this as requested as we find plenty of evidence in research papers during the past several decades that this certainly is the case (see e.g. listed citations)

p4, l15: This and following sections have been modified in the revised manuscript:

.."Presently, the EU directives do not require a similar derivation of stream threshold values based on the ecological status of their marine recipient. However, we recommend that stream and groundwater threshold values are derived together, as stream threshold values can be calculated directly from estimated maximum nutrient loads to lakes and marine areas, when the relative nutrient loads to these recipients directly from groundwater and streams have been estimated. Groundwater threshold values can then be estimated based on the stream threshold values from the groundwater contributions to stream and estuary nutrient loads as estimated by monitoring and modeling data. It should be noted that it may be needed to set stricter nutrient threshold values for streams (e.g. Camargo and Alonso, 2006) or even for groundwater in some cases (Griebler et al., 2010). In this paper, however, we solely derive groundwater and stream threshold values based on the ecological status of the Horsens estuary."...

We believe this clarifies and explains our approach

P5, l12: Danish is inserted as suggested

P5, l20: revised as suggested - the "s" on lives has not been removed though as it refers to population, which is not plural

P6, l3: We have revised the figure and clarified the calculations and data sources. We trust that it now satisfies the reviewer

P6, l7: – "April – March" has been inserted

P6, l19: It is not just the same order of magnitude as mentioned by the reviewer, but quite similar concentrations to what is observed in the mentioned estuaries according to Boynton and Kemp (2008). We have changed "comparable to" to "similar to"

P7, l14: As mentioned in bullet 1 under general comments the following has been inserted in sections 3.2.1 and 4.1 and a thorough description of the calculation is given in Appendix A.

"The precision and bias of the estimated N-loading from the gauged catchments is assessed to amount to 10% and 0%, respectively, based on Monte Carlo evaluations of sampling frequencies and load estimates (Kronvang and Bruhn, 1996)."

.."The mean precision and bias from the validation of the model for total N at the two gauged stream stations are calculated to amount to 15.2% and 10.5%, respectively. Combining the

uncertainty of the total N loading from both gauged and ungauged catchment areas to the Horsens estuary reveals a mean precision and bias amounting to 9% and 5%, respectively."…

P7, l15: corrected

P7, l20: We have changed the wording to: "was made for..."

P8, l1: revised as suggested

P8, l4: revised as suggested

P8, l12, 21, 23 and p9, l5: The long section has been revised extensively to the following:

.."Monthly freshwater discharge and transport of nutrients (total N and total P) are calculated using a linear interpolation method (Kronvang & Bruun, 1996) by multiplying daily nutrient concentrations with mean daily discharge calculated from stage-discharge relationships, developed for each of the two gauging stations situated in the main stream inlets (Fig. 1). Land based monthly nutrient loadings and freshwater discharge from the entire catchment to the Horsens estuary for the period 1984 to 2009 have been estimated utilizing data from the two gauged stations, and adding modeled monthly freshwater discharge and nutrient loadings from the ungauged part of the catchment by using the DK-QN model complex according to Windolf et al. (2011) (Fig.2.). The precision and bias of the estimated N-loading from the gauged catchments is assessed to amount to 10% and 0%, respectively, according to Kronvang and Bruhn (1996). The DK-QN model is a combination of an empirical nutrient loss models and the physically based, distributed and integrated hydrological "DK-model" ("the Danish National Water Resources Model", Henriksen et al., 2003), which is based on the integrated hydrological modeling system MIKE SHE (Abott et al., 1986; Graham and Butts, 2005), and calibrated against groundwater heads and runoff. The latest version (second generation) of the DK-model is developed with a grid size of 500 m x 500 m (the first setup was 1000 m x 1000 m). In this study we have reduced the grid size even further to 250 m x 250 m, and used this resolution for the discharge estimation in both gaged and ungauged subcatchments. The surface/stream and subsurface water discharges from the catchment to the estuary, 87 % and 13 %, respectively, are derived from DK-model simulations of the Horsens catchment. Monthly nitrogen loadings were also modeled for the two gauged catchment thus allowing a validation of the applied DK-QN model complex against measured nitrogen concentrations at the two gauged stations. Moreover, the nitrate leaching from the root zone (upper 1 m) was calculated for the entire catchment to the Horsens estuary using the Danish empirical NLES leaching model, which performed well in a large inter-comparison with seven other well-known nutrient models (Kronvang et al., 2009b)."..

We trust that the revisions above take care of the reviewer comments to this part of the manuscript.

P9, l7-8: We have deleted the sentence about the environmental authorities as it is not correct - P loadings were computed using linear interpolation as for N

P9, l8-9: The sentence has been revised to:

.."The total loadings were apportioned to sources according to equation 1 and Kronvang et al. (2005), Table 3."..

Further the abbreviations have been spelled out to: *(Industrial Plants (IP's), Waste Water Treatment Plants (WWTP's), and Fish Farms (FF's)*

P10, l1: Equation two has been deleted as requested by the other reviewer (reviewer #2), this also deals with the comment in line 17 by reviewer #1

P10, l5-6: Revised as suggested

P10, l14: corrected as requested

P10, l116: Revised - the following has been inserted in parentheses after DIN and DIP, respectively:

(dissolved inorganic nitrogen = NO_2-N + NO_3-N+NH_4-N)

(dissolved inorganic phosphorus = PO_4-P)

P10, l19: The following has been inserted:

.."for both depend and independent variables"..

p10, l23: corrected

p11, l7: reference corrected in ref list

p11, l8: The following was inserted:

.."RMSECV were also used to determinate the maximum number of explanatory variables (between two and five) without overparameterisation of the model. Outliers where identified from the jack-knifing procedure according to Martens and Dardenne (1998)."..

P11, l9: We do not understand this comment - yes there's a small difference in coefficients as would be expected

P12, l1-2: The following has been inserted at the end of this section (3.2.2):

..."Nutrient limitations is assumed to occur at 14 µg DIN L^{-1} and 6.2 µg DIP L^{-1}. These values are equivalent to K_m-values for growth in a Michaelis-Menten expression of 1 µmol L^{-1} for DIN and 0.2 µmol L^{-1} for DIP based on values given by MacIsaac and Dugdale (1969), Eppley et al. (1969), Falkowski (1975) and Quile et al. (2011). "...

P13, l8: We believe that we explain it in the next sentence, but the following has been inserted to clarify further:

..., "while the groundwater threshold values depend on how and where remediation measures are applied and nutrients are removed/immobilized. Hence, from the point of view of an associated estuary groundwater thresholds for e.g. nitrate (or total N) can be significantly higher if efficient

wetlands for removal of nitrate before discharge to streams or the estuary are constructed (see discussions in section 3.3. and 5.3).”..

P13, l18: No - it is not among the 83 catchments. This is noteworthy and emphasizes the good performance of our model system (see e.g. fig. 3). Further, it gives us the opportunity for independent validation of our model and estimation of the model precision and bias in the two gaged catchments. We then assume that these also apply to the ungauged catchment/total catchment.

P13, l20: Missing reference *Windolf et al., 1996* has been inserted

P14, l1: Please note that we write that 90 % of the total N loads to the estuary are from streams in the beginning of section 3.4. However, as written in the abstract and elsewhere the acceptable level of N and P stream concentrations are estimated to 52 and 56 % of the current, respectively – approximately corresponding to the required reduction level for the estuary (as streams by far supplies the largest amount - 90 % of total input). We hope this clarifies the issue

P14, l14: The drain flow is predominantly in drainage tiles. In some rare circumstances ponding on the surface and preferential flow directly to the drain tiles through fractures may occur, but we are quite confident that this is an insignificant part in our system.

P14, l19: We have inserted (ca. 8 ha) after level to specify the size

P15, l21: The following has been inserted at the end of sect.4.1:

…”The mean precision and bias from the validation of the model for total N at the two gauged stream stations are calculated to amount to 15.2% and 10.5%, respectively. Combining the uncertainty of the total N loading from both gauged and ungauged catchment areas to the Horsens estuary reveals a mean precision and bias amounting to 9% and 5%, respectively…”

P16, l3: The following text has been inserted in sect. 4.2:

..”The DK-model simulations estimate that approx. 13 % of the net precipitation in the catchment to the Horsens estuary is discharged directly to the estuary via groundwater (sect. 3.2.1). As the redox-boundary generally is located few meters below the water table in the catchment we estimate that the major part of the groundwater that discharge directly to the estuary is reduced and without nitrate. Hence, we argue that the nitrogen loading to the estuary directly from groundwater most probably is insignificant.”…

P18, l3: Yes, data are checked for normal distribution and other requirements for the statistical method applied. The outliers were identified statistically from the jack-knifing procedure according to Martens and Dardenne (1998). A sentence about that has been added to the method section as mentioned previously. There were no other reasons for excluding the two points. We also find that the correct procedure is to identify outliers with an objective statistical procedure. However, a non steady state relationship between sediment and water column might also be important as indicated in the added text.

The last four years where excluded from the procedure that selected the explanatory variables, in order to see if these years would deviate significantly from the other years. The last four years were chosen to test the models capability to predict the future development. We fully agree with the reviewer that there is a tendency to overestimation, which we believe is associated with the pool of nutrients buried in the sediment. We have added new text in sect. 4.3 on this issue, - see reply to p18, l15 below:

We have no reference supporting that wind stress increase nutrient concentrations. Several hypothesis can be suggested, however, e.g. Increased resuspension in the shallow estuary or more light limitation of photosynthesia in a turbulent water column, which will lower the uptake by phytoplankton of nutrients. However, we feel that it is beyond the scope of this paper to include discussions on this.

P18, l5: The following has been inserted in the first paragraph of section 4.3:

…"The patterns in the residuals (fig. 6b) reveals that negative residuals are mainly found in the beginning and the end of the period and positive residuals in the midle, starting in 1992 and continuing for about 10 years. This could indicate a non steady-state situation where the nutrient pool in the sediment for a period of approximately ten years leak nutrients to the water column (Lomstein et al. 1998, Christensen et al. 2000) before a new equilibrium is established between external loadings and the sediment pool…"

P18, l18: The following references have been inserted:

(Lomstein et al. 1998, Christensen et al. 2000).

P19, l7: described in new text above

P19, l15-17: This sentence has been moved as suggested to sect. 3.2.2.

P20, l12: We feel that these have been explained by the text above and Figure 8 in a reasonable detail; we do not see the need for further explanations

P21, l18: corrected

P23, l23: We have inserted precision estimates in the text in sect.3.2.2. and 4.1 as described previously - note also reviewers own comment in p24, l3.

P24, l12: Yes – the P sources, transport and mobilisation processes are not as well-known as for N. Reference has been changed to Kronvang et al., 2009b

P24, l13: We feel that this has been explained in sufficient detail considering that the focus of the paper is the derivation of groundwater threshold values.

P24, l21: reference is corrected

P28, l21-23: We agree that ecological driven thresholds should solely reflect the requirements of the target ecosystem, and this is also what our values do, or at least what we are trying to do. The

message here is that such values are not universally applicable for all catchments to estuaries, but that they depend on the actual setting and therefore have to been derived specifically for each setting

P29, l18: not corrected – breached is correct

P30, l10: The stations have been “highlighted” further in the figure

P31, l17: Changed to Jeppesen et al., 2009, 2011; "and to the Baltic Sea in general (Hagg et al., 2010)" has been inserted after cited list of references

P32, l3: corrected

P35: References without citations in the text have been either deleted or inserted in the text, and the py of the Broadhurst et al paper was corrected

P37-42: The references have been checked and corrected, inserted or deleted as requested.

P45, l9: We did that already – HESS does not use italics for “et al.”

On behalf of all authors,

Klaus Hinsby