RESPONSE TO REFEREE'S COMMENTS

Referee #1 – Comments

More description of the qualitative analysis of inputs (section 3.4) earlier in the text would be helpful. Perhaps move the relevant text from p 7572 line 10+ to section 3.4.
The relevant paragraph from section 4.3 has been moved to section 3.4 to add more information about the qualitative analysis of input data.
Links between model uncertainty and sensitivity to input data are discussed in the corresponding section in the discussion.

It would be interesting to compare predictions of N and P source attribution to that of other models. Nutrient Exports from Watersheds (NEWS) has been applied at a global scale (e.g. Mayorga 2010, Dumont 2005, Harrison 2010). While NEWS is coarser in scale, such a comparison could be interesting. Also, are there any isotope studies in the catchment that address nutrient sources and could be used to compare to model predictions?
References quoted in the text, section 1.
While it would be very interesting to apply the model NEWS (or other nutrient apportionment models) to La Tordera catchment and compare the estimations of nutrient emissions obtained by different models, this is a complex undertaking that we feel goes beyond the scope of our present paper and would require a separate paper.
With regards to isotope studies addressing nutrient sources, in the context of Spanish national project ISONEF, our group at the Department of Ecology (University of Barcelona) has already started working on La Tordera basin, studying N15 signal of primary uptake compartments (biofilm, algae, macrophytes, etc.) in the stream, in relation to the natural isotopic signal of nitrogen sources (agricultural, point sources, N deposition, etc.).

I am not sure Fig 8 provides much insight beyond what could be accomplished in a line or two of text.
It would be interesting to see maps of the single largest source of N and P.
The figure is relevant here; it shows spatial variation in nitrogen retention, while showing strong contrasts between a humid year and a dry year.
Also, with regards to your other comment, we have improved the figure by adding a map of total nitrogen emissions for the same years (see Fig. 8).

Referee #2 – Comments

The research identifies some interesting points that upon further investigation should generate interesting and valuable conclusions. For example, the model results suggest a wide range of in-stream nutrient retention. These results are very important with regard to reducing nutrient export and some novel research questions could be investigated: Are there specific land-use types associated with the areas with low nutrient retention? How do physical characteristics of the streams with low nutrient retention differ from those with high nutrient retention? What, if anything, can be done to improve the in-stream retention of streams that currently have low retention? Although a more detailed discussion of the retention is provided on p. 7574 line 20 through p. 7575 line 15, these types of questions regarding spatial variability are not addressed and have important implications for land management. Such information would help agencies decide what management practices should be implemented and where they should be implemented in order to significantly reduce nutrient loads.
Rivers in Mediterranean Europe have been less intensively monitored and less studied than rivers in Central Europe. Due to poor databases, we encountered many uncertainties, notably related to diffuse sources, which are still largely unaddressed.
Also because of low and variable flows (typical of Mediterranean rivers), physical characteristics of the river's soil, riparian areas (not considered explicitly in this study), variability in precipitation, which are the main relevant factors related to nutrient retention during nutrient transport, the study of nutrient retention was complex to perform. One of our main points regarding retention is that it is the result of a large set of processes that we cannot tease apart with the data and model at hand. In addition, because retention is modeled as a function of discharge and calibrated from data, it must incorporate biases in emissions estimates, which the

model may overestimate. While interesting as a question, trying to relate the estimated retention to catchment characteristics may be too much of a stretch.

Additionally, the research suggests that "agricultural diffuse sources on nutrient loads remains a problem" (p. 7574 lines 10-11) despite decreases in fertilizer use (p. 7574 lines 3-6). Similar trends have been observed by other researchers for agricultural catchments and have very important implications regarding the best management practices likely to most effectively reduce nutrient export. Please refer to Basu et al., 2010 and Thompson et al., 2011 (references given below) and include an enhanced discussion of this aspect of the modeling results.
References quoted in the discussion and more information about this aspect has been added in the text.

The manuscript should shift the focus away from model calibration, validation, and sensitivity and instead emphasize the implications of the research findings in terms of management strategies for reducing nutrient export. Specifically, the researchers should further investigate: (i) spatial variability of in-stream nutrient retention; (ii) reasons for the long-term impacts of agricultural land; and (iii) inter-annual variability of flow-weighted concentrations.
The objective of this paper was not to focus on the management of nutrients nor on the evaluation of optimal management strategies for the anthropogenic sources of nutrients. In this paper, we present a modeling exercise of N and P emissions to a river catchment. This application of the model MONERIS presented here have served as a basis for the elaboration of quantitative nutrient emissions scenarios and, therefore, of management strategies aiming at reducing nutrient emissions. An assessment of the effectiveness of the scenarios in terms of nutrient loads is presented in the context of catchment management in a separate paper, which is ready for publication (Caille 2009; Caille et al., in prep.)

Specific Comments

p. 7559 lines 8-10: Dominant soil type(s) should be included here.
We have added a sentence with information on the main soil classes in the catchment.

p. 7559 lines 16 – 19: It would be helpful to provide a summary of the flow variability along with Figure 2, where the authors show annual precipitation box and whisker plots.
See new figure 2 showing annual precipitation and flow.

p. 7560 line 19: Readers should be referred to Figure 3 when the Forgars monitoring station is introduced.
Figure 3 and label of subcatchment added in the text (see manuscript).

p. 7562 line 20 through p. 7566 line 17: Moving this section from the main body of the manuscript to Supporting Information would help to make this manuscript much more concise.
In this paper, we present a modeling exercise of nutrient emissions to a river catchment. Our main objective is to validate the application of MONERIS to La Tordera catchment in order to explore future scenarios in the context of river basin management plans as required by the Water Framework Directive. All this section refers to model setup and is essential for understanding how to run the model MONERIS and describe the analysis.

p. 7563 lines 7-8: What are the dominant soil drainage classes in irrigated agricultural areas? If the soils are well-drained, it is highly unlikely that the area is tile-drained, whereas if the soils are poorly-drained, than the assumption of tile drainage is probably correct.
Irrigated agricultural areas in La Tordera basin are generally small in area, close to the river, and drain quickly to the stream after heavy rainfall (Fig. 1). Thus, we have categorized them as tile drained areas as the closest land use class for MONERIS.

p. 7563 line 17: It is unclear what the authors mean by "good or poor porosity". Perhaps referring to the soil drainage class would be more beneficial to readers.
We followed the definition of hydrogeological classes given in the MONERIS manual: subdivided into consolidated rock with high porosity or impermeable and unconsolidated rock types with shallow and deep groundwater (Venohr et al., 2009). For La Tordera catchment, the

four classes were obtained by digitising the hydrogeological map of Catalonia (referenced in the text).

p. 7563 lines 20-24: This information should be moved to the Study Site section.
This information refers to the model setup, as it concerns the origins of spatial input data required to run the model. Thus, we have left it unchanged.

p. 7563 line 26: Use of the phrase “best judgment” is vague. The authors should attempt to describe how DARP and IRTA estimated values (*e.g.,* knowledge of past and current land use, types of crops grown on agricultural land, etc.?).
Experts from DARP and IRTA have a lot of experience with analysis of agricultural soils from Catalonia and a broad knowledge of past and current land use and conditions. Their estimated values were based on various studies and analysis conducted on soils adjacent to and partially including La Tordera catchment. See changes in the manuscript.

p. 7565 lines 3-4: How was precipitation used to make these estimations? What methods and/or assumptions were made and what validation was done to ensure these methods were appropriate?
Discharge was modelled with the Sacramento model as part of a Catalan-wide analysis of stream discharge using the best time series data of meteorology and discharge. See in the reference section the following document: ACA, 2002b, where methods, assumptions and results are presented and discussed in detail.

p. 7568 lines 22-23: What criteria were used to assign a reliability rating for the input data? The ranking from 1-5 seems ambiguous without further discussion in this section of the manuscript or as additional information that could be added in the SI.
First paragraph of section 4.3 moved to section 3.4 to add information about the description of the qualitative analysis of input data (see changes in the text, section 3.4).
Input data from the study catchment were better than estimated data based on external areas (e.g., N and P content in arable topsoil, maps of soil classes, flow, etc.).

p. 7570 line 5: The E value prior to this change should be provided; “substantially improved the model fit” is not quantitative enough.
The model was calibrated for a correction factor to increment industrial inputs yearly from 2001 backwards towards 1996 for two reasons: 1) without the correction, model results consistently underestimated loads backwards in time, and 2) industrial waste water treatment was progressively implemented over the previous decade. We were forced to make to introduce this factor because data on nitrogen and phosphorus loads were only available for 2002, as explained in the text. We do not include changes in Nash-Sutcliffe efficiencies because these were not so significant overall, yet visual inspection of estimated and observed loads versus time per catchment revealed significant biases in specific catchments.

p. 7570 lines 9-13: The values reported for the range of N and P retention are actually quite large. It would be very interesting to investigate what areas in the catchment had the least retention and see if any connections can be made between land use and low retention.
See our first comment to Referee #2 above.

p. 7573 lines 6-8: It has been discussed in previous sections of the manuscript that the model is particularly sensitive to precipitation. Of course, the precipitation varies from year to year, as does the amount of flow discharged by the catchment. The spurious relationship between load and flow suggests that simply comparing inter-annual nutrient loads is insufficient. Please calculate the annual flow-weighted concentrations (annual mass exported/annual flow discharge) and compare these values, as they remove the bias caused by inter-annual variations in flow.
The referee is right in pointing out a spurious correlation between load and flow, and its impact on model sensitivity to precipitation. However, we are quick to point out in the discussion that sensitivity to precipitation was expected given the model formulation, and that MONERIS would not be appropriate to explore impacts of climate variability, including climate change. Model sensitivity to other input data certainly has greater relevance to catchment management.

p. 7474 lines 22-23: How much of the 50% reduction was nitrogen and how much was phosphorus?
Values of P and N, 46% and 52% respectively, have been added to the text.

p. 7577 lines 19-21: Although it is clear from the sensitivity analysis results that this statement is true, it is unclear how this statement translates to useful information for reducing nutrient export. For example, it is unlikely that inhabitants will decrease, that tile drainage will be removed, or that atmospheric deposition will decrease in the near future. Perhaps a more detailed discussion regarding the surplus of nutrients in the topsoil would prove useful.
We added a sentence focusing on nutrient management and emissions reduction. Information related to erosion control (i.e., protecting soil from direct impact of rain and wind by keeping it covered with plants) and stronger reductions in fertiliser application that should lead to a reduction of nutrient emissions coming from on-site soil loss and N surplus, respectively. Among the other input data, such as atmospheric deposition, it is more difficult to manage and control nutrient emissions (See changes in the text of the manuscript) Also, as noted above, the present paper aims at discussing the model calibration and sensitivity to La Tordera, while an application to future scenarios is presented elsewhere (Caille 2009; Caille et al., in prep.).

Figure 1: The figure is cited as coming from the Catalan Cartographic Institute; however, the authors do not provide any documentation of permission from this institute to use this figure for publication.
The figure does not come from the Catalan Cartographic Institute. We made the figure based on data coming from the Catalan Cartographic Institute. Modified and replaced in the figure legend by "Original, based on data from ICC".

Technical Corrections

p. 7558 line 18: catchment,
Done

p. 7560 line 5: The phrase "land use change" is more suitable than "territorial change".
Done

p. 7561 line 4: The word "prohibited" is more suitable than "advised against".
In this context, the term "prohibited" is a bit too strong and categorical. We wanted to explain that the use of a complex and dynamic model is not recommended if the study catchment has limited data availability.

p. 7561 line 22: The word "sought" should be replaced by "thought".
Not changed: "sought" is what we wanted to say.

p. 7563 line 10: Replace "mapped" with "determined" or "calculated.
Not changed: we think "mapped" is more explicit and suitable.

REFERENCES

Caille, F.: Integrated environmental assessment of nutrient emissions in a Mediterranean catchment: A case study in La Tordera, Catalonia. PhD Thesis, Autonomous University of Barcelona, Bellaterra, Spain, available on-line at http://cataleg.uab.cat/, 2009.

Caille, F., and Riera, J. L.: Quantitative nutrient emissions scenarios for a Mediterranean basin, La Tordera (NE Spain), in preparation.

Venohr, M., Hirt, U., Hofmann, J., Opitz, D., Gericke, A., Wetzig, A., Ortelbach, K., Natho, S., Neumann, F., and Hürdler, J.: The Model System MONERIS, version 2.14.1 vba, Manual, Leibniz-Institute of Freshwater Ecology and Inland Fisheries in the Forschungsverbun, Berlin e.V., Müggelseedamm 310, 12587 Berlin, Germany, November 2009.
Available on-line at: http://moneris.igb-berlin.de/tl_files/downloads/Handbuch_englisch.pdf).

P.S.: please do not hesitate to contact me if you require further information on the corrections, and if you would like to receive the updated maps and the corrected paragraphs.