Dear Dr. Seibert,

We are very grateful for your dedication and comments to our manuscript. The deep review at which we have subjected to our paper certainly has substantially improved it.

We hope to have responded adequately to all the issues raised. The specific answers to each question are found in the replies to the published comments, which have been posted on the hess-discussion website. (http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-606/#discussion)

The **language** has been improved in **accuracy** and **understanding**. A new certificate of the new uploaded version of the paper is included.

Uncertainty has deserved further exposure in an appendix. It was considered the possibility of inserting different paragraphs in the different sections of the paper or to give a specific section within the main body of the text. However, we have finally chosen to include this discussion in an appendix (after References) because it allowed us to give the deserved importance without further complicating the writing of the different chapters. It also allowed us to re-quote questions already dealt with in the main text without being unnecessarily redundant.

Thank you very much.

Yours sincerely,

Jose M. Santiago

Dear Dr. Ouellet,

We appreciate very much the meticulous work that you did. Your comments are very valuable for us and it is doubtless our work will enrich from them.

GENERAL COMMENTS:

Since both air and water temperature terms are used in the paper, please specify throughout the manuscript to which term the authors are referring, thus avoiding the use of only the term temperature since in some paragraph it could be confusing. Thank you. Truly, many times the context does not clear up of which temperature we are talking about.

In the IS notation, there is a non-breaking space between numbers and °C. Please modify throughout the document. Certainly, we should have been more careful to follow the same criteria throughout the manuscript.

Those are difficult results to present but the presentation could be improved (see specific comments) to help the reader having a better understanding and be able to have a quantitative appreciation of the differences between scenarios. Taken into account.

SPECIFIC COMMENTS:

P2-L2: physiological functions such as blood… can you be more specific? Are you referring to the blood cell formation/maturation? We refer to the blood physiological function. Certainly, this must be clarified this. A more appropriate way to say it could be: "physiological functions such as **blood function**…" We will change it.

P2-L13: add **by** between ecosystems and altering. Thank you for noticing.

P2-L15: will be interesting to add with the geographical location a mean increase value. We changed the wording to: "Stream temperature increases have been documented for the last decades throughout the globe, in Europe (e.g., Orr et al., 2015, reported a mean stream temperature average increase by 0.03°C per year in England and Wales), Asia (e.g., Chen et al., 2016, mean stream temperature increase by 0.029-0.046°C per year at Yongan River; eastern China), America (e.g., Kaushal et al., 2010, mean stream temperature increases by 0.009–0.077°C per year) and Australia (e.g., Chessman, 2009, stream temperature increases by 0.12°C per year between sampling campaigns)."

P2-L32: is instead of was. Thank you. It was changed.

P3-L10: I will suggest merging the two sentences, directly mentioning changes in fish habitat suitability and availability. New wording: "The results are daily values to be used for the assessment of fish habitat suitability and availability."

P4-L19: what do you mean by not probable? Territorial planning does not consider significant changes of land-use at mid-century and, objectively, changes are not expected after that horizon because a high percentage of the territory is protected. (This will be included in the corrected manuscript.)

P5: were the logger shaded and tested prior to deployment? Did you check if the data from AEMET were corrected for change in instruments or station location trough time? Loggers were tested for malfunction before been deployed and they were placed avoiding direct sunshine. Air temperature and precipitation data obtained from AEMET were tested to assess their reliability by applying a homogeneity test. This test is based on a two-sample Kolmogorov–Smirnov test,

and it marks years as possibly inhomogeneous data. In a second phase, the marked years are matched against the distribution of the entire series to determine if they have true inhomogeneities, searching for possible dissimilarities between the empirical distribution functions. This technique was used by us in the previous paper: Santiago et al. (2016). Only reliable series were used. The location of the stations did not change in the studied period. These explanations will be included in the manuscript.

P9-L19: A table summarizing the different values found across different geographical range will be interesting here. The 7 days period is usually used for incipient lethal temperature (ILT) (it is highly variable depending on acclimation and the rate of change in water temperatures) and the values are higher than the one chose in this study. Studies on thermal tolerances usually use shorter exposure time… I feel more explanation is needed to understand if the goal is to assess the changes regarding to ILT so brown trout will be expected to disappear from the habitat or regarding to suitable thermal tolerances linked to growth and other physiological parameters (as the chosen threshold suggest), which implies that the specie may still be found but not be performing. I think the manuscript will benefit from a slightly extended justification.

The new table is below:

Table 3. Different classes of thermal thresholds for emerged trout classes found in literature. Type of experiments differentiate experiments with controlled (laboratory) and uncontrolled (wild) temperature. Latitude of the experiments' location is showed.

variable	temperature (°C)	type of experiment	latitude	reference
maximum growth	13.1	laboratory	54ºN	Elliott et al. 1995
maximum growth	16	laboratory	61ºN	Forseth & Jonsson 1994
maximum growth	16.9	laboratory	43ºN	Ojanguren et al. 2001
maximum growth	13.2	wild	43ºN	Lobón-Cerviá & Rincón 1998
maximum growth	13	wild	41ºS	Allen 1985
maximum growth	15.4-19.1	laboratory	59ºN	Forseth et al. 2009
thermal optimum	14.2	wild	47ºN	Hari et al. 2006
upper growth limit	19.5	wild	41ºS	Allen 1985
upper thermal niche	20	wild	47ºN	Hari et al. 2006
upper thermal niche*	18.1	wild	41ºN	Santiago et al. 2016
upper thermal niche*	18.7	wild	41ºN	Santiago et al. 2016
critical feeding temperature	19.4	laboratory	54ºN	Elliott et al. 1995
critical feeding temperature	≥23	laboratory	59ºN	Forseth et al. 2009
incipient lethal temperature*	24.7	laboratory	54ºN	Elliott 1981
ultimate	27.8	laboratory	Norway	Grande & Andersen 1991
ultimate**	29.7	laboratory	54ºN	Elliott 2000

*: 7 days; **: 10 min.

We don't talk about thermal tolerance, we want to talk about realized thermal niche and on the conditions in which the exclusion probability is high for trout. The realized niche must reflect the energetic efficiency: long time above that threshold makes the animals less efficient competitors and its performance would decrease critically (Magnuson et al. 1979, Verberk et al, 2016). Thus, we focus our study on realized thermal niche. In experiments in which water modelling was done, it was usual to use weekly moving average stream temperature and to contrast it against a threshold, like the one given by Elliott et al. (1995). On the other hand, the usual time for

determining thermal tolerance is 7 consecutive days (Elliott and Elliott 2010). However, using the weekly moving average could introduce errors such as the overestimation of the importance of a threshold. This is because a given weekly moving average does not indicate that every considered daily average is equal to or higher than the weekly moving average. Furthermore, in Santiago et al. (2016), we tested the adequacy of using: (1) daily mean stream temperature (DM); (2) 7-day moving average of DM; (3) daily maximum stream temperature (DMax); and (4) 7-day moving average of DMax to model thermal behaviour of streams and to determine the brown trout presence/absence ecological thresholds. We found that DM was the best solution to model thermal behaviour of the streams, and the study of events of 7 consecutive days above the threshold was better than 7-day moving average. In addition, the used threshold (18.7°C during 7 -or more- consecutive days) was originally determined in one of the streams of this paper (Cega stream). Consequently, daily mean temperature and 7 consecutive days threshold were used in this study because they better reflect the average conditions that trout experience for an extended period.

Bustillo, V., Moatar, F., Ducharne, A., Thiéry, D., & Poirel, A. (2013). A multimodel comparison for assessing water temperatures under changing climate conditions via the equilibrium temperature concept: case study of the Middle Loire River, France. *Hydrological Processes*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/hyp.9683/full

Edinger, J. E., Duttweiler, D. W., & Geyer, J. C. (1968). The response of water temperatures to meteorological conditions. *Water Resources Research*, *4*(5), 1137–1143.

Elliott, J., & Elliott, J. (2010). Temperature requirements of Atlantic salmon Salmo salar, brown trout Salmo trutta and Arctic charr Salvelinus alpinus: predicting the effects of climate change. *Journal of Fish Biology*, *77*(8), 1793–1817. https://doi.org/10.1111/j.1095-8649.2010.02762.x

Elliott, J. M., Hurley, M. A., & Fryer, J. (1995). A new, improved growth model for brown trout, Salmo trutta. *Functional Ecology*, *9*(2), 290–298.

Magnuson, J. J., Crowder, L. B., & Medvick, P. A. (1979). Temperature as an Ecological Resource. *American Zoologist*, *19*(1), 331–343. https://doi.org/10.1093/icb/19.1.331

Santiago, J. M., García de Jalón, D., Alonso, C., Solana, J., Ribalaygua, J., Pórtoles, J., & Monjo, R. (2016). Brown trout thermal niche and climate change: expected changes in the distribution of cold-water fish in central Spain. *Ecohydrology*, *9*(3), 514–528. https://doi.org/10.1002/eco.1653

Verberk, W. C. E. P., Durance, I., Vaughan, I. P., & Ormerod, S. J. (2016). Field and laboratory studies reveal interacting effects of stream oxygenation and warming on aquatic ectotherms. *Global Change Biology*, *22*(5), 1769–1778. https://doi.org/10.1111/gcb.13240

P14-Figure 6: this figure is difficult to read, text overlap, difficulty to discern the white dots, etc. I am not sure which sites belong to which clusters from the figures. May be split in 2 figures based on RPC4.5 and 8.5? We have tried several alternatives (even using GIS-maps) and, finally, we selected the following solution as optimal.

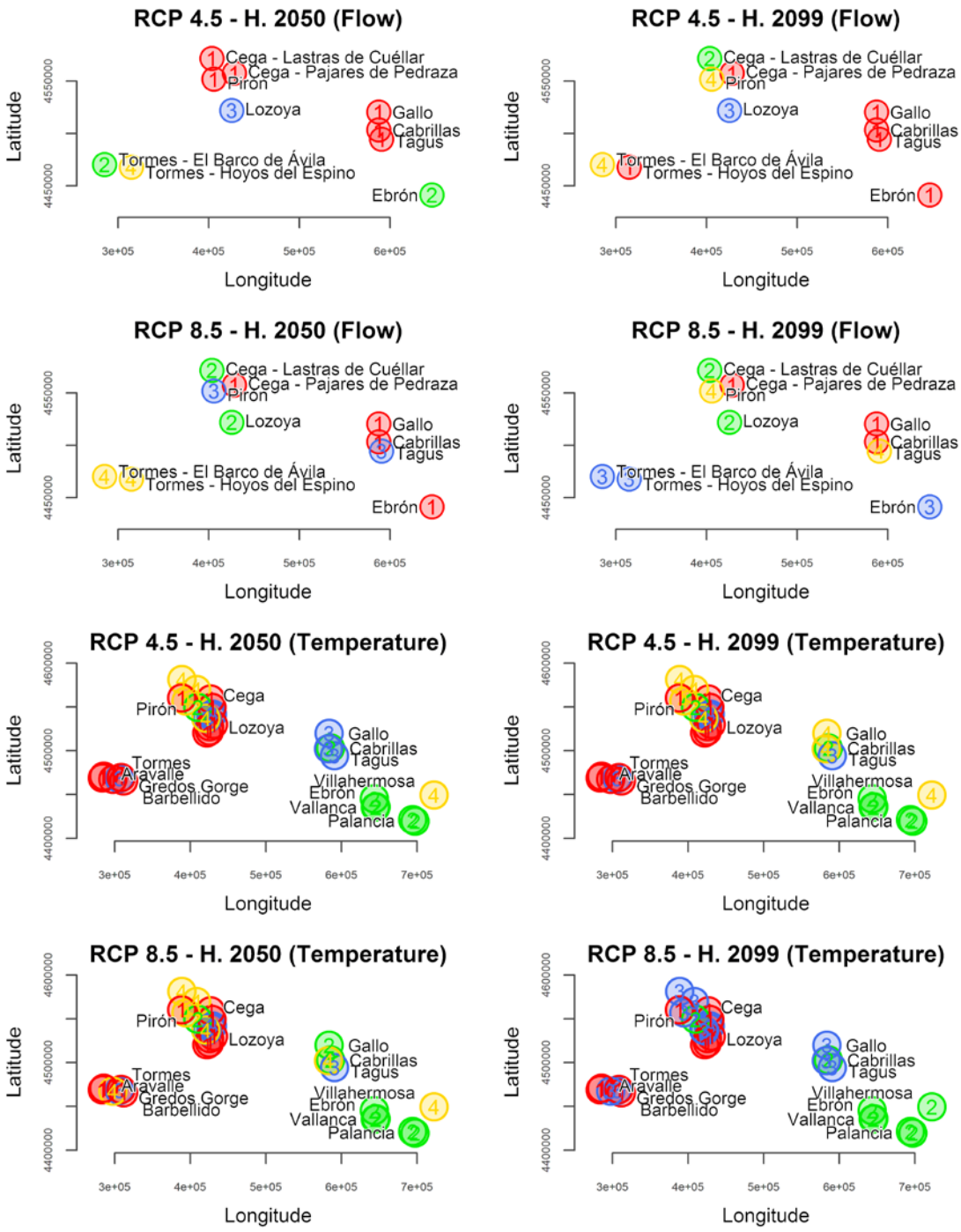

Figure 6. Study sites clustered by the predicted change ratios of the monthly mean streamflow (gauging stations) and by the predicted increase of the monthly mean temperature (ºC, at water temperature recording sites) at H-2050 and H-2099 for the RCP4.5 and RCP8.5 scenarios. Axes show geographic position (UTM coordinates). Colours and numbers show clusters.

P16-Figure 8: This figure is also hard to read. May be have different temperature ranges for the 2 scenarios so the results for RCP 4.5 are easier to read. I understand your concerns but still we think that, to compare both scenarios, keeping the same scale makes it easier to see the differences between them.

P18: a table or figure with the water temperature reached (to present not only the consecutive days above the threshold but also by how much this threshold is passed) will give a deeper understanding of the consequences for thermal habitat and strengthen the discussion.

Table 7. Maximum daily mean stream temperature (°C) at each site at the current time (2015) and horizons H2050 and H2099.Both scenarios (RCP4.5 and 8.5) are showed.

	maximum daily mean stream temperature (ºC)					
		RCP4.5			RCP8.5	
site	2015	H2050	H2099	2015	H2050	H2099
Aravalle	19.8	20.4	21.0	19.8	20.7	22.0
Barbellido	17.9	18.4	18.7	17.9	18.6	19.3
Gredos Gorge	16.5	17.1	17.6	16.5	17.4	18.5
Tormes1	18.1	18.6	19.1	18.0	18.9	20.1
Tormes2	20.5	21.2	21.4	20.7	21.1	22.1
Tormes3	21.8	22.7	23.1	22.4	22.4	24.5
Cega1	12.4	13.1	13.6	12.5	13.3	14.0
Cega2	15.2	15.9	16.3	15.2	16.1	17.3
Cega3	19.8	20.7	21.4	19.8	21.0	22.8
Cega4	18.1	18.5	18.9	18.1	18.7	19.7
Cega5	16.6	16.9	17.3	16.6	17.1	17.8
Cega6	18.7	19.5	19.9	18.8	19.6	21.0
Pirón1	12.9	13.8	14.2	13.2	13.9	15.6
Pirón2	14.9	15.1	15.4	14.9	15.3	15.7
Pirón3	14.1	14.1	14.2	14.0	14.2	14.3
Pirón4	17.2	17.5	17.8	17.2	17.7	18.3
Pirón5	19.3	19.8	20.2	19.3	20.0	21.1
Lozoya1	16.8	17.4	17.8	16.8	17.6	18.8
Lozoya2	17.6	18.1	18.6	17.5	18.4	19.6
Lozoya3	19.0	19.5	19.9	18.9	19.7	20.8
Lozoya4	19.5	20.0	20.5	19.5	20.3	21.4
TagusPeralejos	16.7	17.2	17.6	16.6	17.4	18.6
TagusPoveda	18.1	18.6	19.0	18.1	18.8	19.9
Gallo	17.9	18.3	18.6	17.9	18.4	19.3
Cabrillas	14.9	15.0	15.1	14.9	15.1	15.2
Ebrón	16.2	16.5	16.5	16.2	16.5	17.0
Vallanca1	16.8	17.1	17.3	16.8	17.2	17.9
Vallanca2	16.5	16.8	17.0	16.5	16.9	17.5
Palancia1	15.0	15.1	15.1	15.0	15.1	15.3
Palancia2	16.0	16.1	16.1	16.0	16.1	16.4
Vistahermosa	16.0	16.1	16.1	16.0	16.1	16.5

P19-L10: I will suggest use detailed prediction resolution instead of finer (or another synonym).
Yes. We'll do it.

P20-L20: This does not guaranty model robustness… You should present model performance or at least explain how you tested the model robustness or change this paragraph.
Certainly, the wording of the sentence was not good. We changed it to: "We used a regression-based method to assess the impact of climate change in river temperatures. Bustillo *et al.* (2013) recommended this type of methods that rely on logistic approximations of *equilibrium temperatures* (Edinger *et al.*, 1968), which are at least as robust as the most refined classical heat balance models."

P22-L8: do you mean maturation or development instead of their duration? Yes, “development” is better.

REVIEWER 2: Thank you for your revision. We have read your comments carefully and proceeded to make the necessary changes.

We have reviewing the manuscript to do the reading more fluid and to avoid redundancies, especially between text and figures/tables.

We agree that abbreviations and terminology may make it complex to easily follow the text, however we strongly believe that they are essential for accuracy of the exposition. Nevertheless, we have reviewed the wording in order to make understanding easier.

We are not native English speakers, therefore, we got the manuscript edited for proper English language, grammar, punctuation, spelling, and overall style by native specialists. Please, see the attached certificate. However, we have given another "turn of the screw" to the whole manuscript.

Detailed comments:

- **Comment**: "Please provide more specified objectives."

Response: Done. We have included this paragraph to address this comment:

Specifically, in this paper: (i) we assess both the streamflow and geology effects on stream temperature; (ii) we predict the changes in streamflow and stream temperature in the IPCC5 climate change scenarios; and (iii) we assess the expected effects of these changes on trout habitat aptitude.

- **Comment**: "There has been newer IPCC climate scenarios (IPCC6). Please let readers know how this reflects to your results."

Response: As far as we can see today, we don't know any published results on IPCC6. CMIP6 initiative is in progress and experiments defined:

- CMIP6 experimental design finalized
- Forcing datasets for DECK and CMIP6 historical simulations finalized

Thus, it is not possible for us to interpret how the new experimental designs affect our results.

(Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev., 9, 1937-1958, doi: 10.5194/gmd-9-1937-2016, 2016.)

- **Comment**: "Study sites: Please specify which kind of forest and geology sites contains."

Response: We have taken into account this comment. Forest are mainly composed by coniferous belonging to genus *Pinus* (P. sylvestris, P. nigra, P. pinea, P. pinaster). This is specified in the new version.

Sites geology is described in the main text and Table 1 (see also Figure 2) and in p 4 line7. Our concern on geology relies on its hydrological response. In the Iberian Peninsula are distinguished four main lithological classes: igneous, carbonated, detrital and volcanic. These

main classes are used because resume very well their different behaviour relating to the water cycle.

- **Comment**: "Data collection: what are time periods for temperature data collection? How logger was installed? Was discharge measured from all sites?"

Response: We have incorporated in the text additional information on these matters. Regarding time periods, they are specified in Table 1 (total recording days at each site). Loggers were kept recording all throughout the year. Also, loggers were tested for malfunction before being deployed, and they were placed avoiding direct sunshine (as specified in the response to the Referee 1). Discharge was obtained from 10 gauging stations of the official network (p 5 line 9, and Table 2). These 10 stations were used to model running flows.

- **Comment**: "Hydrological modelling: Whole section is confusing, please clarify and make in more compact. Did authors calibrate M5 models with measured discharge from all sites? Was model validation done?"

Response: Done. Sites in which discharge was measured were the gauging station sites. Five-fold cross validation was done in each case.

- **Comment**: "Stream temperature modelling: Please re-write whole section."

Response: Done. We agree that this section can be particularly complex but this complexity is somewhat inherent to the matter we address and we cannot see how it can be further simplified.

- **Comment**: "Page 9, lines 10-14: Correct place for geology part? What geology classes where used?"

Response: We think this is a suitable place because geology is used to analyse particularities of the temperature models. As said above, geology (lithology) classes were described in page 4 line 7 (and following) and Table 1 (see also Figure 2).

- **Comment**: "Page 10, lines 2-6: Please tell in more details how DEM was used to study stream continuum. Was this information mentioned in Results?"

Response: We have explained it better. An altitudinal interpolation of the parameters of the stream temperature models was performed and a digital elevation model (DEM, at a 5-m resolution, obtained from LIDAR, IGN [National Geographic Institute of the Spanish Government]) was used to determine the geographic coordinates and the altitude (x, y, z) of the points at which the established threshold will be transgressed in the simulations of the effects of climate change. This results will make possible to determine the altitude and the percentage of the length of stream in which the suitable thermal conditions for the trout will be lost.

The results of it are reflected in the cited usable length reductions (p 17 line 30 …56%, 11%, 66%...). This information has been also completed with altitudinal data.

- **Comment**: "Results: Tell first main results (in beginning of the paragraph). Please re-write results, now they are difficult to follow."

Response: Done. The whole section has been rewritten.

- **Comment**: "Figure 6: Not sure is this figure needed. At least need more explanation from main points."

Response: We think this is important for understanding the hydrological and thermal response at a glance. We have improved and simplified the explanation.

- **Comment**: "Figure 7: please tell geological classes already in methods."

Response: It was done. Please, see page 4 line 7 (and following) and Table 1 (see also Figure 2).

- **Comment**: "Page 17: is all numerical results necessary to include to the text? Especially section 3.3.4 is challenging to read."

Response: We completely agree. The section was too wordy. This have been mended by removing unnecessary descriptions of the results.

- **Comment**: "Discussion: Please re-formulate and re-write. No detailed comments provided."

Response: Done.

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EDITORIAL CERTIFICATE

This document certifies that the manuscript listed below was edited for proper English language, grammar, punctuation, spelling, and overall style by one or more of the highly qualified native English speaking editors at American Journal Experts.

Manuscript title:

Waning habitats due to climate change: effects of streamflow and temperature changes at the rear edge of the distribution of a cold-water fish

Authors:

José M. Santiago, Rafael Muñoz-Mas, Joaquín Solana, Diego García de Jalón, Carlos Alonso, Francisco Martínez-Capel, Javier Pórtoles, Robert Monjo, Jaime Ribalaygua

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