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Discussions

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Interactive comment

# *Interactive comment on* "Waning habitats due to climate change: effects of streamflow and temperature changes at the rear edge of the distribution of a cold-water fish" *by* José M. Santiago et al.

**José M. Santiago et al.**

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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." Answer: Thank you. Truly, many times the context does not clear up of which temperature



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we are talking about.

* "In the IS notation, there is a non-breaking space between numbers and °C. Please modify throughout the document." Answer: 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." Answer: 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." Answer: 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." Answer: Thank you for noticing.

P2-L15: "will be interesting to add with the geographical location a mean increase value."Answer: 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." Answer: Thank you. It was changed.

P3-L10: "I will suggest merging the two sentences, directly mentioning changes in fish habitat suitability and availability." Answer: 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?" Answer: 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?" Answer: 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." Answer: The new table (new Table 3) is in attached file. 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?" Answer: We have tried several alternatives (even using GIS-maps) and, finally, we selected the attached solution as optimal.

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." Answer: 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." Answer: Please, see attached file.

P19-L10: "I will suggest use detailed prediction resolution instead of finer (or another synonym)." Answer: 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." Answer: 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?" Answer: Yes, "development" is better.

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*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.

**Fig. 1.**



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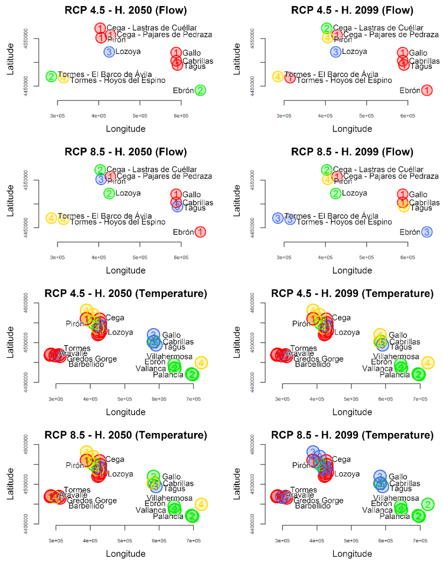


*Figure 6. Study sites clustered by the predicted change ratios of the monthly mean streamflow (gauging stations) and by the predicted increase of the monthly mean temperature (ºC, at water temperature recording sites) at H-2050 and H-2099 for the RCP4.5 and RCP8.5 scenarios. Axes show geographic position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

**Fig. 2.**

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*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 |

**Fig. 3.**