Responses to comments and suggestions

1. **Response to comments and suggestions from the first reviewer:** RC1**: 'Comment on hess-2022-116', Anonymous Referee #1, 16 Sep 2022**

Q1

In the introduction section you started discussing the main impacts of the increase of stream temperature in the water chemistry (dissolved oxygen, salinity, and pH.), and how these changes may influence certain species, which is totally fair. However, you did not discuss how those changes may affect some hydrological and meteorological parameters…

Statements and paragraphs were added to the introduction and discussion section expanding on the effects of stream temperature on hydrologic parameters as well as additional effects and benefits of riparian vegetation. Here are some of these sentences.

- **How changes in stream temperature affect hydrological and meteorological parameters?**

The following was added/included to line 33 of the revised manuscript:

Changes in water temperature also influence hydrological parameters such as evaporation through altering the heat flux at the air-water interface, as well as other parameters indirectly, because all processes in the water cycle are linked (Edinger et al., 1974).

- **Impacts of riparian vegetation in hydrological and meteorological parameters.**
- **The benefits of riparian vegetation are also sediment reduction, alleviating runoff, and nutrients.**

In the line 112 (introduction section) it was added/included:

"Riparian vegetation has been identified as an efficient strategy to control stream temperatures by blocking solar radiation from reaching streams (Chen, Carsel, et al., 1998; Roth et al., 2010; Rutherford et al., 1997). Previous studies in, for example, the US (Abbott G., 2002; Abdi et al., 2020; Chen, McCutcheon, et al., 1998), Brazil (Ishikawa et al., 2021), Europe (Johnson & Wilby, 2015; Kalny et al., 2017; Kałuza et al., 2020), Asia (Liao et al., 2014; Liu et al., 2019), New Zeeland (Rutherford et al., 1997), among other places have demonstrated the efficacy of riparian vegetation restoration in lowering stream temperatures. Riparian vegetation has also been shown to be effective in lowering silt, nutrients, and boosting biodiversity (Malkinson & Wittenberg, 2007; Poole & Berman, 2000). Furthermore, riparian vegetation also impacts hydrological and meteorological parameters. Prior research, for example, found that riparian plants like bibosoop helped to reduce wind speed and evapotranspiration in crop fields in Korean locations (Koh et al., 2010). Guenther et al. (2012) reported effects of logging on vapor pressure, wind speed, and evaporation. Rodrigues et al. (2021) also provided facts about the impact of riparian vegetation on the evaporation of reservoirs. Dugdale et al. (2018) linked riparian vegetation to changes in the flow of energy across the air-water interface and then to evaporation."

In line 462 (Results and Discussion), the section 3.3.5 "**Evaluating additional effects of riparian vegetation for optimal restoration (future research)**" was also aggregated.

Q2

I noticed that you separated the objectives from the introduction, which most of the time they are together (Introduction and in the end the objectives). I do not know if it is a requirement of the journal, ...

The objective was joined to the introduction section and revised and reformulated in accordance with the suggestions.

Q3

Why did you choose to improve the Edinger et al. (1974) equilibrium temperature approach? Just asking…

The energy balance equation involving sources such as long- and short-wave radiation includes implicit quartic terms that make it difficult to manipulate. The quartic terms in the equilibrium equation approach are linearized fairly accurately in the range -30 to 50 C, which is a wide range for typical river water temperatures.

Q4

Why did you just evaluate the reduction in the number of days above survival limits for salmon and trout? Rather than other animals…

Regarding this question, in line 42 the following was added/included:

In the local area, Winter Steelhead, Coho Salmon, and resident Cutthroat Trout are among the primary inhabitants of the Dairy McKay watershed streams, whose population is declining due to a variety of water quality factors, including water temperature (CWL, 2019; Hennings, 2014; ODA, 2018). In this regard, the Oregon Plan identified salmon health as a crucial indicator of the ecosystem (Hawksworth, 1999; ODEQ, 2001, 2008, 2010). Additionally, in this area, declines in ecosystem structure and function have also been linked to declines in salmon numbers(Hennings, 2014; ODA, 2018).

Q5

I also do not think you should outline the whole work, like in Lines 109 to 113, it can be removed.

Changes were made as recommended. Lines 109 to 113 were removed.

Q6

In Figure 1, I would recommend having a zoom out with the whole map of the USA…

Changes were made as recommended. The US map was added to Figure 1.

Q7

In the Line 131 you mentioned that 40% of the area has agriculture, how far these zones are from the study rivers? I was just wondering how you separated the natural riparian vegetation…

In the downstream DMW, streams flow through agricultural areas. Agricultural fields are separated from streams by a buffer of 25 to 30 meters. Previous research has found that riparian buffers with widths of 30 to 50 m provide great advantages in managing stream temperatures (DeWalle, 2010). Thus, we considered taking 30 m of buffer in this study. Existing Vegetation Height (EVH) data retrieved from the Land-fire Program (LP) database (LANDFIRE, 2019) over this buffer zone were averaged and then used to calculate the shade factor (parameters that represented riparian vegetation in the stream temperature model). To simplify, the average height has been considered as a solid barrier that blocks solar radiation.

Agricultural lands separated from rivers by a buffer and composed of short-growing plants would not have a role in limiting solar radiation heading toward streams. However, agricultural lands have a key role in other components of the hydrological cycle such as evapotranspiration, surface flow, and groundwater, all of which are incorporated in the SWAT model and also in the Ficklin stream temperature sub-model. In this way, the stream temperature model takes agricultural areas into consideration indirectly.

Without identifying the type of vegetation, the existing vegetation height data obtained in raster format was averaged and used to calculate the shade factor. This simplification was adopted due to the limited data we faced in the DMW. Further study might add factors such as plant species and canopy density in the shadow factor calculation and examine their influence on stream temperature using the enhanced stream temperature model proposed here.

Q8

For the hydrological model, why did you choose SWAT? Please, you have to mention it in your section 2.1

The SWAT model, which is based on physical principles, is widely used to evaluate the effects of land-use changes, strategic conservation practices, and non-point sources on flow and water quality at the sub-basin and river basin levels. With outstanding results in terms of regulating flow, erosion, nitrate and other nutrients, the SWAT model has been applied in several watersheds across the world. However, in simulating stream temperature, the SWAT model still uses the linear equation of Stefan & Preud'homme (Stefan & Preud'homme, 1993), which is very limited in evaluating the effects of land changes on stream temperature.

Sentences supporting the use of SWAT were added to the article in section 2.2. in line 167 the following was added/included:

The SWAT has been utilized in watershed modelling at the sub-basin level in many places across the world with outstanding results in terms of controlling flow, erosion, nitrate, and other nutrients (Abbaspour et al., 2015; Moriasi et al., 2007). The physical-based SWAT model is widely used to assess the impact of non-point sources, strategic conservation practices, conditions of soil management practices, and changes in land use in large and complex watersheds and predict their effects on flow, production of sediments and chemicals, and instream temperature (Neitsch et al., 2009).

Q9

I also noticed that Ficklin et al. (2012) model uses different types of data (snowmelt flow/melt temperature, groundwater temperature, surface runoff, and lateral flow) to compute the local stream temperature…

Many variables in the Ficklin et al. model, such as lateral flow, groundwater, and surface runoff, are outcomes of the SWAT model. Since the SWAT model has been successfully used in flow and water quality modeling in several European watersheds (Abbaspour et al., 2015), the improved model developed in this article is a promising tool to extend water quality modeling including stream temperature simulation at the sub-basin level. With regard to data such as groundwater and snow temperature, these are variables that show little variation throughout the year and can be obtained from global models/maps. I'm not very familiar with the ERA5 database. However, watershed modeling with SWAT and the ERA5 database have produced effective results in recent studies (Marcinkowski et al., 2022; Senent-aparicio et al., 2021).

Q10

In section 2.4, you mentioned that the shade factor varied from 0 to 1, how and why did you put this range? Is there any reference that mentioned such this nomenclature "shade factor"?

The shade factor (SF) was computed as the rate of solar radiation blocked by the topography and riparian vegetation (represented by the shaded area in the stream generated by the topography and vegetation of the stream banks) divided by the potential solar radiation that would reach the stream surface without any barrier (represented by the stream surface area) (Boyd & Kasper, 2003). The blocked solar radiation was computed as the shaded area on the stream surface and potential solar radiation was computed as the stream surface area. Thus, the maximum value of SF would be one, when the shaded area is equal to the stream surface (full shaded stream), and the minimum value of SF would be zero, when there is no shadow on the stream surface. This nomenclature was employed, for example, buy Rutherford et.al (Rutherford et al., 1997). Similar ratios have been mentioned by authors such as (Boyd & Kasper, 2003) and Loicq et.al. (Loicq et al., 2018).

Prior studies and references that used shading in stream temperature modeling were included in the paragraph added to the introduction (Line 124). In addition to the section 3.2.1 "Shade Factor", the supplement S2 "Shade Factor Calculation" accompanying the article shows details and equations employed to compute the shade factor. The code written in python is also available at (https://github.com/noayarae/SF_model.git).

Q11

In addition, you also said in Lines 240 and 241 "the shade factor was different for each stream, each day within the year, and each instant within the day." How and in which locations did you calculate the solar radiation for these streams?

The shade factor calculation process was developed in the Python environment (available at: https://github.com/noayarae/SF_model.git) (it is mentioned the article – Line 277) and then input into the SWAT model. More details of this process are available in section S2 in the Supplement material accompanying the article. The modified SWAT model and input data is also available as: Data on An Improved Model of Shade-affected Stream Temperature in Soil & Water Assessment Tool. https://doi.org/10.5281/zenodo.6301709 (Noa-Yarasca, 2022) (it is mentioned the article – Line 568). These data include land cover, soil type, water rights, weather (precipitation, temperature, solar radiation, humidity, and wind speed), flow and stream temperature, and the calibrated DMW SWAT model.

Q12

Section 3.1: It would be great if the NSE, and PBIAS were first explained in the Methodology section, in a subsection called "Statistical Analysis" or something similar.

In line 295, Section 2.5 "**Model calibration evaluation**" was added to the article. This section defines the criteria with which the model was evaluated, such as NSE, PBIAS and MAE.

Q13

I would recommend an additional paragraph for this section 3.3, to discuss more about these consequences.

In line 462, the following paragraph was added to include further explanation of the extra benefits of riparian vegetation.

3.3.5 Evaluating additional effects of riparian vegetation for optimal restoration (future research)

In addition to the positive impacts of riparian vegetation on stream temperature reduction revealed here and earlier research (Abbott G., 2002; DeWalle, 2010; Garner et al., 2017; Kalny et al., 2017; Roth et al., 2010; Sahatjian, 2013), other impacts should not be overlooked when evaluating the implementation of buffer vegetation. Riparian vegetation has also been linked to other services such as reducing nutrients in streams caused by agricultural and livestock activity (Groh et al., 2020; Lutz et al., 2020), controlling soil erosion and bank stability (Dickey et al., 2021), and controlling storm runoff by slowing down water contribution to streams, absorbing rainwater, and allowing groundwater recharge, among others (Hawes & Smith, 2005). While water temperature regulation is based on the canopy's capacity to block solar radiation, other riparian-vegetation services are linked to plant functional features such as root absorption capability, root density, and root depth. The efficient restoration of riparian vegetation reported in this work does not necessarily imply effective restoration for other purposes (nutrient reduction, flow, and erosion control), since these other services are related not only to the canopy but also to other plant functional properties(Hawes & Smith, 2005; Malkinson & Wittenberg, 2007).

A riparian buffer consisting of a mix of trees, shrubs, and grasses is much more efficient in removing a broad range of contaminants than a riparian buffer consisting primarily of trees. This is because grasses' shallow and dense roots are excellent in slowing overland flow and trapping sediments, whereas tree roots are good at absorbing nutrients from groundwater, stabilizing banks, and regulating streamflow (Hawes & Smith, 2005). Furthermore, trees provide shade to cool the water, habitat for birds and other wild critters, and falling leaves and branches provide a source of food for wildlife and aquatic animals. Thus, grasses and shrubs can provide services that forests cannot (Parkyn, 2004).

On the other side, fully riparian vegetation restoration may greatly increase transpiration on hot days, resulting in greater water extraction from rivers by plants, which may be temporarily detrimental to sensitive aquatic species (Garner et al., 2017; Hernandez-Santana et al., 2011). Furthermore, heavy shade could affect the population of primary food producers such as periphyton and grazing snails, which are important oxygen providers for secondary consumers, water quality regulators, home to tiny creatures, and soil moisture reservoirs (Hill et al., 1995; National Park Services, 2020; Schiller et al., 2007).

If riparian vegetation could be planted along the entire length of the river, the main expected impact would be a reduction in nutrients, sediments, overflows, and stream temperature in various measures, as well as changes in certain sub - processes of the water cycle in the river environment such as transpiration and aquifer recharge, among others. Other expected consequences include the loss of some primary food producers, which may affect the food chain near the river. The findings of effective riparian vegetation restoration in this work are centered on a single goal: stream temperature. These results may vary in a multi-objective assessment of riparian vegetation restoration. Further work is encouraged to assess and evaluate the implementation of multi-target riparian vegetation.

Q14

The section 3.3.2 is very interesting, you should dig more in the literature and discuss more your results with other author,

Results from other authors were added to section 3.3.2. In line 413, the following was added to the paragraph.

This finding is consistent with previous studies seeking strategic placement of riparian vegetation to achieve the greatest reduction in water temperature. DeWalle (2010), for example, discovered that during summer solstice, south bank riparian vegetation in E-W streams produced 70% of total daily shade compared to 30% of north bank on a 40°N stream, while in N-S streams shading from both banks were equivalents. Similarly, Garner et al. (2017), reported that planting on the southernmost bank of Northern Hemisphere streams flowing E-W, NE-SW, or NW-SE, and vice versa, would result in optimal planting targeted at cooling stream water due to its greater contribution in shadowing compared to the northern bank. Likewise, Jackson et al. (2021), found that in E-W/W-E oriented rivers, the contribution of the north bank riparian vegetation was negligible when compared to the south bank. Thus, tree planting on the north side may be unnecessary for stream temperature control. In N-S/E-N oriented streams, the riparian vegetation on both sides had the same shading effect on streams.

Q15

The section 3.3.3, in my opinion, is your peace of gold result, you showed the positive impact of riparian vegetation in reducing the stream temperature…

Results from other authors were added to section 3.3.3. The following paragraph was added in line 434.

"Previous studies have also obtained positive relationships between increased riparian vegetation and reduced stream temperature using various metrics (Abbott G., 2002; Garner et al., 2017; Kalny et al., 2017; Parkyn, 2004; Wondzell et al., 2019). However, given that future climate change scenarios foresee prolonged hot days that would affect aquatic life (Brander, 2007), this work presents the reduction of days with 7dAM that exceed 18°C, which could be a more practical value/metric for experts and non-experts. The reduction in the number of days with 7dAM indicates encouraging findings for DMW; nevertheless, it was not able to compare with earlier research since they directly concentrate on temperature reduction under various conditions."

Positive and negative effects of adding riparian vegetation were also included and discussed in the added section 3.3.5 "Evaluating additional effects of riparian vegetation for optimal restoration (future research)" (Line 462)

Q16

Do you think would be a good idea to insert the riparian vegetation through the whole river section? Why? Which impacts it would be expected?...

The following paragraph was added in line 455 in section 3.3.4 to answer this question.

"If riparian vegetation could be planted along the entire length of the river, the main expected impact would be a reduction in nutrients, sediments, overflows, and stream temperature in various measures, as well as changes in certain sub - processes of the water cycle in the stream environment such as transpiration and aquifer recharge, among others. Other expected consequences include the loss of some primary food producers, which may affect the food chain near the river. The findings of effective riparian vegetation restoration in this work are centered on a single goal: stream temperature. These results may vary in a multi-objective assessment of riparian vegetation restoration. Further work is encouraged to assess and evaluate the implementation of multi-target riparian vegetation."

Additionally, in line 462, the section 3.3.5 "Evaluating additional effects of riparian vegetation for optimal restoration (future research)" was added/included to answer the second part of the question.

Q17

I suggest to change or exclude Lines 391 and 392 …

The indicated sentence was changed as suggested by (Line 554):

"Therefore, the application of the improved stream temperature model could be replicated in other regions with characteristics similar to the DMW"

Q18

It is essential a section of "Sources of uncertainty" or "Uncertainty analysis"

In line 492, the section 3.3.6 "Model limitations and uncertainties" was added to the article as suggested.

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