Dear Reviewers and editors,

We would like to thank you for your comments. These were all very insightful and on point and we believe they have really improved our manuscript. Attached you will find the new version where we address each of the comments you made. Below you will find direct responses to each comment you made.

Thank you again for your time and dedication,

The authors

**-----------------------------------------------------  
Recommendation of guest editor**

**-----------------------------------------------------**  
  
 I fully agree with the detailed comments by the two reviewers. The  
 article should be substantially revised to address all the critical  
 comments.

**Response:** All comments made by reviewers have been addressed in the new version of the manuscript

 The authors need to be consistent and accurate in distinguishing formal  
 fisheries treaties and informal fisheries arrangements.   
 The Gulf of Maine fisheries management situation might best be described  
 as a transboundary fisheries management arrangement as there is no  
 overarching treaty but cooperation is based on exchanges of letters and  
 institutional mechanisms. The authors might also note how  
 many transboundary stocks are not yet under any agreed to conservation  
 measures, for example, Atlantic mackerel and herring.

**Response:** We have changed the Gulf of Maine agreement to “arrangement” and have expanded the discussion on those species not currently co-managed by Canada and the US.  
  
 In line 28, the United Nations incentivized actions in 1982, not 1985, as  
 the Convention on the Law of the Sea was adopted in 1982.  
**Response:** Addressed in text

 The final article of this Special Issue by Engler and Saunders is  
 expected to be submitted within the next few weeks. The authors should  
 consider cross referencing to that article also to ensure an "integrated"  
 set of papers.

**Response:** Addressed in text.

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**Recommendation of Anonymous Reviewer A**

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**Comments to Author:** I found the subject matter of "Challenges to transboundary fisheries  
 management in North America under climate change" to be timely and  
 interesting. The authors examine the transboundary management  
 implications for 33 stocks that are shared by the U.S. and Canada on the  
 east and west coast of each country, which is an important area of  
 research as stock shifts are happening more rapidly and finding workable  
 solutions for improving the climate-readiness of national and  
 international fisheries management is of the utmost importance.

**Response**: Thank you for recognizing the importance of our paper.  
  
 However, I found that the paper did not go quite far enough to really  
 make a novel contribution in that it just looked at the amount of species  
 change for stocks that are shared and jointly managed by the US and  
 Canada relative to current management areas and stock share agreements. I  
 think that more focus on the particular solutions and strategies that  
 could/should be employed specific to each case study would go a long way  
 to improve the paper and make this a very worthy contribution. Given that  
 the modeling is based on previously published bioclimatic envelope  
 models, there was nothing new in the modeling that I could see except  
 that the authors were looking specifically at the species under joint  
 management frameworks.

**Response**: We have now focused the discussion towards using the model projections to examine possible solution options for each case.  
  
 While it was interesting to see the metrics of MCP and stock share ratios  
 and how those would change relative to the management areas, what I was  
 hoping for was more and better treatment of these shifts relative to the  
 management constructs in place in the two case studies. Additionally,  
 ideally, there should be some evaluation and recommendations of potential  
 solutions and strategies for dealing with these changes. As it stands  
 now, the same list of possible solutions were presented in this paper  
 that I've seen in other papers (Pinsky et al. 2018 on governance for  
 example), but there were few specifics related to the two case studies  
 selected. Since the authors are looking at species changes for a region  
 that has been explored by other papers recently in publication (Morley et  
 al. for example), I would have expected more of a focus on the solutions  
 rather than just the outcomes of stock shifts.

**Response:** As we mentioned, we have included a more thorough discussion on the consequences of species shifts (and stock share ratio shift) on the management rules in place for the two case studies. As it stands now, the manuscript brings a new dimension of the literature by analyzing the impacts of climate change to transboundary fisheries management at the treaty level.

 With respect to the modeling, I didn't find the approach invalid or  
 incorrect. However, there were some missing elements from the equations  
 and methods description that made the analysis hard to validate. I also  
 think that the paper could benefit greatly from a thorough proofread and  
 more attention to details.

**Response**: This was also pointed out by the other reviewer. Unfortunately, there seemed to be a problem uploading the manuscript to the journal website. We have made sure all the equation’s elements are there and will bring this point to the editor. We have carefully revised the manuscript for details.

 I've noted specific comments and recommended edits below by line:   
  
 Lines 10-12: The sentence on this line says "We then look at the specific  
 cases of X and Y" but doesn't clarify for what purpose. Nor does the rest  
 of the abstract indicate the use of these cases and what they are  
 intended to illustrate or test. Is it only how these shares of these  
 specific stocks will be potentially altered or is there a more nuanced  
 analysis of the management framework that will be tested?

**Response:** We have included a sentence in the abstract pointing out that we use these examples to discuss our results under the umbrella of shared stocks, it now reads:

“We then look at the specific cases of the International Pacific Halibut Commission that manages pacific halibut (*Hippoglossus stenolepis*) and a resource sharing arrangement in the Gulf of Maine for cod (Gadus morhua), haddock (*Melanogrammus aeglefinus*) and yellowtail flounder (*Limanda ferruginea*) to discuss the management consequences of shifts in transboundary stocks.”

 Line 26: This sentence makes it sound like game theory is the only method  
 to analyze the management of transboundary stocks. Are there no other  
 analyses or analytical methods that have been used to examine stock  
 sharing arrangements and best practices for stock sharing?

**Response:** We modified the sentence, so it is clear that game theory is not the only way to manage shared stocks, it now reads:

“Game theory is one of the most common approaches used to analyze the management of transboundary stocks, as often, success depends on effective cooperation between parties”  
  
 Line 28: The use of "Therefore," suggests that this sentence about the UN  
 incentivizing actions to cooperate stems from the use of game theory. I  
 don't think that this is what you are intending is it?

**Response:** Thank you for this observation.We have modified the whole first paragraph

 Line 34: "extremely hard"? While I don't doubt that this is true, this  
 seems like a pretty subjective statement. Can you provide some real world  
 evidence or examples for this?

**Response:** We changed the wording to “can be convoluted” as we want to state that it can be more complex to manage a shared stock than a stock with a single owner.

 Line 44: add an apostrophe to "species"

**Response:** Addressed in text  
  
 Line 76: "stocks" should probably be "fisheries"

**Response:** Addressed in text  
 Line 96: "will affect"

**Response:** Addressed in text

 Line 97: "keeps" should be "keep"

**Response:** Addressed in text

 Line 107-108: I would perhaps couch this as "geographic constraints and  
 geo-political features".

**Response:** Addressed in text

 Also, the Kleisner et al. 2016 paper that you cite later discusses  
 geographic constraints for the US northeast shelf and GoM in  
 particular--might be a good reference here.

**Response:** Thank you for point this out, we have included the reference.

Line 116: "EEZ" should be plural

**Response:** Addressed in text

 A severe limitation of this study is that there does not seem to be any  
 treatment of uncertainty in these model projections, nor is there any  
 quantification of model skill for forecasting, i.e., testing the models'  
 ability to forecast in sample for a current segment of the data before  
 using the models to forecast the future. I believe Jim Thorson may have  
 some papers that look at model skill in short-term forecasts and there's  
 a newer Kleisner paper that assesses long-term forecast skill. You might  
 look at these for examples of what to do here.

**Response to** there does not seem to be any treatment of uncertainty in these model projections:

We have included uncertainty metrics in the projection’s dependant on GCMs; however, we agree that these were not clear before. Figures 2, 5, A1 and A3 have “x” making regions where global circulation models do not agree in direction of change, similar figures 3 and A2 have a “\*” in IPHC regions where models do not agree. We have made them more visible now. Moreover, we have included a section of “uncertainty” in the discussion to highlight the importance of considering these in the management of transboundary stocks.

**Response to** nor is there any quantification of model skill for forecasting, i.e., testing the models' ability to forecast in sample for a current segment of the data before using the models to forecast the future**:**

In case of the DBEM uncertainty, the model has been further developed (e.g. Cheung et al. 2011) and tested for structural uncertainty (e.g. Cheung et al., 2016). In Cheung *et al.* 2016, the authors test the DBEM’s model algorithm that estimates habitat suitability against those of AquaMaps (DBEM-AquaMaps) and Maxent (DBEM-Maxent), two commonly used models to predict species distributions (Cheung et al. 2016). The results show no changes in the trend of MCP change between models while suggesting using multiple algorithms if the objective is to quantify abundance or MCP. In here we only use DBEM-Basic to project species distributions as we present a change rate, rather than absolute values. We also compare the results from our model to other approaches, using different models but similar species and found an overall agreement of results (e.g. Pinsky and Fogarty 2012, Pinsky et al. 2013, Morley et al. 2018). We have included this in the Discussion. It reads:

“Structural uncertainty within the DBEM has been previously tested for agreement against commonly used species distribution algorithms such as Maxent (Phillips et al. 2006) and AquaMaps (Ready et al. 2010, Kaschner et al. 2011) resulting in no qualitative differences in trends between algorithms (Cheung, Jones, Reygondeau, et al. 2016).”

 Line 164: there's a set of parentheses here with nothing in it (and I  
 noticed this elsewhere: Line 183). Missing a reference?

**Response** It seems that the journal format changed the equations (and related characters) and many of the symbols are missing from the original text. We have asked the journal to include a PDF version of the manuscript attached to this document. This is the same issue for your comments on line 167, 176, 183 and 186

 Line 167: The equations is missing here - just empty parentheses

**Response:** See response to line 164.

 Line 176: "where is the future..." Something is missing here. Also the  
 equal sign after "periods" doesn't make sense.

**Response:** See response to line 164.

 Line 178: the concept of "threat point" is impossible to validate or  
 understand without some description of what this is here. Please define  
 as well as cite Sumaila et al. Also on the next line you call it "thread  
 point".

**Response:** We have provided a description based on Sumaila et al. and corrected the second term (it should say “threat point”). It now reads:

“In addition, we borrowed the concept of “threat point” from game theory defined as the minimum payoff that a player is willing to receive in order to cooperate with other players (see Sumaila et al., this Special Feature). Thus, we estimate the change in the RA (threat point) that each country RA (players) would have for each species (hereafter referred as stock-share ratio), for both the IPHC and the GoMA. The stock-share ratio can be seen as the proportion of the stock’s distribution within the study area that each country has.”  
  
 Line 186: where what is?? Again, something missing here. Also, please  
 define all terms in equation 3. In other words, "the aggregated WHAT of  
 each region (r)". What are sigma and delta?

**Response:** See response to line 164.

 What is missing from the methods is what the treatment is for each of the  
 case studies. There should be some description of what you are  
 investigating in the 2 case studies presented in the methods. There must  
 be some analysis, metrics or information, either quantitative or  
 qualitative, that you use to assess the impacts of these stock changes on  
 the management in each of these agreements.

**Response:** We have changed the “Study Area and Fisheries” section of the methods to describe the management specifics of the two case studies. These have been further addressed in the discussion as a more qualitative analysis of the likely consequences of our results to the management arrangements and potential solutions.

 Line 206: Do you mean "each country's"?

**Response:** Addressed in text

 Line 206-207: What do you mean by the sentence "would change in the  
 direction as expected from the effects of ocean warming?" Are you talking  
 about poleward shifts (which while they may be the dominant pattern are  
 not consistent across all species as demonstrated in this and other  
 studies) or something else? It's not clear.

**Response:** We agree that this sentence needed context and was confusing. We simplified by saying:

“In consequence, each country's share-ratio of different species will change with an overall benefit to northern regions, regardless of the RCP scenario.”

 Lines 215-217: This statement seems a bit underwhelming--sure, it's  
 already been noted by other studies that while the overall trend in  
 species shifts may be poleward, there will be regional variability. How  
 is this a novel result? What is the nuance reflected in this analysis of  
 these North American fisheries? And what are the "management consequences  
 related to the rules placed by the different treaties"? It seems that  
 this is not a "result" so much as a discussion point, so perhaps it's  
 better to make a statement like this there where you can back it up with  
 refs or examples unless you have some analysis to present in the  
 results.

**Response:** Addressed in text. We have removed the text from the result and place it under the discussion section where we talk about the implications of our results to the management of IPHC.

 Lines 220-222: This sentence doesn't make much sense to me: The former is  
 the US contiguous states, and the latter is Canada, which is a "northern  
 region" when compared to the US contiguous states, so what are you trying  
 to say here?

**Response:** Addressed in text. We meant “later” not former.

Line 224: Change "northwestern of" to "to the northwest of..."

**Response:** Addressed in text

 Line 225: change "on" to "to"

**Response:** Addressed in text

 Line 225: What do you mean by "from positive to negative"? I understand  
 that there will be an increase in MCP in the northern region 4C and 4E  
 under the high emission scenario, but this is not the case under the low  
 emission scenario..which seems a little counterintuitive. It would be  
 helpful in each of these mapped figures to clarify if this % change of  
 future MCP is relative to the MCP in the current time period. I'm  
 assuming so, but I don't see that clarified anywhere. When you say "only  
 regions northwestern of 3B will see a gain in MCP", one would expect to  
 see blue in both maps indicating that MCP increases in the future, but  
 this is only the case for the high emission scenario. This needs significant clarification.

**Response:** We agree that this was poorly phrase. We have addressed this comment on the text, in addition, we have included an analysis to better explain the results from regions 4CE. Follows the text and below related clarifications:

“Regions 4DE, the most poleward regulatory areas of the IPHC, are expected to gain MCP by mid (Fig. 3) and end of the century (Fig. A1.2) under a high emission scenario due to the expansion of halibut suitable habitat as sea ice retreats (Fig. A3.1). In contrast, under a low emission scenario, sea ice is expected to stabilize towards mid century, thus providing less “new” suitable habitat for P. halibut and resulting in undetectable changes in MCP for the region (Fig 3. B) and decreasing even more towards 2100 (Fig. A1.2).”

**Response to** What do you mean by "from positive to negative"?… region 4 seems a little counterintuitive”:

By “from positive to negative” we meant that under a high emission regions 4DE will increase in MCP in both time steps relative to today. However, this is not true under a low emission. The reason why region 4D increases under strong climate change but is almost undetectable under low emissions scenarios is likely due to the effects of sea ice retraction under high emission scenarios. We have included a sentence and a figure in the supplementals to support this claim. Follows supplemental figure:

[Figure A3.1.]

Fig. A3.1. Projected bottom salinity and temperature and ice extension for IPHC regulatory areas 4D (top) and 4E (bottom) for both high emission scenario -RCP 8.5 (Red) and low emission scenario-RCP 2.6 (Blue). Solid line is the 10 years running mean of the three GCMs used in the present study (GFDL, IPSL, MPIs) and shaded area is +- the standard deviation.

**Response to:** …. clarify the % change in mapped figures…:

All of the figures (maps and box plots) are relative to the present time period, we have clarified this in all figure legends.   
  
 Line 232: "Maintaining emissions at lower levels through...?"

**Response:** Addressed in text  
  
 Line 235: "in almost half..."?

**Response:** Addressed in text

 Line 241: What is "increments in species' MCP"? Do you mean "incremental  
 increase"?

**Response:** Yes, addressed in text

 Line 245-247: But there must be some underlying reason for these increases? Could it be habitat related? Aren't there deep pockets in the GOM? Could yellowtail flounder move deeper into these areas?

**Response:** The results particularly for these regions are driven mainly by one global circulation model (the GFDL) and a potential artifact of the model’s scale, especially on northern region where grids are partially covered by land. We have included a statement in our results, a figure in supplements showing this model difference and the following paragraph in the discussion:

“Overall, results for the Gulf of Maine agree with a reduction in MCP of all three species. However, some discrete areas show a positive change for Y. flounder by mid century (Fig. 4), mainly driven by the GFDL model (**Fig A3.2**). Potential model artifacts could also be contributing to the results, especially in the northern part of the study area (Bay of Fundy) as most disagreeing grids are covered by land, which could be influencing the results.”

[Figure A3.2]

Fig A3.2. Changes in maximum catch potential of yellowtail flounder (Limanda ferruginea) within the study area by mid-century relative to present time. Results for the three global circulation models (GFDL, IPSL, MPIS) used in the current study and two climate change scenarios (High emission – RCP 8.5 and Low Emission – RCP 2.6). Grid-cells in yellow represent discrete areas where average MCP is projected to increase by mid-century.

 Line 255-256: Again this result seems very odd and counterintuitive. it's  
 hard to evaluate based on what's presented here if this is a problem with  
 the analysis, some artifact of the data, or an actual valid result. I  
 don't find it sufficient to just say that "patterns somehow invert"  
 without some investigation and discussion.

**Response:** We remove the “pattern somehow invert” because we considered it was confusing. It now reads :

*“*Despite the expected decrease in MCP for the region, changes in the stock-share ratio of species within the Gulf of Maine show different outcomes dependent on the climate change scenario and species in question. Following a high emission path will affect mostly Canada’s share of Y. flounder and in less degree haddock, with an increase of cod share. Under the low emission scenario, haddock and cod patterns intensify, while Y. flounder’s share approaches almost no change (Fig. 6). Such pattern is likely the combination of the bathymetry or the Gulf, the warming gradient, and the species distribution (see discussion).*”*

 Line 263: and MCP too right? Why only mention species' stock-share ratios  
 here?

**Response:** Changed to “species' MCP and stock-share ratios”

 Line 266: "depending" should be "dependant"

**Response:** Yes, addressed in text  
  
 Line 287-288: This is not accurate: the GOM is deeper in the south in  
 some pockets (a bathymetry map will illustrate this) but bottom  
 temperatures are cooler in the southwestern GOM, which may explain some  
 of these results.

**Response:** We originally meant that according to the ESMs we used, the Gulf will warm more slowly on the south than in the north. We have modified the text to reflect the effects of depth and temperature in our results and discussion and included a figure in the supplements to support this claim, it reads in results and discussion:

Results: “Under the low emission scenario, haddock and cod patterns intensify, while Y. flounder’s share approaches almost no change (Fig. 6). Such pattern is likely the combination of the bathymetry or the Gulf, the warming gradient, and the species distribution (see discussion).”

Discussion: “In the Gulf of Maine, the stock-share gain of Y. flounder and haddock by the US (Fig. 6) could be a response to a temperature gradient shift combined with geographic barriers as southern waters are deeper and warming slower than northern waters (Fig A3.1).”

[Figure A.3.3]

Supplemental figure x. Depth profile (A) and bottom water warming of the Gulf of Maine. Everything deeper than 1000 meters is colored in green. B) Percentage change of bottom temperature relative to the present showing more intense warming in northern regions, especially under a high emission climate change scenario.

 Line 301-302: It would be helpful to discuss this point in the context of  
 these east and west coast examples rather than in the abstract. Where are  
 the closed areas in the study regions? How do these potential shifts  
 threaten these areas or could you assess a bit whether these areas would  
 continue to be useful in light of these shifts?

**Response:** We have expanded in the problematic of closed areas and overlapping stocks using the IPHC as an example in the discussion section  
  
 Line 303: "gear-limitation management" such as? Can you describe what is  
 in place now and how these rules might be affected?

**Response:** We responded to this comment with the previous   
  
 Line 318-319: What would be interesting and more valuable here would be a  
 discussion of how the dynamic quota allocation system has worked (or not)  
 in light of climate change and shifting stocks. As this reads now it's  
 just an observation with little connection to the argument you are posing  
 for the need for better and more dynamic regulations. Throughout the  
 discussion, I think that tying each point into what is currently going on  
 would make this a much more interesting and relevant paper and  
 discussion.

**Response:** We have addressed this comment in the discussion.   
  
 Line 319-321: Seems like it's more than just treaties, but all aspects of  
 the regulatory framework (quotas, limits, stock assessments, etc.) that  
 need to be flexible right?

**Response:** Yes, by treaties we meant all of the regulatory framework. We have made that explicit in the text.  
  
 Line 337-342: But all treaties are not necessarily binding--there are  
 plenty of exmples of non-binding treaties. To me this is too cursory of a  
 treatment of this topic. Where are binding treaties with penalties used?  
 How effective are they? What are their limitations?

**Response:** After some consideration we have removed this section from the discussion as we decided to expand In other sections.  
  
 Line 348-350: But there's still no quantification of uncertainty for the  
 models you present here. In my opinion this discussion doesn't go far  
 enough to address

**Response:** We have addressed this comment in the discussion.

 Line 368-370: Most of these potential solutions are mentioned in Pinsky  
 et al. 2018 and Morley et al forecasted over the same areas that you  
 present in this study (with a broader analysis of North America), so it's  
 not clear to me what the value added here is. I expected a more thorough  
 treatment of the current regulations in place for your species of  
 interest (maybe an MSE type of framework to evaluate different  
 interventions and solutions), and what the forecasted shifts will mean  
 for these regulations. Overall, I feel that this paper falls short in  
 this regard.

**Response:** We have addressed this issue and hopefully have improved the discussion in a way we reflect the direct impacts to the management of the species we selected in our case studies.  
  
 Figures:   
 Figure 2 & A2: I think "referent" should be "referenced"

**Response:** We changed it to “relative” as these changes are relative to the present time. We also made those changes in text

 Figure 2, 5 & A3: there are no points that show up on these figures, at  
 least that I can see

**Response:** We notice the points were not visible, we have made them clearer

Figure 6: "Ration" in the y-axis should be "ratio"

**Response:** Yes, addressed in figure

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**Recommendation of Anonymous Reviewer B**

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 This is a well-established approach to show maximum catch potential  
 changes with climate change scenarios without fish population dynamic  
 models. Nevertheless, it should state gaps between the maximum catch  
 potential changes and fish distribution changes explicitly. Assumptions  
 and rationalities for the relationship between two concepts should be  
 stated by adding sentences.

**Response**: We thank the reviewer for its comment and point out that we have included a sentence in the methods differentiating maximum catch potential from distribution changes.  
  
 L176-177; More lucid explosions for Equation 2 are necessary.  This  
 equation is critical to define the time horizon, but current explosions  
 are not apparent how it corresponds to L176 and 177.

**Response:** We modified the equation and text as requested

Also, it would be helpful to provide rationales to define these two periods in this study.

**Response:** We have included a sentence that addresses this comment, it reads:

“The rationale between choosing these time periods was to provide a relative short-term projection (mid-century) that would be more policy-relevant but also show the long term trend.”  
  
 Should have a word consistency for "transboundary species, transboundary  
 fisheries and transboundary stock

**Response:** We have reviewed the text and changed all “transboundary species/fisheries” to “transboundary stocks”. We left “transboundary fisheries” in the title and abstract as we believe is a more friendly term for non-experts.

 L55: this sentence should be elaborated for non-fishery background  
 readers (also L313)  For instance,  (e.g., quota or spatial delimitation)  &#8658; catch quota or spatial  
 delimitation for fishing activities

**Response**: Addressed in text  
  
 L117 : Fig 1 does not have enough information to correspond to this  
 sentence.

**Response:** This sentence refers to table 1 and not figure 1. We show in the table the treaties and the number of species they manage

 L164, 167, 174, 183: no equation numbers, references or symbols in  
 parenthesis?

**Response:** Equation numbers will be included by the journal  
  
L192: Github link does not work.

**Response:** It is available now. We have uploaded the code along with the responses for the reviewer to see.

 L203: "transboundary fisheries" should be "transboundary stocks"

**Response:** Revised  
  
 L300; these are not "management objectives." these should be management  
 devices (or other appropriate words).

**Response:** Revised  
  
 Fig 6: A vertical line divides "High emission" and "Low emission" into  
 two areas would help to understand.

**Response:** Revised

**References in response**

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Morley, J. W., Selden, R. L., Latour, R. J., Frölicher, T. L., Seagraves, R. J., and Pinsky, M. L., 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. *PLoS ONE*, 13 (5), e0196127.

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