**Edits to Capture fisheries section**

#### **4.1.1 Importance of capture fisheries to the ocean economy**

*Elena: Missing reference to SSF and their importance for subsistence economy and food security?*

We added the following sentence: “Small-scale fisheries are the backbone of socioeconomic well-being in many coastal communities (Bene 2006; Bene et al. 2007, 2010), especially in the tropics where the majority of fish-dependent countries are located (Golden et al. 2016).”

*Ragnar: These are not facts but according to FAO estimates some of which (esp. labor in capture fisheries) are highly inaccurate. The text is should reflect this.*

We added the underlined text: “In 2016, the UN Food and Agriculture Organization (FAO) estimated that marine capture fisheries produced…. They also estimated that approximately 30.6 million people participated…”.

*Ragnar: I believe this is within the group of food commodities and international trade not just trade.*

We added the underlined text: “Fish and fish products are among the most traded food commodities in the world”.

**Section on “Climate change modifies the life history of marine fish and invertebrates, including their growth, natural mortality, and recruitment rates.”**

*Ragnar: These exclusively negative impacts are misleading and contradict a previous statements about the habitat impact going possibly both ways. I think the preoccupation with the negative impacts probably reduces the credibility of this chapter.*

We modified the text about impacts of CC on recruitment to more clearly highlight the evidence for both net decreases and net increases in recruitment:

“Finally, recruitment of juveniles is often more strongly driven by environmental factors than by spawner biomass (Szuwalski *et al.* 2014; 2019). The net effect of historical environmental change on recruitment is under debate: Britten et al. (2016) document a net decline while Szuwalski (2016) documents a net increase.”

The text on the impacts of CC on mortality rates already featured positive/negative impacts and I can’t find any evidence that CC has positively impacted growth rates.

*Ragnar: Formally this is a unequivocal, general statement. I think there are many cases of environmental change which has enhanced recruitment of particular species.*

See above changes to the recruitment discussion.

*Elena: Specific actions to adapt fisheries to these impacts include targeting sustainable & age-diverse populations so that age structure and genetic diversity buffer against impacts, and adaptive management where institutions can experiment and learn from observed and monitored changed (Ojea et al., 2017).*

We added this point to the section on impacts of CC on net productivity and how management can adapt to that. This section is intended to be on impacts of CC on life history and how stock assessment must account for that.

**Section on “Marine fish and invertebrates are shifting distributions”**

*Jorge: The discussion below focuses on entries and emerging fisheries but exits and disappearing ones are as important from a management/adaptation point of view.*

We added “in and out of jurisdictions” to emphasize the two-way nature of shifts.

*Ragnar: I think this assertion misses the main reason, i.e. that the stock appeared in large quantities in new EEZs. There is a real danger in this work to rely on few imperfect references. I think this chapter should try to avoid making assertions that are potentially misleading or even erroneous.*

We are happy to change this if you can provide a better example of where a shifting stock has resulted in a transboundary conflict and decreased status of that stock and outcomes for that fishery. This is the example that gets used across the literature and seems to be the most high profile. We have retained it for now.

**Section on “Although the net global impacts of climate change on fisheries productivity”**

*Ragnar: The logic of this assertion warrants thought. If there is no overall impact on productivity, this implies that global fish stocks will be geo-politically more unequally distributed than before. Does that really make sense? Does the opposite hold true if there is global cooling?*

As we detail in the next two paragraphs, every study agrees that net impacts on productivity are not huge (+1% to -5% under most CC scenarios) but that regional impacts can be huge >25% negative or positive.

*Elena: I think winners and losers is misleading as “winners” can have productivity increases nut at the expense of communities composition change with no idea on the changes in functional traits in the ecposystems, or the impacts of invasive species etc. This becomes more eviden if you think in small scale fisheries. I could write this in detail with examples for example in Japan that Jorge Garcia molinos has if necessary where communities are not keeping up with tropicalization (ie. TURFS).*

I like “winners” and “losers” because its short-winded but I changed “with pronounced winners and losers” to: “with some regions experiencing large gains in productivity and others experiencing large losses”.

*Ragnar: Is this an uncontroversial fact? Don’t think so. We can’t even accurately measure the MSY of stocks today let alone 80 years ago. While MSYs may have declined, there have been many other factors at play other than ocean warming.*

I reworded to: “Free et al. (2018) estimate that…”. FYI – this is my 2019 *Science* paper.

*Ragnar: This is not this simple. Commercial stock are a small minority of all stocks. If commercial stocks are enhanced, ecosystem responses will ensue with inevitably some other stocks declining which then will become less resilient with virtually unpredictable dynamic ecosystem implications even for the stocks that were initially rebuilt.*

*Elena’s follow up to this: Maybe we can mention ecosystem-based management then? I think with EbM the consideration of the ecological complexities mentioned should be covered.*

We added a sentence and a reference discussing the need for ecosystem-based approaches that consider these complex interactions:

“First, preventing overfishing and rebuilding overfished stocks will enhance resilience to climate change (Free et al. 2019). However, this will require ecosystem-based approaches that consider the complex interactions between recovering populations and changing environmental regimes (Link and Watson 2019). Second, fisheries stock assessments and management procedures will need to account for shifting productivity. This will involve one of many strategies (Pinsky and Mantua 2014) including: (1) using assessments with time-varying productivity; (2) using climate-adaptive harvest control rules and more precautionary buffers; and (4) targeting age- and genetically-diverse population (Ojea et al. 2017).”

*Elena: its not clear to me from this text how this analysis differs from Gaines et al., 2018. Maybe explaining the novelty first/need will help to understand the specific contribution of this study as results mimic those of the cited paper.*

We present results at the country-level rather than at the global-level.

*Elena: I think an interesting policy scenario would be sustainable management now, and sustainable management in the future with no transboundary agreements.*

We agree and we include it in the paper in preparation but there isn’t room for this scenario in the Blue Paper.

*Ragnar: I think this is true. However, you do not need to base this on this unpublished reference. It is well established (numerous publications including the two Sunken Billions reports) that gains from improved global management are very large, so large that it can offset the reduction in productivity due to CC. However, the real point is that the gain from improved management will be less if CC has a negative impact on biological productivity and/or the global economy.*

We added citations of the Sunken Billions report in the final recommendations section but retain the focus on our novel analysis because it explicitly measures the benefits of implementing climate-adaptive management reforms under multiple climate scenarios.

**Recommendations section**

**Edits to Aquaculture section**

*Yimnang: In Palau and I suspect, many other small islands, the issue is not regulations but maybe lack of expertise and entrepreneurship to fully develop the aquaculture industry. Many project over the years in Palau have tried to develop different aquaculture and many have failed after the grants run out or initial funding stops. The longest running aquaculture now is the clam hatchery that is run by the government and highly subsidized. They spawn the clam, rear them and sell the small clams to farmers at very low cost. The farmers would just put them in the water, wait for them to grow a bit, then sell them to restaurant or to exporters. Without the support of the government facility, the farmers would not be able to make money from it. While I am not sure how many small islands have the same situation in Palau or how significant this is globally but I want to raise it to see what you guys think about it.*

We have expanded the following paragraph:

**“If the potential for production is so large, why is current mariculture production so low?** This gap is likely driven by two factors: (1) a lack of expertise and capacity for conducting mariculture operations in many developing countries; and (2) challenging regulatory barriers for developing mariculture operations in many developed countries. In Palau, for example, many mariculture operations have been initiated with outside funding but have failed once the initial funding period ends. The longest running mariculture operation in Palau is a government subsidized clam hatchery that would be unprofitable without government support (Y. Golbuu, personal communication). In the United States, on the other hand, precautionary regulations restrict mariculture development (Wardle 2017; Sea Grant 2019). Thus, despite having one of the largest EEZs and longest coastlines, the United States produces only 1% of global mariculture (FAO 2018).”

**Comments from Annette :**

*Increasing storm frequency and intensity are very critical factors not considered in assumptions for suitable ocean farming e.g. g effects of monsoon throughout Asia/ tropical ; seasonality of favorable sea conditions may not be sufficient for growing to marketable size of finfish and other species, even with higher temperatures. For example, if growing period is six months, sea and weather conditions related to monsoons/typhoon season is shorter, this constraining optimal production (see related major comment below)*

*But the current production for ocean aquaculture ( both offshore and nearshore) estimates based on Gentry 2017, and the new analysis extending the analysis of Gentry, do not consider variability in weather and sea conditions e.g. affected by storminess, rainfall ( seasonal and biogeographical) which are major factors (as noted in 4.2.2) . Even without climate change, these are factors that primarily constrain mariculture production at least in the tropics , aside from economic considerations.*

*Potential mariculture maybe considerably overestimated specially in the tropical areas affected by seasonal changes ( monsoon) as well as episodic severe atmospheric and sea conditions. This is also where many developing countries with poor governance and regulatory systems (e.g. small island states) are found. No one pays for environmental costs/degradation of ecosystems except the poor small fishers.*

*Whether production from mariculture can offset the productivity of multispecies fisheries if better managed may not be likely.*

We have added the following caveats paragraph to the new analysis paragraph to reflect these caveats:

“Caveats: This model was parameterized using mariculture equipment maintenance costs and growing seasons typical to the United States and not in regions with higher environmental risk and variability (e.g., tropical monsoons in Asia and elsewhere). Thus, it may overestimate mariculture production potential in these regions by (1) underestimating costs of maintenance and overestimating profitability or (2) overestimating the amount of time available for production.”

*The conclusions about why current mariculture production is so low is not substantially supported and should be qualified (e.g. for some temperate developed countries such as the US); given that direct effects of climatic factors on location and duration of production areas were not factored in; aside from the overall, forecast declines in the biological potential and impacts on marine ecosystems.*

We have modified the text to read:

**“If the potential for production is so large, why is current mariculture production so low?** This gap is likely driven by two factors: (1) a lack of expertise and capacity for conducting mariculture operations in many developing countries; and (2) challenging regulatory barriers for developing mariculture operations in many developed countries. In Palau, for example, many mariculture operations have been initiated with outside funding but have failed once the initial funding period ends. The longest running mariculture operation in Palau is a government subsidized clam hatchery that would be unprofitable without government support (Y. Golbuu, personal communication). In the United States, on the other hand, precautionary regulations restrict mariculture development (Wardle 2017; Sea Grant 2019). Thus, despite having one of the largest EEZs and longest coastlines, the United States produces only 1% of global mariculture (FAO 2018).”