Reply to comments

This manuscript suggests the potential mechanism to explain the biological richness (higher tropic level food web) of Kuroshio based on the indirect experimental results of cultured growth rate estimated by size fractionated Chl.a and mortality estimated by grazing pressure of microzooplankton. These indirect approaches are interesting and might be valuable, however I think further explanation or evidences are necessary to make readers agree to the authors conclusion. I also agree with this manuscript for the possible publication in Biogeosciences after moderate revision. The substantial comments are as follows:

>We appreciate your comments. Our point-by-point responses are indicated below. Hopefully, these are enough responses to your comments and suggestions. The revised manuscript is indicated as blue-colored characters and the revised phrases to your comments and suggestions are shown in highlighted in yellow. Please note that the revised phrases to the other reviewers' comments and suggestions might be included in the all phrases because we already responded to the other reviewers (original manuscript was already revised).

Introduction 1: The current version looks too simply. Why don't authors add the research background of this study citing references? For example, the importance of fish resources from Kuroshio is not described in this version and the significance of fish catch in the Kuroshio to the entire the North Pacific or global. In addition, what kind of lower trophic level organisms compose of assemblages of phytoplankton and zooplankton in the study area? What nutrient regulates the primary production in this study area N? or P? Etc....

>Thanks for suggestions. Just after this manuscript was submitted to Biogeosciences, the review papers have been published. Based on these results, we added more description on the research background.

In spite of such seemingly unproductive conditions, the Kuroshio in the East China Sea (ECS-Kuroshio) is neighboring major spawning and nursery grounds for foraging species such as sardine (Watanabe et al., 1996), jack mackerel (Sassa et al., 2008), and chub mackerel (Sassa and Tsukamoto, 2010), and common squid (Bower et al., 1999). Indeed, good fishing grounds have been formed for various fishes and squid using the Kuroshio and their catches composed more than half of total catch in Japan (Saito, 2019). Highly vulnerable early life stages of many foraging species have a risk to grow and recruit under the oligotrophic and unproductive waters in the ECS-Kuroshio (hereafter called the "Kuroshio Paradox": Saito, 2019), even if the warm temperatures of the Kuroshio Current could enhance cellular metabolic processes and then growth……Use of waters in the vicinity of the oligotrophic Kuroshio as a nursery and feeding ground would therefore appear to be a risky strategy unless there is a mechanism that enhance biological production in the Kuroshio.

There is increasing information on community structure of phyto- and zooplankton in the Kuroshio. Pico- to nano-autotrophs contributed to phytoplankton standing stocks in the Kuroshio and predominant components were cellular cyanobacteria like Prochlorococcus and Synechococcus, haptophytes and diatoms (Hasegawa et al. 2019; Endo and Suzuki 2019). Heterotrophic bacteria and calanoid copepods contributed to heterotrophs biomass in the Kuroshio, while microzooplankton biomass were minor (Kobari et al. 2019). Based on the mass balance model, mesozooplankton standing stocks were supported by micro- and nano-autotrophs and microzooplankton (Kobari et al. 2019). However, we

have little knowledge how biogeochemical processes and trophodynamics support plankton community in the Kuroshio.

Here we report phytoplankton productivity and subsequent microzooplankton grazing stimulated by turbulent nitrate flux that can happen in the Kuroshio Current.

Introduction 2: Nutrient supply mechanism by turbulent mixing or other physical processes should be more explained citing references because there is a large gap between the paragraph 1 and 2 in the current introduction.

Introduction 3: Why is Tokara Strait important in the Kuroshio track area? Is there any geographical characteristics or bottom topographic characteristics? Is the area of Tokara Strait hot spot of turbulent mixing? Is there any other hot spot of turbulent mixing in the Kuroshio track area? Please explain the above questions in the revised manuscript because the readers who are not familiar with Kuroshio and the North Pacific would not understand the significance of research of Tokara Strait.

>We appreciate your kind suggestions. Agree. The two issues you suggested are associated each other. We added more description on the nutrients supply mechanisms and importance of the Tokara Strait before the last paragraph in Introduction section. The information was also based on the recent review papers as mentioned above.

In recent years, some mechanisms have been found for nutrients supply to the oligotrophic Kuroshio waters. The Kuroshio nutrient stream contributed significantly to productivity in the euphotic layer, similarly to the "nutrient stream" along the Gulf Stream (Komatsu and Hiroe, 2019). Turbulence around the Kuroshio appeared to be important for upward nutrients supply in the Kuroshio (Nagai et al., 2019). Frontal disturbances also contributed to nutrients supply to the surface layer in the Kuroshio (Kuroda, 2019). Moreover, the Island Mass Effect was produced by the Kuroshio Current around the archipelagic topography and induced upward nutrients supply (Hasegawa, 2019). These nutrients supplies have been suggested to stimulate biological productivity in the Kuroshio. In the wide Kuroshio track area, these nutrients supplies can happen particularly around the Tokara Straits due to the extensive frontal disturbances (Nakamura et al., 2006) and strong turbulence (Tsutsumi et al., 2017; Nagai et al., 2017, 2019).

Here we report phytoplankton productivity and subsequent microzooplankton grazing stimulated by turbulent nitrate flux that can happen in the Kuroshio Current.

Results 1: The manuscript described that nitrate flux induced by turbulent mixing at the subsurface Chl maximum was observed as 0.788 mmol m-2 d-1 in the Tokara Strait (150 km wide) and authors assumed that the same concentration was kept during 5 days. What potential physical mechanism does keep almost same nitrate concentration at the Chl maximum layer during week?

>Thanks for good comments. Our assumptions are based on the direct observations of turbulence (see Tsutsumi et al., 2017; Nagai et al., 2017). The strong turbulence was likely kept when the Kuroshio Current passed over the Tokara Strait due to the narrow and shallow topography with many islands and seamount. Also, our assumption of the nitrate supply might be conservative in the ambient waters because the upward nutrients supplied with the Island Mass Effect was not considered here.

Results 2: In terms of gradient enrichment experiment and dilution experiment, the please add further descriptions of the details e.g., methods themselves and what purpose are achieved by these methods etc.

>Thanks for your suggestions. We mentioned them briefly at each paragraph but added clearer descriptions of the purpose and results achieved at the beginning and end of the phrases as follows.

Gradient enrichment experiments

To evaluate how these turbulent nitrate fluxes measured in the Tokara Strait increase the standing stocks of phytoplankton and micro-heterotrophs in the Kuroshio, we conducted bottle incubations of the phytoplankton and micro-heterotrophs communities enriched with the different nutrient concentrations (EXPa)…..Thus, the standing stocks of phytoplankton and micro-heterotrophs were likely increased within the range of the turbulent nitrate fluxes measured in the Tokara Strait.

To explain whether growth rates of the size-fractionated chlorophyll might be variable with initial nutrients concentrations (bottom-up control) and predator biomasses (top-down control) at the beginning of the experiments, the slopes were compared to the nitrate+nitrite (Fig 5a) and phosphate concentrations (Fig 5b) and micro-heterotrophs biomass (Fig 5c) in the ambient seawater without enrichment….. Thus, the variations in phytoplankton growth rates are likely associated with nutrients concentrations at the beginning of the incubations.

Dilution experiments

To evaluate how much and which size-fractionated phytoplankton was removed by microzooplankton grazing, the dilution experiments were conducted simultaneously to the gradient enrichment experiments…..These results imply that gen of all size-fractionated chlorophyll balances the microzooplankton grazing mortality with the maximum growth. Particularly for the nano-fractionated chlorophyll, the net growth rates were slightly low due to the mortality rates by microzooplankton grazing exceeded the maximum growth rates.

Results 3. Lines 161-167: I could not understand what authors would like to describe in this paragraph. Especially, the sentence of the line 163 (To explain ...) seems quite to be abrupt. The more explanation needs for Fig. 5. Does the fig 5 show the data comparing among all stations? Why can the Fig. 5 be used to explain the difference in growth rate of size fractionated Chl. a among stations? Please explain more details of the similarity or difference of characteristics among stations. In addition, no Supplement Fig.1 is attached in the manuscript.

>Thanks for your comments. We added more descriptions on the reason why we compared the slope of a linear regression of phytoplankton growths to nutrients supply using supplement Fig. 1 as follows. At the platform of Biogeosciences, supplement materials seem to be provided with different files from the manuscript. You can find the Supplement (205KB) below the manuscript PDF or XML files at the website.

The slope of a linear regression between growth rates of the size-fractionated chlorophyll and the logarithms of the nitrate enrichments at each incubation provided a metric of the sensitivity of their growth rates to nutrient supply. As shown in Supplement Fig 1, the steeper slopes were found at some

stations in the upstream Kuroshio in the Tokara Strait compared with those at the other stations, suggesting that apparent phytoplankton growths were variable with the nutrients concentrations or predatory impacts at the beginning of the incubations. To explain whether growth rates of the size-fractionated chlorophyll might be variable with initial nutrients concentrations (bottom-up control) or predator biomasses (top-down control) at the beginning of the experiments, the slopes were compared to the nitrate+nitrite (Fig 5a) and phosphate concentrations (Fig 5b) and micro-heterotrophs biomass (Fig 5c) in the ambient seawater without enrichment.

Discussion 1: Line205: Why is microzooplankton standing stock in the Tokara Strait of the Kuroshio track low, although the grazing pressure of phytoplankton by microzooplankton are relatively large? Is there any evidence or previous studies to indicate the rapid energy transfer of the microzooplankton to larger size organisms? Please give the potential mechanism in the revised version.

>Thanks for your comments to the low microzooplankton biomass. Unfortunately, there is no direct evidence why microzooplankton biomass was low in the Kuroshio, excepted for the indirect evidence that microzooplankton might be removed by mesozooplankton predation based on the carbon flow among various components (Kobari et al., 2019). Thus, we added this brief information there.

Microzooplankton standing stocks in the Kuroshio Current at the Tokara Strait were lower than those on the continental shelf of the ECS (Chen et al., 2003) and might be removed by mesozooplankton predation (Kobari et al., 2019). These results expected low microzooplankton grazing on phytoplankton.

On the other hand, we have conducted the other bottle experiments to evaluate how much microzooplankton was removed by mesozooplankton predations. As you expected, the results from the bottle experiments demonstrated that naked ciliates predominated in microzooplankton biomass were removed by mesozooplankton predation. Since these results are recently submitted, we could not mention more.

Discussion 2: Line219-220: The sentence of this line is abrupt because there is no evidence or discussion in terms of the large variation in microzooplankton standing stocks among stations.

>Thanks. Large variations in microzooplankton standing stocks among the stations were already shown in Table 1, and thus we added “Table 1” in this sentence.