Press Releases

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Scientists reveal the relationship between phytoplankton size diversity and productivity in the changing oceanic environment

Drs. Bingzhang Chen and Sherwood Lan Smith of the Research and Development Center for Global Change at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) have investigated the effects of phytoplankton size diversity on primary productivity in the North Pacific. By using a new model for communities resolving differently sized phytoplankton, the results have unraveled partially unknown mechanisms that link biodiversity and productivity. This study project was carried out in collaboration with Prof. Kai Wirtz of the Helmholtz Centre Geesthacht (HZG) in Germany.

Phytoplankton support the base of marine food webs. Just as is true for plants on land, the biodiversity of phytoplankton in the ocean is very important for maintaining the overall productivity and resilience of oceanic ecosystems. Furthermore, compared to land plants, more species of oceanic plankton tend to coexist in any single place, even though they differ greatly in size and other traits. While different relationships have been observed between biodiversity and productivity, impacts on productivity by phytoplankton diversity remain unknown because the interactions of so many species in the highly variable oceanic environment are extremely complex.

To simulate the growth of plankton across the different regions of the North Pacific Ocean, the scientists have newly developed a continuous trait-distribution model for phytoplankton community of gleaners—those species that grow well when nutrients are scarce—competing with opportunists—those species that grow well when nutrients are plentiful. Then, the scientists examined the simulated results of diversity-productivity relationships under different environmental conditions in different areas.

As a result, they demonstrated that the effect of diversity on productivity depends much on the balance between two major effects. On the one hand, in dynamic environments, diversity in terms of both size and function is advantageous to phytoplankton communities, which is to say that it helps them sustain consistent productivity under changing environmental conditions. By contrast, competitive exclusion narrows the size distribution around the optimal size or type in static environments, so that the most productive phytoplankton communities have low diversity in calm areas. The research group also clarified how ocean currents and other physical processes, by mixing plankton from different waters, sustain size diversity levels high enough to support relatively high production across most of the North Pacific Ocean. The underlying mechanisms are consistent with previous theoretical predictions: more diverse communities tend to be more productive in regions with frequent disturbance because diversity enhances adaptive capacity, which is an ability to recover from sudden changes in environmental conditions. On the other hand, less diverse communities tend to be more productive in relatively calm areas, because there highly productive communities are composed of nearly identical species having just the right traits or inherent characteristics for the nearly constant environmental conditions. Therefore, the effect of diversity on productivity depends on local environmental conditions, in particular, the frequency of disturbance. Built upon the insights of pioneering scientists such as Charles Darwin, these findings are the first to represent phytoplankton communities in terms of a continuous size distribution within a three-dimensional ocean simulations using a new model.

Marine life conservation is defined as one of 17 goals for “conservation and sustainable use of the oceans, seas and marine resources” within the new agenda of the UN Sustainable Development Summit of 2015. To optimize marine resources, the frequency and intensity of disturbance should be considered to sustain the biodiversity and productivity of the marine food chain and fisheries. Specifically, it would be more important to limit the loss of biodiversity in areas subject to frequent disturbance in order to maintain the adaptive capacity of ecosystems there, compared to areas where disturbances are relatively rare and the loss of biodiversity is less likely to reduce productivity.

Moreover, besides plankton ecosystems, this approach could be applied to other different research areas such as economics and human resource management. For example, how to best manage the diversity of employees’ skills or products for maximizing business productivity?

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Title: Effect of phytoplankton size diversity on primary productivity in the North Pacific: trait distributions under environmental variability
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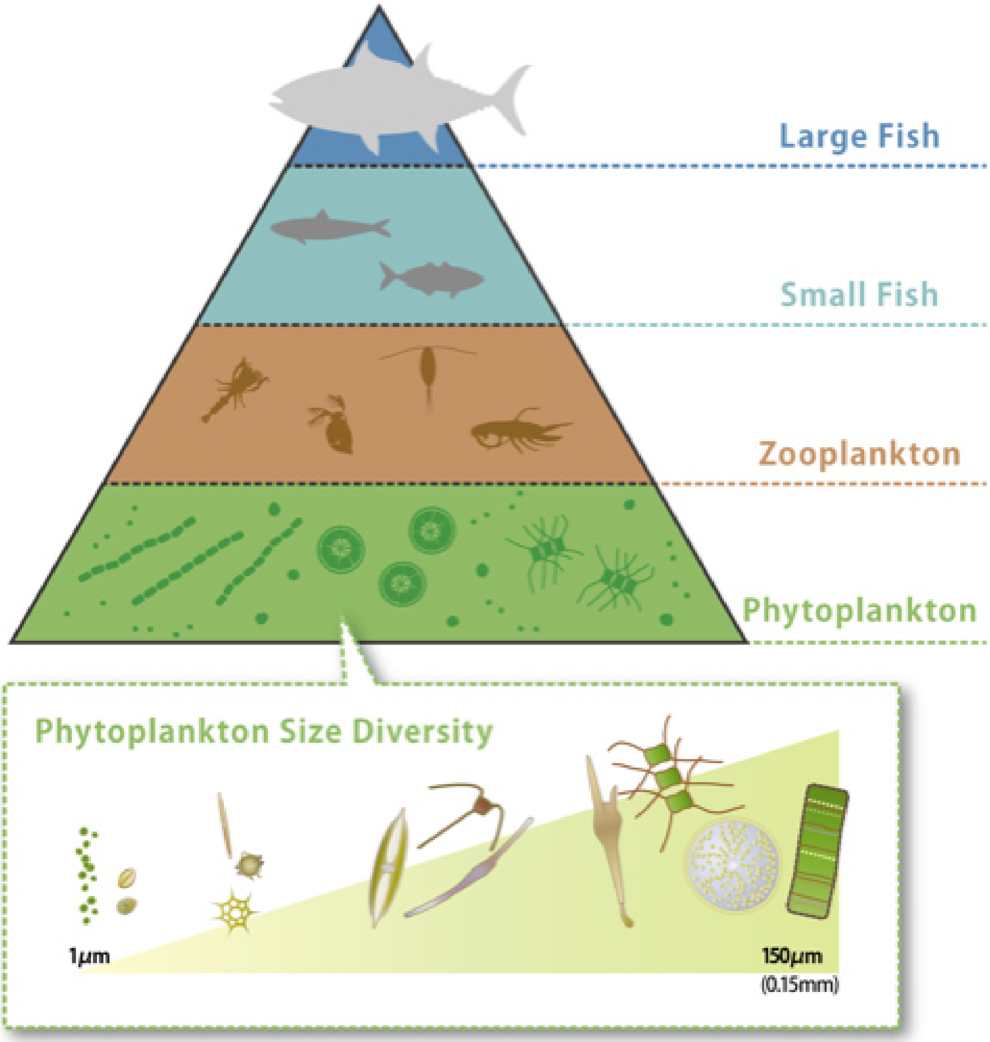

Figure 1. A marine food chain is supported by plankton, which provide energy and nutrition to support zooplankton, fish and marine mammals.

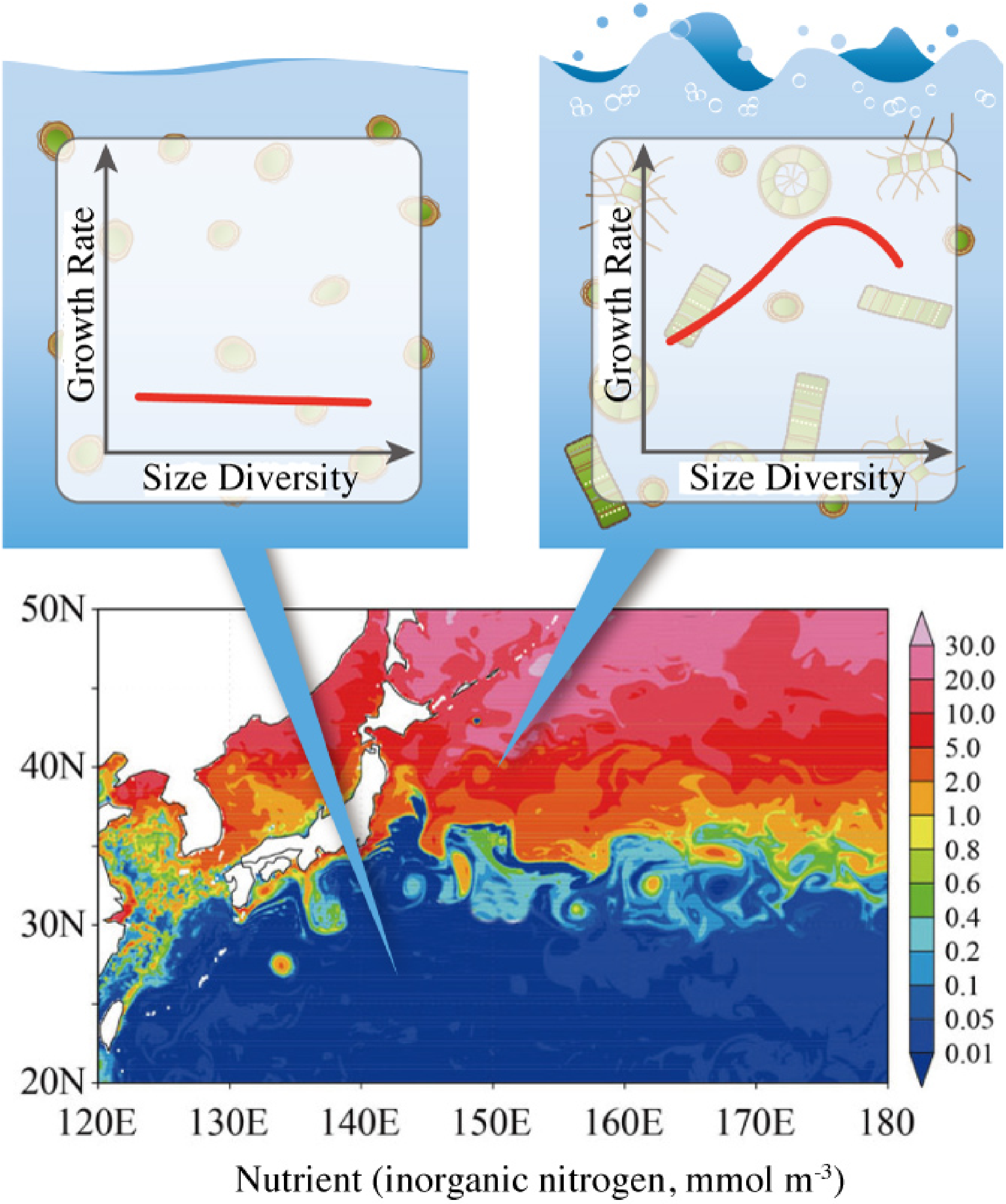

Figure 2. Different relationships between phytoplankton size diversity and their production are typical of different areas in the North Pacific. In calm areas, less diverse phytoplankton communities tend to be more productive (left), but in areas with more frequent disturbance (ocean mixing) more diverse communities tend to be more productive (right). Across most of the North Pacific, the environment just happens to correspond more to the stable conditions depicted in upper left part, than to the more dynamic conditions depicted in the upper right.

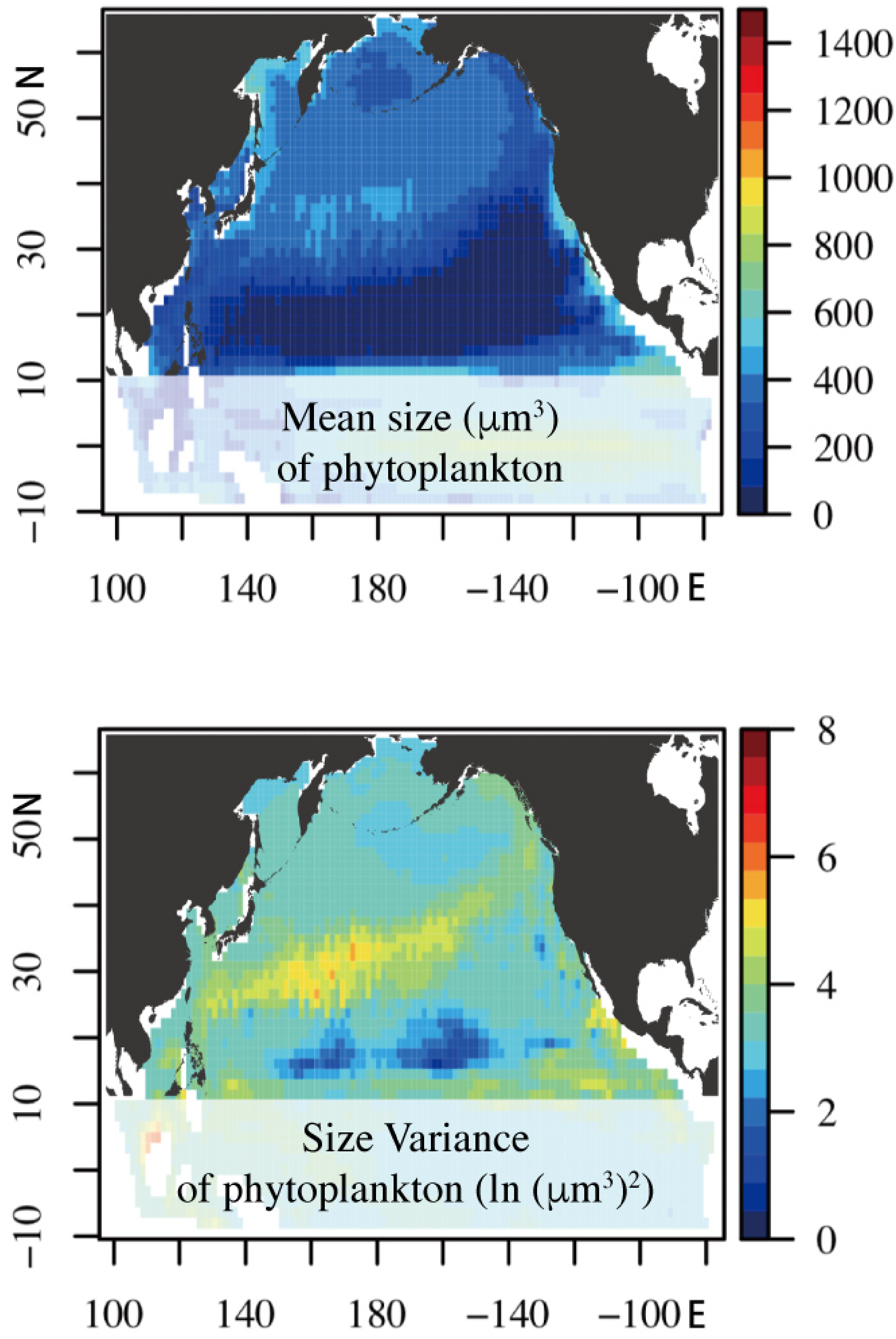

Figure 3. Simulation results for phytoplankton mean size (top) and size diversity, represented as variance (bottom), across the North Pacific.

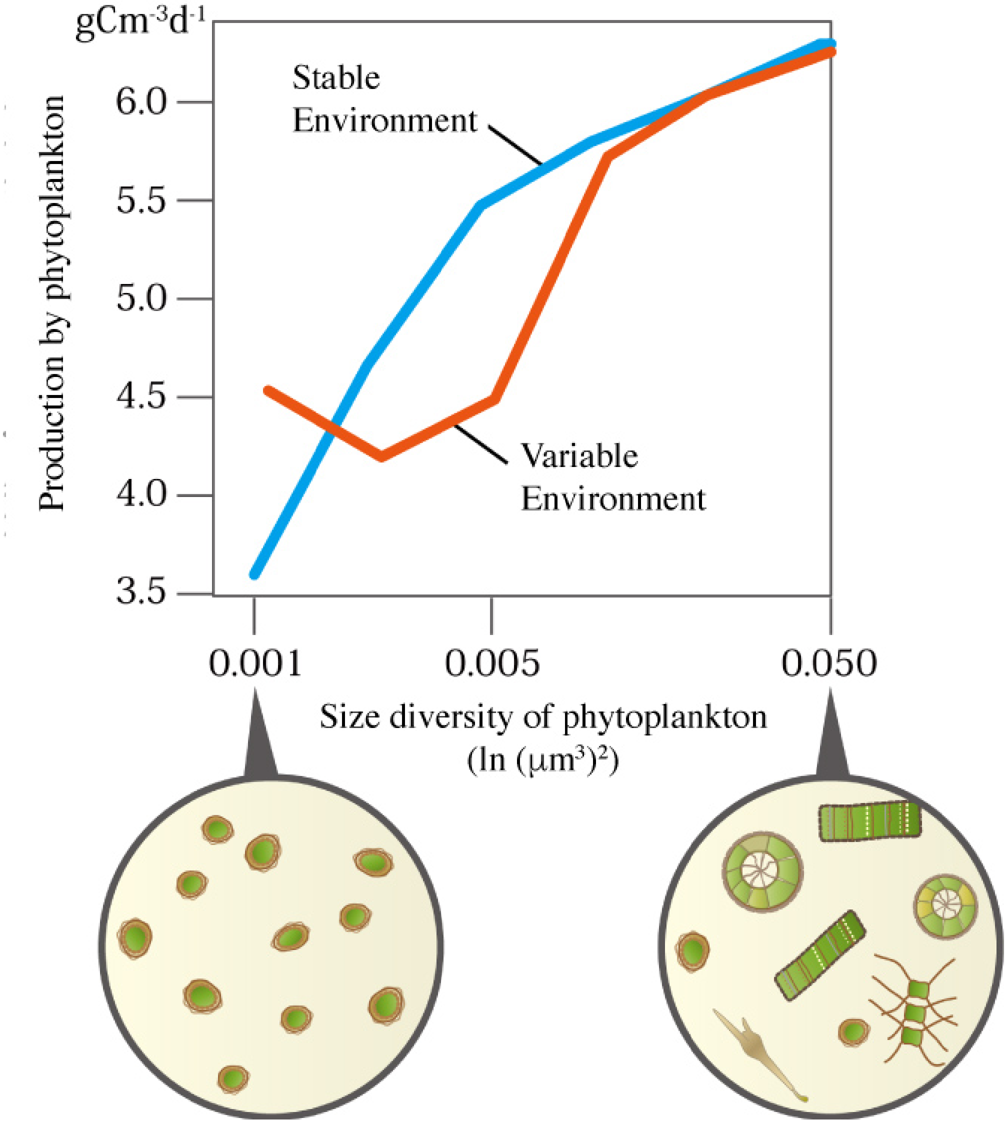

Figure 4. The relationship between the production of carbon biomass by phytoplankton (vertical) and their size diversity (horizontal) for stable conditions (low environmental variability, blue line) and for more variable environmental conditions (red line).

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