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The Effect of Iron and Copper on Nutrient Utilization and New Production in High Nitrate Low Chlorophyll Waters

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It now is generally accepted that iron enrichment of High Nitrate, Low Chlorophyll (HNLC) waters will result in diatom blooms, but the magnitude of the response can vary dramatically. As a consequence, there are very large uncertainties over how the export of carbon, nitrogen and other nutrients will change due to fluctuations in aerosol iron deposition associated with climate change. Thus it is important to understand the fundamental reasons for differences in the magnitude of iron-stimulated phytoplankton blooms in HNLC waters. Results from our deck-board experiments during the SEEDS II mesoscale iron enrichment experiment in the western subarctic Pacific Ocean show that phytoplankton were unable to fully utilize the added iron present in the enriched waters. This iron limitation resulted in minimal new production and draw-down of P and Si, as also observed in the in-situ response. However, low-level copper additions reversed this situation and increased new production, presumably by enabling diatoms to induce a high-affinity Fe uptake system capable of sequestering Fe from strong organic complexes. Moreover, our findings show that adding Fe and Cu together resulted in greater growth than adding these metals separately, indicating that a larger proportion of the added iron remained accessible to the diatoms. These growth responses paralleled changes in macronutrient drawdown amounts and ratios. During the early stages of the in-situ enrichment, Cu additions to our deck-board samples increased the silicate to nitrate uptake ratio, indicative of increased diatom growth. In contrast, nitrate:phosphorus uptake ratios remained relatively constant. However, in the weeks following the last in situ Fe infusion, Cu additions became less beneficial

and even negatively affected growth several weeks later. These findings demonstrate that new production associated with aerosol deposition is critically dependent not only on increased Fe inputs, but also on increased Cu availability which enables diatoms to fully utilize the added resource. Given the low content of Cu relative to Fe in aerosols, this co-dependency has significant implications for predicting the effect of deposition events on new production in HNLC waters.