Rory Welsh Synthesis 1

Two papers selected for Synthesis 1:
Justin R. Seymour, et al. 2010. Chemoattraction to Dimethylsulfoniopropionate Throughout the Marine Microbial Food Web. Science 329:342-345.

Munday P, et al. 2010. Replenishment of fish populations is threatened by ocean acidification. Proceedings of the National Academy of Sciences 107:12930–12934.

Ocean acidification causes reduced response to chemical cues throughout the marine food web.

Recent empirical evidence studying the implications of elevated CO_2 concentration on marine noncalcifying species is limited, and far-reaching ocean acidification impacts on marine diversity remain unknown. Two recent publications by Munday and others 2010 (Munday) and Seymour and others 2010 (Seymour) could have illuminated how ocean acidification will affect marine diversity by incorporating certain aspects of each others work into their own research. Both presented strong papers, but if they were to combine several areas of their experimental designs together, each publication could have really benefited.

Munday studies how ~~various~~ elevated dissolved CO_2 concentrations diminish the ability of two larvae phase reef fish to respond to chemical cues. Although specific compounds were not tested, the paper benefited from strong lab-based, and environmental experiments. The experiments concluded that elevated CO_2 concentrations reduced the ability of larvae to respond to chemical cues resulting in increased mortality during recruitment to adults. In contrast Seymour's research highlights how motile marine planktonic microbes can respond to microscale chemical cues from specific compounds.Various motile strains of marine plankton were examined for attraction behavior to specific compounds such as Dimethylsulfoniopropionate (DMSP) and other related compounds. Seymour only studied in natural seawater conditions and as a result ocean acidification conditions were not tested. When the two papers are considered together, the novel hypothesis that emerges is that ocean acidification will cause a reduced response to chemical cues throughout the marine food web.

A detailed summary of the strengths and weaknesses of each of the two papers will help highlight how the novel hypothesis ties together certain areas from each paper. First off Munday's paper does an excellent job introducing the current conditions and future trajectories of ocean acidification. Contrasting his work against numerous other studies on ocean acidification and marine calcifiers he focus on the implications of increased CO_2 concentrations on fishbehavior. The paper highlights two noncalcifying benthic marine larvae phase reef fish species clownfish (*Amphiprion percula*) and wild-caught damselfish (*Pomacentrus wardi*). Both species were reared in a series of increasing CO_2 concentrations and tested for responses to predatory cues in a two channel choice flume. In a controlled lab setting, the larvae could choose between a stream of water containing the predator cue and one without the cue. The predatory cues were olfactory indicators from bulk tank water containing a common reef predator, rockcod *Cephalopholis cyanostigma*, and not specific compounds. In a final experiment Munday expands his findings from reduced response to predatory cues to reduced fitness. Here he transplants settlement stage damselfish from the previous experiment to various reefs to see if exposure to increasing CO_2 concentrations leads to increase risk-associated behavior and mortality during recruitment.

Several key elements strengthen Munday's paper. One such item is the foresight to test how ocean acidification will affect marine noncalcifying species if current trajectories of global emissions are maintained. It has been well documented that ocean acidification results from increased atmospheric CO_2 concentrations, which then increase the dissolved CO_2 concentrations in the shallow ocean and reduce the pH (Hoegh-Guldberg and others 2007). Numerous studies have also shown that decreased pH affects marine calcifiers ability to produce skeleton and shells by reducing the carbonate-ion saturation (Doney and others 2009; Fabry and others 2008). Only recently have studies begun to look at how ocean acidification might affect the marine noncalcifying species ability to respond to chemical cues selecting preferred settlement areas (Munday and others 2009). Munday could have expanded his previous work on this understudied area if additional focus was added to include motile planktonic species that help comprise the microbial food web.

Munday's decision to look at only predator cues was a logical next step from his previous work, but even within the confines of predatory cues alone, there is still room for improvement. Munday's predatory cue was water directly removed from a tank containing *C cyanostigma*. Some important issue that results from using bulk tank water are brought up during the discussion by the researches. He states further studies are needed to see if the elevated CO_2 concentrations caused a general effect on physiological processes or if the fish no longer perceived the odor as threat after repeated exposure. One way to help strengthen the research and resolve some of these issues would be to test a range of specific compounds in addition to the predator cue. An obvious choice would be DMSP, which has been demonstrated to be a foraging cue in coral-reef fish (DeBose and others 2008). In addition, DMSP has been intensely studied for its role in global climate regulation and oceanic sulfur cycles. By adding a separate test using specific compounds like DMSP and related compounds to the predator cue experiment, Munday could have expanded on this relatively understudied area.

A strong point of the paper is that the research incorporates both controlled lab experiments and environmental transplant experiments. Wild-caught damselfish that had been reared to settlement stage in the series of increasing CO_2 concentrations were transplanted onto various natural reefs to test if exposure to higher CO_2 concentrations altered their behavior. Again, had the specific compound DMSP been used, as well as the predator cue, an additional environmental experiment could have been applied. DeBose and others (2008) demonstrated evidence that reef fishes aggregate to controlled experimental deployments of DMSP over natural reef habitats. A follow-up study testing how exposure to elevated CO_2 concentration affects damselfish's ability to aggregate to DMSP deployments on natural reefs would certainly be a valuable and worthwhile experiment.

In contrast, Seymour's research focuses on DMSP and several related compounds, and the ability of multiple motile planktonic strains to exhibit chemoattraction towards these specific compounds. Seymour excelled in explaining the important role of DMSP in the marine ecosystem. At a cellular level, DMSP can provide up to 10% of a phytoplankton's total cellular carbon (Stefels and others 2007). He makes a compelling argument that because of the direct influence of DMSP and DMS on climate in the marine biosphere, the microbe's microscale interactions are mediating marine climate. Seymour acknowledges the lack of clarity surrounding the chemical ecological role of DMSP due to contradictions in previous research studies (Miller and others 2004; Stom and others 2003) and quickly sets out to resolve them. However, the paper would benefit by taking the research one step further and testing how elevated CO_2 concentrations affect the chemoattraction of each organism towards these specific compounds.

Seven different motile strains throughout the microbial food web including heterotrophic bacteria, phytoplankton, and bacterivore and herbivore microzooplankton were tested for chemoattraction. Although Seymour's experimental design could not accommodate the larger sized larvae used by Munday, he could have benefitted from growing each of the cultures in media containing a series of elevated CO_2 concentrations. By incorporating addition sets of cultures for each strain, Seymour would have been able to test not only the affects of increased CO_2 concentrations on their chemoattraction abilities, but also their relative growth rates at the various CO_2 concentrations. Another area that would have benefitted Seymour's research by incorporating the additional set of cultures would be implications stemming from varied chemotaxis responses in some, but not all, of the individual compounds tested. If individual cultures responded statistically different to some chemicals but not others after being cultured in elevated CO_2 concentration media, it might help shed some light on the factors driving these changes.

Furthermore, Seymour illustrated that the predators also exhibited chemoattraction towards DMSP. He points out the benefits of chemoattraction responses in the phytoplankton and heterotrophic bacteria must outweigh the cost associated with higher encounter rates of grazers. He could test this by adding additional microscale pulses of filtered media taken from cultures of grazers similar to the predator cue used in Munday's experiments. Finnaly by spiking the filtered grazer media with varying concentrations of DMSP and related compounds, perhaps a tradeoff boundary concentration will emerge.

Although both publications were strong works in and of themselves, clear benefits become apparent when the works are considered together. If each paper would have incorporated all of the relevant ideas from the other paper into their own then we might have an in depth analysis of what the future impact ocean acidification will have on several organisms throughout the marine food web in terms of their chemotaxis ability.

However, the two papers have already been published and an additional set of experiment is now needed to test the hypothesis; ocean acidification causes reduced response to chemical cues throughout the marine food web. I propose one set of experiments repeating Seymour's work and adding the elevated CO_2 concentration series used by Munday for each planktonic strain. In addition to the specific compounds used in Seymour's original experiment a micro pulse of a bulk predator cue with elevated DMSP concentrations should be tested. The bulk predator cue similar to Munday's predator cue should come from filtered media from a culture of a common microbial planktivorous strain. Finally I propose Munday's experiment be repeated with additional specific compounds at various concentration similar to compounds and concentrations used in Seymour's original experiment.

Rory,
You basically nailed the assignment. You have done a nice job - and I could believe that this hypothesis could even make one's career in science.
I was not real happy with your figure - for one, I asked that you give me a single file, not two - and because I think you should try to graphically illustrate the concept itself, not how the ideas of the two papers lead to the hypothesis.
Grade:
A

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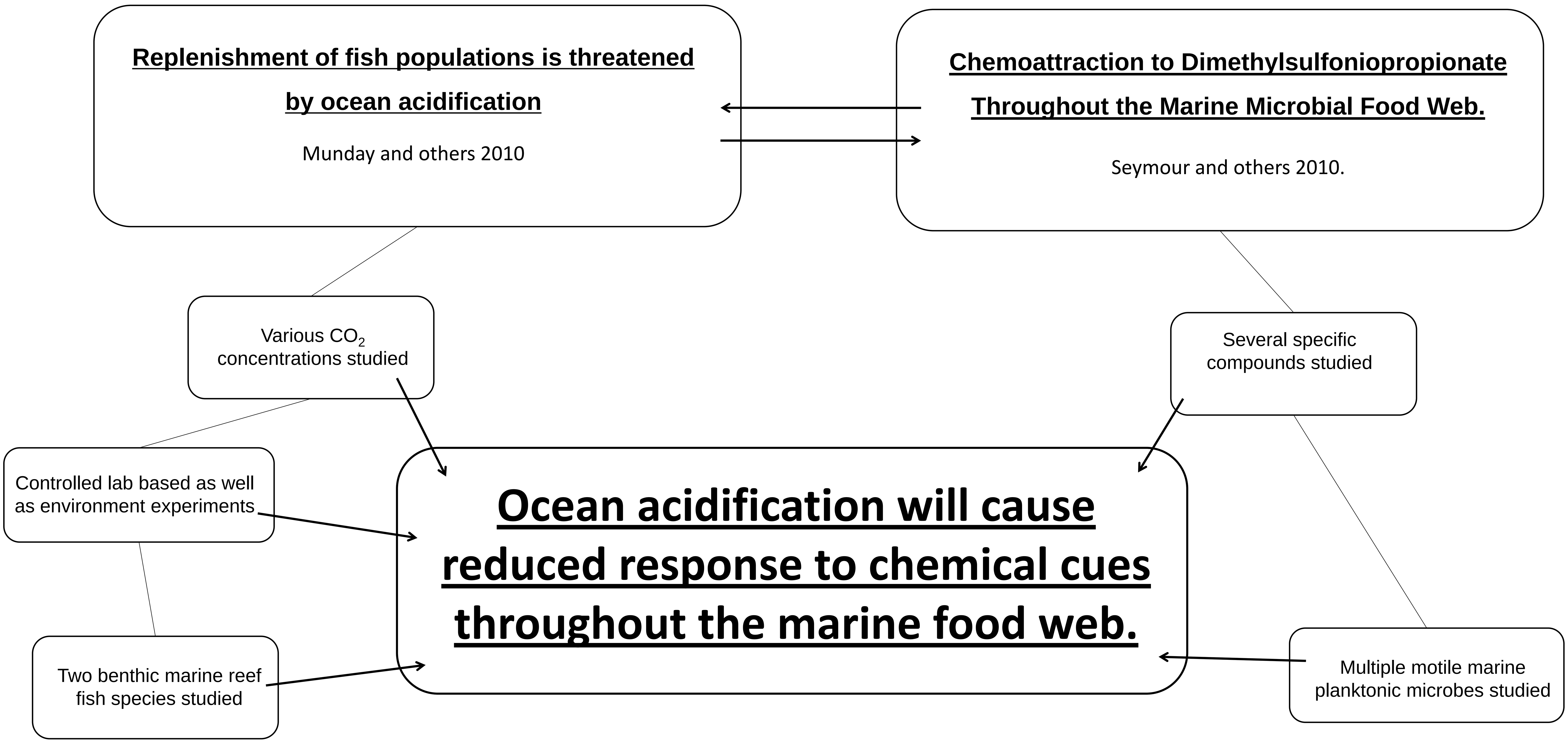

Figure 1. A conceptual diagram illustrating the novel hypothesis which emerges when Munday and others 2010 is considered along with Seymour and other 2010.