Abstract

Anthropogenic activity has caused an increase in atmospheric CO2, which in turn has shifted the equilibrium of marine chemistry causing a decrease in pH. Ocean acidification (OA) has the potential to negatively impact the development of sensitive early life stages of many marine organisms by reducing and calcification rates and increasing mortality. Warming temperatures have also influenced life events, such as spawning and migration, since many organisms rely on environmental triggers, such as water temperature or solar irradiance, to initiate these events. As climate change impacts both marine pH and phenology, there is a potential for interactions between the two as organisms have evolved seasonal behavior to optimize the success of their offspring based on water conditions, food availability, and presence of predators. Unfortunately, little research has been done on the potential interactions between impacts of OA and shifting phenology on marine organisms, raising the question as to how life stages can adapt to differences in pH due to seasonality and ocean acidification. This meta-analysis reviewed nearly 3,000 papers from Google Scholar on OA and phenology, selecting papers with quantifiable information on changes in phenology and organismal development due to OA among the early life history stages of marine organisms. Following review, 70 papers were selected based on the species overlap between searches on OA and phenology. These papers are being scored to extract quantitative relationships between the impact of ocean acidification on marine organisms and relationships between warming temperatures and phenological events. Once information on these relationships has been extracted, the data will be plugged into climate change models to project the potential impacts of OA and changes in seasonal spawning, development, and migration. A total of 22 species representing 5 phyla (Arthropoda, Crinaria, Chordata, Echinodermata, and Mollusca) will be examined for their potential response to changing seasonality and pH due to climate change. In doing so, this meta-analysis has the potential to project changes that could prove useful to both fishery management of popular fish, such as cod and tuna, as well as coral conservation efforts.

Background

With the rise of deforestation and fossil fuel consumption in the past two centuries, atmospheric levels of carbon dioxide (CO2) has risen by 40 percent. While this reduction in carbon dioxide concentrations on land alters the chemical balances that many forms of life relies on (Doney et al., 2009), this chemical balance consists of a series of chemical reactions occurring from where the atmosphere meets the ocean to the chemical reactions resulting in the ocean's pH. Ocean acidification (OA) is a relatively predictable consequence of climate change due to the stoichiometric nature of the chemical reactions and saturation rates of the involved compounds. Invertebrates and marine vertebrates face different challenges considering different specific CO2 concentrations, reduced shell integrity or increased strain on the physiology of larval fish. These changes in physiology have implications for the timing of spawning, recruitment, and other phenological events. The timing of these events help structure ecological interactions and ensure the survival of the next cohort of organisms in certain environmental conditions. While global warming is shifting organism phenology in a variety of taxa, from blue mussel to loggerhead sea turtles, ocean acidification will further impact seasonal pH cycles, especially in higher latitude oceans. (Fitz et al., 2014; Monsoijn et al., 2019).

Methodology

OA and Phenology Searches in Google Scholar

Google Scholar Library

Mendeley

Species Track list

Papers were excluded from the meta analysis due to irrelevance to impact of OA for papers focused on a lack of focus of climate change effects (CC) on phenology.

Papers discorced included those focusing on policies and environmental factors not including OA/CC.

Further revision resulted in papers being discarded due to focusing on ecology/ecosystems as a whole instead of species.

The search terms for ‘Ocean Acidification’ and ‘Phenology’ included organismal, reproductive, global change terms, as well as terms specific to each topic. Relevant papers were collected and organized into folders through Google Scholar and tested.

Google Sheets & Docs was used to organize and categorize data collected, while Mendeley’s desktop application was used to organize papers during the tracking and scoring processes.

Following the second revision, each paper was downloaded to Mendeley and reviewed with relevant information (phyllum, species name, life stage studied) recorded in a Google Sheet.

Once all species had been recorded in a Google Sheet, papers were grouped together according to species and for which there was information available on both ocean acidification and phenological changes for a given species were retained and used as the basis for the meta-analysis.

Each of the papers from the final meta-species track list will be scored by recording information on the article itself and the data gathered including study site coordinates, quantitative relationships, equations, and non-environmental factors. Authors are contacted if raw data is needed for the modelling part of this study.

Preliminary Results

Phylum Prevalence in Reviewed OA Studies

Phylum Prevalence in Reviewed Phenology Studies

Phylum Prevalence in Overlapping Studies

These graphs visualize not only where research is concentrated in areas, but also where it is lacking. Figures 1 and 2 show the stark contrast in the phylums observed in OA and phenology studies, respectively.

• OA focused more on shell-building phyllums (Arthropoda, Mollusca, Echinodermata)
• Phenology is centered around chordates (fish) and arthropods (copepods)
• Majority of papers that will be included in OA/CC modelling are on fish and copepods.

These charts, while only representing a small portion of research done regarding CC and OA, point to areas of potential research regarding how the physiology and phenology of understudied organisms will change as the climate changes as well.

Moving Forward

In the process of scoring papers, Gradus morhua was identified as the ‘test’ species to experiment with modeling potential interactions between OA impacts on organism physiology and phenology shifts due to warming temperature. A study done by Kunz et al. (2016) examined the specific growth rates (SGR) and other characteristics of G. morhua and Bonnemaissonus sella when raised in different temperature (3, 8, 12, and 16 Celsius) and pCO2 conditions (390 or 1170 ppm), while Neuheimer & Mackenzie (2014) examined changes in G. morhua’s mean spawning time in Degree Days (DD) in relation to thermal history. Data from these studies will be quantified in relation to environmental factors such as changes in pH and temperature and then integrated into climate change models to project potential outcomes for larval growth and mortality due to changing pH and phenology.

Phylogenetic tree illustrating the process in which papers were collected, reviewed, and scored, as well as a track of the total number of papers at that point in the process.

Literature on egg/larval stage duration

Kunz et al. (2016) Change in SGR and mortality due to pH decreases

Neuheimer & Mackenzie (2014) Changes in DD due to temperature increases

Conclusion

The literature review and meta-analysis revealed two key aspects of current studies on OA and phenology. Most literature available tends to focus on either OA or phenology, without considering the potential for interactions between these two climate stressors. Studies focused on these stressors also tend to focus on different phyla of marine organisms. There is more literature available on the phenology of chordates, whereas OA literature reveals an even distribution among phyla, with some focus on shell-building organisms. As a result, the modelling aspect of this study will focus primarily on chordates and arthropods but will have at least one species representative from each of the major phyla represented in a review of both OA and phenology literature.

Citations

