# Conservation, Climate Change, and Interdisciplinary Collaborations

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Abstract Human-caused pollutants are continuing to show their impacts on the environment. For decades, scientists have been studying these effects and what they mean for life on Earth. Such effects on nature include increased species extinction rates and climate change. However, these two elements are interconnected, and as a result, an interdisciplinary approach to conservation is necessary to solve these problems. Coral conservation is a prominent issue in both the media and the lab. Thus, using coral to explore an interdisciplinary approach allows scientists and the public to see what each discipline can bring to the table in determining how to effectively proceed in conservation efforts. Though generally there are a continually increasing number of scientific disciplines, this article will focus on marine biology, cell biology, ecology, physics, chemistry, conservation, environmental science, and climate science.

## INTRODUCTION

Climate has been an important area of study since as early as the 16th century (Fleming, 2014). Since then, the effects of anthropogenic pollutants became a significant concern for scientists (Fleming, 1998). By 1957, two groups were formed, both of which were dedicated to the study of different components of climate change (Corfee-Morlot et al., 2007). One group, run by oceanographer Roger Revelle of Scripps, focused on studying the carbon cycle. While the other, run by meteorologist and mathematician John von Neumann, dedicated its efforts to atmospheric modeling (Corfee-Morlot et al., 2007). From 1970 onward, these groups were fundamental to furthering climate change research. They helped unite world leaders to promote climate change research and action (Corfee-Morlot et al., 2007). As this research continued, there have been multiple indicators that global warming is having detrimental impacts on the environment, such as an increase in maximum annual temperatures, and precipitation changes, both of which increase species extinction rates (Cahill et al., 2013; Keith et al., 2014; Román-Palacios & Wiens, 2020).

The rising extinction rate of animals, plants, algae, and other organisms is a serious concern for scientists in multiple fields (Austin & Jr., 2016; Heard et al., 2013; Moat et al., 2019). There are many areas of concern as species loss has a variety of increasing negative effects: invasive species expansion (Burrows et al., 2014; Simberloff & Rejmanek, 2011), alterations in ecosystem processes, changes in productivity and decomposition (Gutiérrez-Salazar & Medrano-Vizcaíno, 2019; Zhang et al., 2008), loss of dependent species, food resource reduction within developing countries (Schuttenberg, 2000), preservation of indigenous livelihoods (Bonebrake et al., 2018), narrowing of potential resources, and effects on pharmaceutical research (Chivian, 2001; Hooper et al., 2012a). Besides these known effects of species loss, scientists are also concerned with the possibility of cascading effects, an unforeseen chain of events with negative impacts (Ceballos et al., 2017; Hooper et al., 2012b).

The efforts of conservation have been greatly impacted by the advancement of climate change (Lawler et al., 2015). Research fields have continually divided into increasingly narrower scientific disciplines (Coccia, 2020). This narrowing of fields also causes issues of narrow-minded researchers, believing their field superior and not stepping outside of its confines, in a time of climate change. This superiority complex has resulted in many eras of research based on the type of competition between scientific groups. The three main research eras indicated by Jonathan Adams are (Adams, 2013): 1) the individual, 2) the institutional and, 3) the national. However, research has entered a fourth era, and rather than being focused on competition it focuses on collaboration. Adams calls this period the age of international collaboration (Adams, 2013). Globalization has increased collaboration between different nations as well as collaboration between academic disciplines (Harvey, 2015). Studying the climate crisis through a variety of lenses strengthens research. Climate change does not affect just a few organisms, but rather, affects interconnected ecosystems. Drawing on the expertise of researchers from various fields is important for understanding the many facets of climate change. Thus, an interdisciplinary approach to climate research has the potential to be most effective in mitigating the climate crisis (Adams, 2013; Harvey, 2015).

One common goal addressed in this paper is the conservation of coral reefs, which will benefit from interdisciplinary research. Through many years of research, coral reefs have been found to be a cornerstone of the survival of tropical marine ecosystems (Hoegh-Guldberg, 1999). There are many components, both research and coral ecology based, that need to be

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addressed when focusing on aiding the survival of coral populations (Hoegh-Guldberg, 1999). Symbiotic relationships, organismal interactions, chemical reactions affecting the coral, the physiology of coral, water temperature change, and ocean currents are just a few factors affecting coral health (Hoegh-Guldberg, 1999).

In this review, the importance of an interdisciplinary approach to conservation in a time of climate change is demonstrated by describing how different scientific fields are working together to prevent coral bleaching due to climate change. Altogether, this work suggests that scientists of varying fields need to contribute information from their own expertise to determine how best to approach conservation, and that postsecondary education is an excellent way to introduce the interdisciplinary concept to future scientists.

## METHODS

A scoping search was done to locate sources that addressed climate change and conservation literature while leaning towards coral reefs as a case study. The articles used were all published in English. The main database used was Google Scholar, allowing a wide range of articles to be considered. Within the searches, the key words and phrases (including synonyms) used were "climate change," "global warming," "coral," "conservation," and "interdisciplinary,".

### Study selection

There was a wide range of articles found through the scoping research. These articles were first screened by their abstracts. Due to the broad reach of this review's topic and the need to look at how research has changed over the years, the author was careful not to exclude articles based on their publication date. Special attention was given to articles having an interdisciplinary approach to the issues of climate change and conservation as well as those looking at coral reefs, which is the case study of this review.

## RESULTS

Species redistribution has led to dynamic changes at different hierarchical levels, from genes to ecosystems. To understand such changes, it is fundamentally necessary to have an interdisciplinary approach, which encourages the rethinking of our current paradigms in conservation science. The reformulation of new paradigms can allow for a better designing of conservation strategies, which includes changes in population connectivity, as well as adjusting to climate change (Bonebrake et al., 2018). Each scientific field of study has important concepts and information that they have developed over centuries of research. However, this information is of limited help to humans and nature unless scientists communicate with each other and see how their works interconnect and complement each other. Climate change and pollutants have combined impacts on the environment. Thus, to address the present-day issues in conservation, we need many scientists of different views and ideas to be in communication with one another (Shimizu & Clark, 2015; Weber, 2016). Figure 1 is the center of this article, portraying different disciplines and their contributions to an interdisciplinary approach to conservation in a time of climate change, all of which must be immersed in effective communication.

## LITERATURE REVIEW

### Marine biologists and their experience with coral

Coral reefs play an important role in marine habitats. The loss of these organisms will have a detrimental impact on life both in and out of the water. Live coral provides both food and shelter for other organisms and studies have indicated that coral loss correlates with a decline in marine organism number and species diversity (Cole et al., 2008; Wilson et al., 2006, 2008). Fish species that are supported by coral reefs and the complexity of coral habitats are important food sources for human communities and other land species (Wilson et al., 2008). In the El Niño-Southern Oscillation (ENSO) event of 1997-1998, severe mortality rates of coral were reported (Robbart et al., 2004). Earlier studies indicate varying resiliency levels among different coral populations and species, as well as the need for further research on this topic (Obura, 2005; Robbart et al., 2004). As research progressed, coral resilience was found to be more complex than what was previously believed, indicating that even more research is needed to better evaluate resilience (Bang et al., 2021). It is important to understand the strengths and limitations of each approach to coral resilience, as well as its capacity to answer common management questions (Lam et al., 2020).

Coral bleaching occurs when a coral has been exposed to prolonged and extreme heat stress, which causes the coral to eject its alga symbionts, such as zooxanthellae (Cziesielski et al., 2019; Lesser et al., 1990). This ejection of their symbiont, which provides energetic requirements for its coral host and enables the host to calcify, will eventually result in the coral's death (Cziesielski et al., 2019). Coral bleaching is a complex biological issue that spans multiple disciplines including marine biology, cellular biology (Weis, 2019), genetics (Cleves et al., 2018; Jones et al., 2018), computational biology (Mollica et al., 2018), and environmental sciences (Schuttenberg, 2000), among others.

Understanding the cellular and molecular basis of the symbiosis between corals and algae is a fundamental step to prevent coral bleaching (Weis et al., 2008; Weis, 2019;). To comprehend this phenomenon, coral biologists started working with cell biologists more than 10 years ago (Weis et al., 2008: Weis, 2019;). An initial stage for this interdisciplinary research was the development of appropriate tools that allowed cell biologists to dissect the pathways involved in coral bleaching (Baumgarten et al., 2015; Cleves et al., 2020; Weis, 2019). One important tool that has been developed is a coral model organism, which allows scientists to regularly test a hypothesis by performing experiments in the laboratory in ways that are impossible in nature (Weis, 2019).

The small sea anemone Exaiptasia pallida, commonly referred to as Aiptasia, is the most studied of the model systems for studying coral symbiosis (Weis, 2019). It provides a tractable laboratory model for investigating mechanisms underlying cnidarian-dinoflagellate symbiosis (Baumgarten et al., 2015; Weis, 2019). The study of Aiptasia and other coral systems has fueled many discoveries, including a detailed understanding of how metabolic dysregulation contributes to dysbiosis and bleaching (Weis, 2019). However, the most important outcome was the involvement of other biological fields to study coral bleaching. For example, geneticists and molecular biologists are using CRISPR to develop mutations that will illuminate many aspects of coral biology and, thus, help to guide conservation efforts (Cleves et al., 2020).

The following is a step in the process of understanding how corals regulate heat stress. The gene HSP70 seems to be tightly coupled to coral symbiosis and health maintenance of coral (Traylor-Knowles & Palumbi, 2014).

### Cell biologists and understanding the effects and uses of HSP70

HSP is classified as a cytosolic heat shock protein (Rosic et al., 2011). HSP70 genes are involved in stress responses, which are important in the symbiotic relationship between coral and the symbiotic dinoflagellates (Leggat et al., 2011). The gene is located within both the corals and their symbionts (Leggat et al., 2011).

The amount of coral surface area exposed to sunlight is related to the levels of HSP60 and 70; an increase in light exposure increases the production of HSPs (Brown et al., 2002). The HSP70 transcriptional response to heat stress aligns with the species stress susceptibility (Franzellitti et al., 2018). The responses and resilience that a coral displays in response to stresses is found to change depending on the species' growth modes, trophic strategies, and physiology (Franzellitti et al., 2018). Not only is the HSP70 gene expression attributed to stress responses of coral, but also to declining sponge populations in coral reef ecosystems due to increasing seawater temperatures (López-Legentil et al., 2008). There are also combined effects of increased temperature and pH changes on the HSP70 gene that need to be explored in future research (Franzellitti et al., 2018).

### Ecologists and understanding the relationships between organisms

Marine ecological studies are fundamental to the development of robust conservation plans, which allows for the sustainable exploitation of ocean resources by fisheries and tourism, among others. There are many essential relationships that occur between coral reefs and other distant marine ecosystems, where the health of one greatly impacts the health of the other (Cowen et al., 2006; Treml et al., 2008). However, despite its importance, the study of these relationships in marine ecosystems is not a simple task, displaying multiple technical challenges. For example, although many marine organisms display an adult sessile or sedentary life,

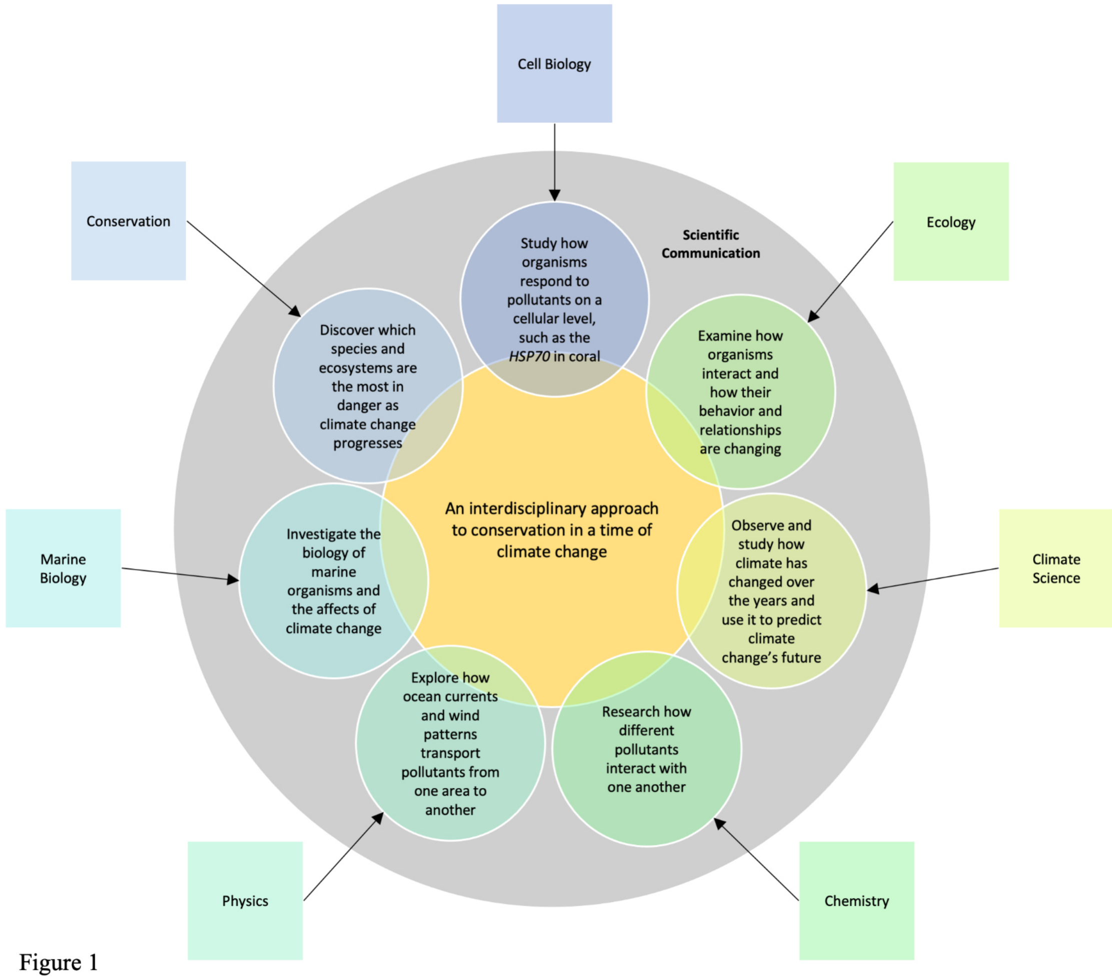


Figure 1: Contributions that different disciplines can make to an interdisciplinary approach directed towards conservation in a time of climate change.

the larval stages are mobile and travel via oceanic currents hundreds of kilometers away, connecting distant ecosystems. As a result, the quantification of the spatial and temporal patterns is only possible in a few marine species, and the dispersal of larvae was previously a neglected component of marine conservation efforts.

To solve this problem, ecologists have collaborated with other disciplines to work towards understanding the connections between species among marine ecosystems. For example, physicists have worked with biologists to explore the connectivity of distant coral populations through larva dispersal through ocean currents (Treml et al., 2008). To do so, physicists developed a connectivity model based on the graph theory, which can quantify population dynamics of pelagic larval organisms in the Pacific (Australia and Melanesia). This collaboration provided better tools to determine which marine reserves should be addressed, focusing the scientists joint energy and resources (Gaines et al., 2003). In addition, to improve these types of models, marine biologists also collaborate with climate scientists to see how the currents are affected by global warming and the sea level rising (Benzie, 1999). This is another example of how an interdisciplinary approach is needed to save coral reefs.

## Physicists and Chemists: understanding the range and effects of climate change and anthropogenic pollutants

At first glance, it would appear unlikely that physicists would be integrated into the interdisciplinary study of coral conservation. However, physics is important in the understanding of currents that transport both chemicals and marine species' larvae and juveniles. Understanding the transport of these different components assists in the process of determining areas that should be prioritized for marine conservation efforts (Treml et al., 2008). It is also vital to determine how these transported chemicals, specifically, will react with each other and the effects they may have (Wuebbles et al., 1989).

Physics is a major component of climate variability and climate change studies. A combination of chemistry and physics can be used in the understanding and study of the bioprecipitation cycle, which, combined with human pollutants, can affect Earth's bodies of water (Dominoni et al., 2020; Weber, 2016). Physics has been a key component of climate modeling for years, especially when combined with the invention of computers (Schmidt, 2007).

The chemicals within both the atmosphere and oceans can have important effects when they react with other elements present (Henson et al., 2016; Wuebbles et al., 1989). Examples of such concerns are chemical reactions causing the depletion of the ozone layer, which contributes to global warming (Wuebbles et al., 1989). Besides determining how anthropogenic chemicals will react in these natural environments, chemists also assist in an interdisciplinary approach by assessing how long individual chemicals will remain in the environment before breaking down (Wang et al., 1998). Chemistry is also an important collaborative voice for learning about natural sources of chemicals and sinks, which can have implications for life and climate change (Elderfield, 2010).

## Environmentalists studying the impacts of humans on the planet

Environmental scientists are continually researching the effects of anthropogenic pollutants on ecosystems. In reference to ocean habitats, environmentalists are sharing their research concerning the acidification of oceans due to increased $CO_2$ caused by human pollution (Godbold & Calosi, 2013; Nikinmaa, 2013). There are many ways that humans are impacting the oceans and, by extension, the coral reefs.

In 2004, there were contradictory findings on whether anthropogenic pollutants had any effect on climate change (Rosa et al., 2004). Scientists continued to study the impacts of humans on the environment and found that the temperature changes they were seeing could not be explained by natural climate variation alone (Rosenzweig et al., 2008). In more recent years, there has been an overwhelming consensus among scientists that climate change is an issue that has been brought about by human activity (Bertoldo et al., 2019).

### Climate scientists studying and predicting the future of climate change

Climate scientists consider the past trends of climate change and the impacts that humans are having to determine the direction global warming is taking. By including climate scientists in the interdisciplinary approach, conservation scientists will be able to take preventative and adaptive approaches to conservation efforts.

Through the years, there have been "fingerprint" studies that have indicated a change in climate that scientists, as well as the public, should be aware of due to the larger impact that these changes can have on the environment and organisms (Epstein et al., 1998). Climate scientists, since they form climate models, must take into account the current state of the environment, the trends of anthropogenic pollutants, the interactions between greenhouse gasses, and other reactions (Arblaster et al., 2011).

### Scientific intercommunication

Communication is beneficial to approaching any type of problem. Communicating with other scientists from different disciplines can be difficult due to the fact that each group has different goals, theories, and concepts when looking at a problem (Heemskerk et al., 2003). It has been suggested that the best way to work towards interdisciplinary approaches is through communication with the aid of conceptual models (Heemskerk et al., 2003). Giving each group a chance to form their data into an easily understandable model for the other party to understand, and vice-versa, is valuable for approaching problems (Heemskerk et al., 2003).

An area that requires communication and collaboration of disciplines is the process of determining which marine ecosystems should be targeted for conservation. Coral reefs have been a major area of research within marine ecosystem restoration. However, seagrass communities are also a major component of marine ecosystems (Unsworth et al., 2019). Seagrass is home to many species of marine life. It filters costal environment, aids in nutrient cycling, and reduces bacterial pathogens that can affect humans (Flindt et al., 1999; Lamb et al., 2017; Mtwana Nordlund et al., 2016). The fact that the funding for coral projects roughly doubles that of mangroves and seagrass research indicates a lack of communication between disciplines (Cullen-Unsworth et al., 2014; Duarte et al., 2013).

However, communication between scientists is not enough. To execute effective conservation plans and put them into action, scientists need to communicate with policy makers, economists, sociologists, and others (Fox et al., 2006). To assist in effective communication, each group involved needs to define what specific terms mean so that there is not any confusion (Hess & Fischer, 2001). Another part of the issue with communication between groups is that they need to better understand the theory, methods, and context of other disciplines (Fox et al., 2006). One way of addressing the issue of broken understanding is to involve and promote researchers early in their careers to an interdisciplinary approach (Gornish et al., 2013). Thus, this raises the question whether an interdisciplinary approach can be introduced to undergraduate students.

Although integrative approaches are needed to address climate change, strategies to teach them efficiently can be equally important (Monroe et al., 2019). A potential problem when teaching interdisciplinary approaches is that undergraduate students are just learning the basis of their field, and a direct introduction to integrative studies may fail in its purpose of establishing a bridge of understanding among other communities about a shared problem. However, in the last decade, several studies have been published suggesting potential pedagogical approaches to include interdisciplinarity in undergraduate courses (Gornish et al., 2013; Leichenko et al., 2021), and future studies are needed to test their efficiency. A potential way to solve this problem is that the topic of interdisciplinarity can be raised by professors to students interested in research on climate change, rather than a key component of the curriculum. A good pedagogical environment to do so in can include journal clubs, lab meetings, and undergraduate research conferences. In addition, upper-level courses, which focus on applications or specific topics, can also achieve this goal.

## CONCLUSIONS

Scientists over diverse fields have agreed that climate change is a grievous consequence of human activity, mainly due to human-caused pollutants. One major consequence of climate change is the continuing decline in biodiversity, calling for urgent action. However, climate change and conservation are two intricate issues that involve the complex interactions of various scientific fields. Through communication and collaboration between a spectrum of diverse disciplines, a mutually and universally beneficial approach can be proposed. Scientific disciplines must come together in an interdisciplinary approach to better assess conservation in a time of climate change and determine how to best address those issues.

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### Conflict of Interest

The author declares no conflict of interest.

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