

How Deep-sea Jellyfish Impact Different Ecosystem Functions

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Abstract:

This paper explores the critical role of jellyfish, particularly deep-sea gelatinous zooplankton (GZ), in marine ecosystems, focusing on their influence on the food web, carbon cycle, and nutrient cycle. Jellyfish, including species like *Bathycorus bouilloni*, have adapted to a variety of ecological niches across the ocean, contributing to essential ecosystem functions. Using in situ observations in the California Current, this study reveals that jellyfish exhibit diverse feeding strategies, making them significant predators within the food web. They help regulate prey populations and transfer energy across trophic levels, comparable to larger marine species. Additionally, jellyfish play a vital role in the carbon cycle by transporting carbon to the ocean floor through their feeding, excretion, and decomposition, potentially alleviating the effects of ocean acidification. Jellyfish blooms, while temporary, significantly impact the benthic ecosystem by enhancing carbon and nitrogen transport. In the nutrient cycle, jellyfish contribute to the redistribution of essential nutrients such as nitrogen and phosphorus, which support primary production and maintain ecosystem productivity. These findings highlight the importance of jellyfish in regulating deep-sea ecosystems and underscore the need for further research, especially as advancing technologies open new opportunities for exploring and understanding deep-sea habitats. Recognizing the ecological contributions of jellyfish is crucial for preserving marine biodiversity and ecosystem health in the face of environmental challenges.

Key Words: Benthic Organisms; Biochemical cycling; Deep-Sea ecosystem services; Food Web; Gelatinous Zooplankton; Trophic Levels

Introduction:

Jellyfish are part of the phylum Cnidaria and belong to the class Scyphozoa, commonly referred to as true jellyfish (Doyle et al., 2013). However, the term "jellyfish" is often used more broadly to encompass various gelatinous zooplankton (GZ) within the marine environment (Doyle et al., 2013). For this paper, the term will include all GZ species, as they share a gelatinous structure and play vital roles in ecosystem functions. Throughout the marine environment, jellyfish have adapted to inhabit diverse ecological niches, contributing to essential processes such as the food web, carbon cycle, and nutrient cycle (Doyle et al., 2013). Near the ocean surface, jellyfish aid in carbon transport by consuming phytoplankton and releasing it to the ocean floor through fecal pellets (Choy 2017). Their movement also enhances primary production and surface mixing (Doyle et al., 2013). Conversely, deep-sea environments remain among the least explored areas of the ocean, though advancing technology is enabling greater exploration of these depths (Gallo, 2015). Fossil evidence indicates that jellyfish have existed for over 500 million years, adapting to environmental changes such as climate shifts (Lucas et al., 2014). This resilience and adaptability allow jellyfish to thrive in deep-sea ecosystems, emphasizing the importance of studying their impact on these environments. For example, the species *Bathycorus bouilloni* was previously undetected in deep-sea environments, likely due to technological limitations in earlier exploration methods. Recent advancements in submersible technologies, however, have allowed researchers to uncover its presence and activity within the deep-sea water column (Raskoff, 2010). This discovery underscores how improved technology is expanding our understanding of deep-sea ecosystems and revealing previously unknown species that contribute to these environments. The detection of *B. bouilloni* highlights the need to reassess

the ecological roles of gelatinous zooplankton in deep-sea habitats. These organisms, including *B. bouilloni*, play critical roles in various zones, such as the bathyal and abyssal columns, influencing key ecosystem functions (Jamieson, 2021). Building on this example, this paper examines how deep-sea jellyfish, as a group, impact essential processes like the food web, carbon cycle, and nutrient cycle, shedding light on their broader ecological significance.

Food Web:

The food web provides essential functions such as energy transfer, biodiversity support, population control, and nutrient cycling, all of which are fundamental to the health and sustainability of marine ecosystems (Sweetman 2016). These interactions influence both marine species and human activities. There are two primary methods for studying feeding interactions. The first involves analyzing gut contents, which can be challenging for deep-sea organisms as their contents are often destroyed during retrieval (Choy 2017). The second method involves in situ observations, which allow for direct study in their natural environment (Choy 2017). This study conducted in situ observations over 27 years within the deep depths of the California Current, recording 743 independent feeding events (Choy 2017). The findings showed that jellyfish, particularly narcomedusae, consumed the greatest diversity of prey. Jellyfish exhibit diverse feeding strategies based on their structures. They may feed on marine snow and phytoplankton through selective grazing, actively hunt other species, or passively trap prey using their tentacles (Choy 2017). These varied methods make jellyfish significant contributors to the food web (Choy 2017). The study highlights their role as key predators with ecological importance comparable to large fish and squid (Choy, 2017). Furthermore, jellyfish serve as prey for higher trophic level predators, facilitating energy transfer across trophic levels. By converting

energy from their prey into biomass, they support energy flow in marine ecosystems. Some large-bodied organisms even feed semi-exclusively on gelatinous zooplankton (Choy, 2017). Jellyfish play a vital role in supporting biodiversity, allowing certain species to thrive in their niches, making them a crucial focus for study.

Carbon Cycle:

Carbon cycling is crucial for maintaining healthy marine ecosystems, as a build-up of carbon can result in ocean acidification, negative impacts on photosynthesis, and reduced oxygen levels, all of which affect biodiversity (Sweetman et al., 2016). Deep-sea gelatinous zooplankton (GZ) contribute significantly to this process, providing multiple ecosystem services. When GZ consume organic matter and subsequently die, their gelatinous bodies sink to the ocean floor, transporting carbon and delivering essential nutrients to benthic organisms (Sweetman et al., 2016). Additionally, population increases associated with jellyfish blooms have been linked to mass jellyfish deposition events, which occur periodically across the globe (Billett, 2006). These large-scale decomposition events significantly impact ecosystems by increasing respiration rates and altering productivity. The short-lived blooms facilitate the transport of carbon and nitrogen to the seafloor through the carcasses of jellyfish (Sweetman, 2011). Such rapid changes in biochemical cycling caused by jellyfish blooms can have profound effects on benthic ecosystems, influencing oxygen levels and disrupting carbon cycling processes (Billett, 2006).

Nutrient Cycle:

Jellyfish play a crucial role in the nutrient cycle of deep-sea environments by influencing both the distribution and availability of nutrients such as Nitrogen, Phosphorus, and organic carbon (Pitt 2009). These gelatinous predators, consume large quantities of zooplankton and

other small organisms, effectively regulating their populations and ensuring a balance in the food web (Pitt 2009). As jellyfish excrete waste, they release essential nutrients like nitrogen and phosphorus into the water, which are readily available for primary producers like phytoplankton (Pitt 2009). This process not only recycles carbon but also delivers other nutrients, enhancing the productivity of deep-sea communities. Additionally, the decomposition of jellyfish carcasses releases further nutrients, such as trace elements and organic carbon, into the benthic ecosystem, which supports diverse life forms (Sweetman 2014). By influencing both the water column and the seafloor, jellyfish help maintain nutrient flow, ensuring the continued health and productivity of marine ecosystems.

Discussion:

The findings presented in this paper highlight the diverse roles that jellyfish, particularly in deep-sea environments, play within ecosystem functions. Including all gelatinous zooplankton in the definition of jellyfish allows us to better understand the diversity each species has on deep-sea marine ecosystems.

The data from in situ observations in the California Current demonstrate that jellyfish are not merely passive inhabitants of the ocean, rather, they are active participants in the food web, showing diverse feeding strategies that allow them to occupy critical ecological niches (Choy 2017). Their role as predators is vital, as they help regulate prey populations and transfer energy across trophic levels, comparable to larger fish and squid species.

Furthermore, the impacts of jellyfish on the carbon cycle are significant. Their ability to transport carbon through their life processes feeding, dying, and decomposing, shows their contribution to both carbon sequestration for benthic communities. Jellyfish help mitigate ocean

acidification through their role in the carbon cycle. As they consume organic matter, such as zooplankton and phytoplankton, they contribute to the downward transport of carbon through their fecal pellets and decomposing bodies, effectively sequestering carbon in deeper ocean layers (Sweetman et al., 2016). This process reduces the amount of carbon dioxide in surface waters, potentially alleviating the acidification of the upper ocean (Sweetman et al., 2016). This aspect is particularly crucial given the ongoing challenges of ocean acidification and ecosystem health. The nature of jellyfish blooms introduces another layer of diversity, with the potential for large-scale changes in benthic ecosystems due to their rapid decomposition and alteration of nutrient dynamics (Billett, 2006).

In terms of the nutrient cycle, jellyfish play a key role in nutrient redistribution. Their waste products and decomposing bodies provide essential nutrients that enhance primary production in the deep sea, thus supporting the overall productivity of these environments (Pitt 2009). This nutrient recycling is crucial for maintaining the ecological health of deep-sea ecosystems, where nutrient availability can be limited.

Conclusion:

In conclusion, jellyfish are a major input to the functioning of deep-sea ecosystems, influencing the food web, carbon cycle, and nutrient cycle in profound ways. Their diverse feeding strategies and significant role as both predators and prey highlight their ecological importance and the necessity of further research in understanding these complex interactions. As we continue to explore the deep sea with advancing technologies, recognizing the contributions of jellyfish and other gelatinous zooplankton will be essential for a comprehensive understanding of deep-sea ecosystems. The resilience and adaptability of jellyfish, observed over their extensive evolutionary history, underscore their potential to respond to environmental changes,

making them a critical focus for future studies aimed at preserving marine biodiversity and ecosystem health in the face of global change.

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Comments

Comment 1: It is unclear the cause-and-effect relationship: the statement "If the previous studies did not find this jellyfish present, they potentially did not consider its contributions to the surrounding environment" is speculative and lacks a clear link to the previous sentence. The fact that a species was previously undetected doesn't imply researchers ignored its contributions. Instead, it may simply reflect technological limitations in detecting it. Please improve the description to make clearer this limitation and the fact that technology is opening up the doors to discover deep sea ecosystems and the role of jelly fish in them.

Also, there is an abrupt transition to broader claims: After discussing *Bathycorus bouilloni*, the text jumps to a general statement about the role of gelatinous zooplankton in deep-sea ecosystems, which is unrelated to the specific example given. A more seamless transition would connect the specific example of *B. bouilloni* to the larger significance of gelatinous zooplankton in these environments.

Addressed: I've addressed this by changing the wording of my sentences for a better understanding and flow.

Comment 2: make sure all your statements are properly supported by citations. I have added examples where citations should be included. Remember that also the statements done in the discussion need references. Additionally ensure that you are not relying on a single reference for an entire section; diversify your sources to provide a more comprehensive perspective.

Addressed: I have gone through and added or removed and reference/citation errors listed.

Comment 3: avoid a colloquial style

Addressed: I switched the word you to avoid this style or writing.

Comment 4: please verify this information as selective grazing here is difficult to be relatable to jellyfish.

Addressed: The information was wrong, and I put the wrong feeding type. I have updated and switched to the correct types/verified.

Comment 5: The structure suggests that GZ being preyed upon is a result of them feeding on zooplankton and marine snow, which isn't logically accurate. Feeding and being preyed upon are two separate actions that both contribute to energy transfer across trophic levels but don't directly cause each other. Please, revise.

Addressed: I have addressed this by separating and rewording the sentence.

Comment 6: please be more specific in the description of which nutrients you are referring to

Addressed: I have added a list of specific nutrients involved in the process.

Comment 7: This section appears to repeat information already covered in the previous discussion on the carbon cycle. Please revise it to eliminate redundancy and ensure that new, relevant content is presented.

Addressed: I have removed this section to prevent repetition.

Comment 8: The assumption that grouping all gelatinous zooplankton under the term 'jellyfish' allows for an understanding of their 'collective impact' on marine ecosystems is unclear. Additionally, I don't believe the aim of your paper is to focus on the grouping of these organisms, but rather on their individual roles and impacts within the ecosystem.

Addressed: I have reworded this sentence, so it shows the diversity of impacts rather than the grouping.

Comment 9: Nutrients are summarized in the next paragraph, so they should not be mentioned here unless you intend to integrate the sections on carbon and nutrient cycling. In that case, providing a clear link between the two concepts would help strengthen the argument.

Addressed: I've removed nutrients from the list to avoid repetition in the next section.

Comment 10: the connection between this and the previous sentence is unclear. For example, the statement "This aspect is particularly crucial given the ongoing challenges of ocean acidification and ecosystem health" introduces ocean acidification but does not explain how jellyfish directly interact with or mitigate the challenges posed by ocean acidification. This connection is important but isn't clearly made.

Addressed: I've added some more information to make a connection between the two.

Comment 11: Too broad. Your topic is about deep-sea ecosystems

Addressed: Reworded the sentence for a narrower view.

Comment 12: There are still some formatting issues in the references that need to be addressed

Addressed: I have gone through the highlighted sections and fixed the references.

