Proceedings of ICEGEE 2025 Symposium: Sensor Technology and Multimodal Data Analysis
DOI: 10.54254/2753-8818/2025.AU23408

The Impact of Barnacles Attachments on Sea Turtles

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Abstract: Barnacles are a sessile crustacean that attaches to the outer surface of sea turtles. Sea turtles are key species in marine ecosystems, and studying the impact of barnacles on sea turtles can indirectly reflect the health status of marine ecosystems. This paper aims to investigate the ecological impact of barnacle infestation on sea turtles, to discover the trend of barnacle load levels and their relationship with turtle health, and further explore how barnacle infestation affects the survival and behavior of sea turtles. The research findings show that light barnacle attachment does not cause harm. The severity of barnacle infection determines its impact on turtle movement while causing skin injuries and making them more vulnerable to infections. Barnacles sometimes function as health indicators instead of being direct threats to turtles. Our knowledge about turtle ecology has expanded through the analysis of research data from various geographic areas and periods. Barnacles' population changes are indicators of invasive species movements, while their distribution patterns invasively correlate with the water temperature and salinity levels. The study thus brings out the importance of separating epiphytes from overgrowth in the context of marine ecosystems. Marine biologists and ecologists who work on monitoring the health of turtles will be able to grasp the significance of distinguishing between epiphytes and overgrowth, as well as to develop assessment protocols.

Keywords: Sea turtles, barnacle infestation, marine health, conservation biology

1. Introduction

Barnacles are sessile crustaceans belonging to the infraclass Cirripedia, characterized by a unique biphasic life cycle that includes a planktonic larval stage and a sessile adult stage [1]. This life cycle begins with planktonic larvae and then transforms into free-swimming cyprinid animals, actively seeking suitable habitats to settle and transform into sessile adults [2]. During this process, barnacles utilize multi-protein adhesives for both temporary and permanent underwater adhesion, a feature that has garnered significant scientific interest due to its potential applications in developing new underwater adhesives [2]. Barnacles are also widely distributed. Many species have spread around the world due to their wide adaptability to the environment and their dissemination through human activities such as ships. For instance, *Amphibalanus improvisus* and *Amphibalanus eburneus* are among the most successful aquatic invaders in the world, mainly spreading through ship transportation and the diffusion of natural larvae [3,4].

Sea turtles act as ecosystem engineers in Marine ecosystems, regulating the populations of jellyfish and sponges in seagrass beds and coral reefs. Their activities contribute to maintaining the health and diversity of these ecosystems [5]. The relationship between sea turtles and barnacles is a fascinating

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example of epibiosis, where barnacles attach to the external surfaces of turtles. This interaction is not purely commensal, as barnacles can sometimes impair their hosts. Consequently, this poses a major problem in that such a type of survival mode could affect the health, behavior, and even the mortality of the sea turtle. Sea turtles play an important role in the marine ecosystem, and examining barnacles' effects on sea turtles may also inform us about the condition of the marine ecosystems as a whole. Nevertheless, there is already minimal investigation on how turtles and barnacles interact with each other, and there are still numerous issues in this field concerning, for instance, whether barnacles are entirely harmful to turtles or may probably be an advantage in some situations.

The issue that will be discussed in this paper is the effects of barnacle attachment on the body and health of sea turtles. Physically, barnacle attachment causes pits and indentations on the shells and skeletons of sea turtles. The evidence shown by the fossil record can highlight the long-standing ecological relationship between the two species [6]. From a health perspective, the number of barnacles on a sea turtle can act as an indicator of its overall health. Healthier turtles generally have fewer barnacles [7]. This suggests that barnacle abundance could be used as an indicator of sea turtle health, providing valuable insights for conservation and ecological studies.

This research revealed patterns in associations related to diversity, distribution, and ecological impact of these relationships. Knowledge such as this proves useful in crafting effective conservation programs and particularly in managing the negative repercussions of barnacle attachment and ensuring the recovery of endangered sea turtle populations. This study, in the end, can used to help and supplement the existing body of knowledge regarding marine ecosystems and the intricate interactions they harbor.

2. Impacts of epibiotic barnacles on sea turtle health and conservation

2.1. Case description

First of all, barnacles are unique marine organisms known for their complex life cycle and attachment mechanisms. Their life cycle includes a planktonic larval stage and a sessile adult stage. In the planktonic larval stage, barnacle larvae (called nauplii) undergo six molts to become free-swimming cyprid larvae. The cyprid larvae then search for suitable surfaces to attach, and undergo metamorphosis, and finally will become sessile adults. Once a suitable surface is located, the barnacles will secrete an adhesive material called barnacle cement, so they firmly stick their bodies to nearly any substrate using their adhesive [8]. This ‘glue’ is extraordinarily strong and lets barnacles stay on even in high-energy habitats like ocean currents or on moving animals like whales or sea turtles. Barnacles typically prefer hard, non-shedding surfaces. However, certain species have adapted to attach to living organisms, initiating an epibiotic relationship. One of the most fascinating examples of epibiosis is the link between barnacles and sea turtles. The barnacles profit from this association because they gain access to nutrient-rich waters as the turtle moves, which increases their feeding possibilities. At, the same time, the turtle seems they will not receive any advantages, and in some situations, the attachment might be harmful. This kind of relationship can lead to physical damage to the turtle’s shell and skin, increased water drags, and potential health issues.

Sea turtles are one of the oldest reptiles on Earth, with a history of about 220 million years. They play an important role in global ecosystems and have been present in human culture for at least 400,000 years [9]. Sea turtles are widely found in subtropical waters. Their numbers are decreasing due, to issues like habitat destruction and pollution from human activities such, as overhunting and marine pollution. To address this problem and ensure the survival of turtle populations conservation groups are taking action to protect them and ensure their ability to reproduce. The effects of barnacles infecting sea turtles is a matter that involves factors including ecology health and how it impacts the

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turtle population over time. Barnacles themselves do not lead to the decrease, in turtle populations. However, they could impact turtles' behavior and well-being indirectly.

2.2. Physical and physiological effects of barnacle attachment

Barnacle attachment on turtle shells can cause significant damage and surface erosion. This interaction is not only symbiotic but also causes some harm, as barnacles can impair their turtle hosts by causing physical damage. A study of Caretta caretta (Loggerhead Sea turtles) from Cumberland Island, Georgia, USA, revealed the presence of various types of pits and holes caused by barnacle attachment on skeletal remains [6]. These include ring-shaped surface grooves, deep circular boreholes, and shallow oval pits, each of which can be linked to a certain barnacle taxonomy. These findings suggest that barnacle-mediated chemical corrosion (through secretions or long-term physical wear) can cause long-term bone damage to turtle bones. This not only has implications for the health of individual turtles but also provides paleontologists with concrete evidence of symbiotic or parasitic relationships between prehistoric marine organisms. However, this skeletal evidence further confirms that barnacle-epiphyseal relationships are not benign. Repeated erosion of skeletal structure can lead to secondary infection, reduce shell strength, and increase vulnerability to predators or environmental stressors. In severe cases, especially when penetrating taxa are involved, the damage can be debilitating or fatal.

In addition to structural damage to the shell, barnacle attachment to soft tissues such as the eyes, fins and cloaca areas can also cause serious damage to turtles. Unlike the carapace, which can provide a relatively hard surface, the soft tissues are more susceptible to pressure erosion caused by constant mechanical stimulation from barnacle plates. A proteome investigation of barnacle adhesive fluids has shown proteins linked to wound healing mechanisms, implying potential antibacterial capabilities and interactions with host tissues [10]. While these proteins may help barnacles adhere to surfaces and guard against microbial invasion, their release on sea turtle skin and shells may disrupt the host's natural microbial ecosystems and perhaps cause localized immune responses. Essock-Burns et al. discovered that barnacles secrete a wide range of bioactive chemicals during attachment and growth, including phenoloxidases, antimicrobial peptides and reactive oxygen species [10]. While these secretions are necessary for barnacle adhesion and shell growth, they may chemically stimulate the surrounding host tissue, increasing inflammation and susceptibility to infection at the attachment site. Such interactions demonstrate the complexities and potential risks of barnacle-host relationships.

According to a 2023 study published in Frontiers in Marine Science, turtles with DTS had high barnacle covering on their carapace, plastron and sensitive tissues [11]. This is partly owing to their compromised condition—sick turtles are lethargic, spend more time floating at the surface, and have a reduced ability to clean themselves, all of which promote the establishment and proliferation of epibiotic organisms such as barnacles. Researchers examined 117 dead loggerhead sea turtles (Caretta caretta) that were stranded along Italy's North Adriatic coast between 2020 and 2022. Necropsies were carried out on fresh or partially decayed carcasses. Barnacle sampling entailed scraping and preserving epibionts from various body regions, with 13.1% randomly chosen for species identification and size assessment. Photographs were utilized to map the spread of barnacles using ImageJ software. Each turtle's curved carapace length (CCL) was measured to determine its life stage.

Statistical analyses included two-way ANOVA to assess relationships between barnacle abundance and turtle size or body region, Wilcoxon tests for abundance across body parts, and paired t-tests to compare barnacle loads in Debilitated Turtle Syndrome (DTS) affected turtles versus unaffected individuals. Among the 117 studied specimens, 11 noted individuals suffered from Debilitated Turtle Syndrome (DTS), a condition marked by lethargy, anemia, and heavy barnacle growth. Juveniles, particularly with CCL between 17.5 and 24.5 cm, appeared disproportionately vulnerable to health decline and its deleterious consequences. These DTS-affected turtles had an

DOI: 10.54254/2753-8818/2025.AU23408

exaggerated barnacle burden on the neck, limbs, and tail in addition to the shell, which are areas generally less impacted in healthy individuals. It is hypothesized that this atypical barnacle distribution is a result of the prolonged surface-floating behavior the turtles exhibited due to their weakness. Paired t-tests revealed that DTS-affected turtles had significantly more barnacles than unaffected turtles, which indicates a strong relationship between health degradation and epibiotic colonization. These findings emphasize the negative impact, meaning that when the barnacle burden increases, it can cause more drag, physical irritation, and even skin injury. This can further jeopardize the turtle's general health. As a result, the presence of excessive barnacles may reflect the poor physiological conditions in sea turtles, which points out the necessity of early intervention and health monitoring in conservation initiatives.

2.3. Conservation actions for sea turtles with barnacle burden

Some specific conservation measures must be put in place in light of the effects that barnacles have on Debilitated Turtle Syndrome (DTS) in sea turtles. Tracking coral loads can be used as a bioindicator to determine the overall health of specific sea turtle populations in the first place. Scientists can around assess a turtle's well-being by routinely measuring their barnacle load during field monitoring or treatment procedures. Tracking changes in coral weight over a period can also aid in the early detection of failing health before more serious symptoms start to show up. Because regular evaluations enable earlier action, targeted care, and better decisions regarding launch or continued treatment, they become more productive in conserving efforts. The regular evaluation procedure is made easier by including barnacle burden assessments in normal health check-ups.

Turtle rescue centers may use barnacle removal techniques to reduce the burden on individuals with poor health, for turtles with conditions such as DTS, increased barnacle colonization can substantially increase their natural condition by increasing drag and creating opened wounds prone to infection. These natural strains are quickly relieved by the removal of barnacles, which allows the snake's immune system to shift its focus away from regular defense against outside parasites. Rescue organizations can use chemical techniques to loosen barnacle adhesions without harming the snake's tissues or employ gentle mechanical removal techniques.

The marine environment is crucial to maintaining Earth's natural parity and ensuring people's civilization's continued expansion. Pollution has reached hazardous levels as a result of the combination of human activity and various factors. Economic pressures destroy biodiversity while affecting the relationships within ecosystems. These outcomes have an impact on sea turtles ' health and other aquatic lives. Saving sea conditions is a vital need because it safeguards biodiversity while maintaining climate change and keeping healthy ecosystems for threatened species. Although there are numerous international and national marine safety laws, there are still gaps in their protection and execution. To achieve science-based environmental governance, the issues need greater global cooperation [12]. In the end, improving sea economic value is the first step in reducing water turtles outside natural pressure, strengthening their health and survival prospects in the wild.

3. Conclusion

This paper investigated how barnacle attachment affects the bodies and health of sea turtles and found that having barnacles is not only a surface problem but also an indication of the turtle's health condition. The study emphasizes that barnacles could cause long-term harm by leaving marks on the turtles' shells. Furthermore, turtles with a high density of barnacles may not only suffer from ailments such as Debilitated Turtle Syndrome (DTS) but this may also indicate that barnacle levels can be used as a non-invasive indicator of turtle health. Hence, this finding will encourage the inclusion of barnacle assessments in health checks for turtles, and in conservation and rehabilitation programs, for

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early detection of problems and better recovery chances. This research increases our understanding of sea turtle ecology by integrating studies from different areas and various ancient times. These discoveries hold significance for conservation science by enhancing protocols for rescuing turtles and shaping frameworks for monitoring their health. Furthermore, changes in barnacle populations can reflect the dynamics of invasive species, such as in the waters of Korea, where the distribution of invasive barnacles is closely related to water temperature and salinity. Barnacles are also used to monitor heavy metal contamination. as their soft tissues can accumulate trace metals such as Cd, Zn, and Fe. The giant barnacle *Megabalanus azoricus*, a common seafood species in the Azores, has proven to be an effective bioindicator of trace metal pollution, with elevated levels of elements such as arsenic and cadmium detected in its tissues despite the region's lack of heavy industry. However, this research is founded upon an analysis of literature, than firsthand field studies. Consequently, the findings are built upon data that has already been published in the past. This data may be influenced by regional sampling biases or methodological differences. Furthermore, the absence of evidence hinders the ability to make conclusive statements regarding causation, such as whether barnacle attachment directly results from health issues or if other variables play a role, in the process. The studies ought to focus on observing barnacle levels over time, in natural turtle habitats and investigating the connection between immune system health and the attachment of organisms like barnacles. Examining physical data might provide perspectives on how susceptible hosts are, to infestations and their ability to recover. Overall, this research emphasizes the importance of utilizing barnacle loads for purposes and sheds light on the ecological interactions impacting the well-being of endangered sea creatures; this contributes to better planning and conservation efforts.

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