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PRACTICAL APPLICATIONS OF EMBEDDED SYSTEMS FOR MARINE ECOSYSTEM CONSERVATION

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ABSTRACT: Embedded systems offer a comprehensive array of information crucial for the observation, preservation, and management of marine environments. The integration of these technologies with advanced sensing, data collection, and analysis methods enhances the capabilities of researchers, conservationists, and environmental managers, improving their efficacy in safeguarding marine ecosystems. By delivering accurate and real-time information on ecosystem states, embedded systems facilitate more efficient and adaptable management of natural resources. Consequently, this enables the implementation of targeted, evidence-based conservation strategies, ultimately contributing to the protection of marine biodiversity, the maintenance of healthy seas, and the promotion of environmental sustainability. This article examines the role of embedded systems in the conservation of marine ecosystems, emphasizing environmental monitoring and sustainable resource management. It is based on a thorough literature review that investigates the potential of embedded systems as conservation tools within marine ecosystems. Through the analysis of scientific articles and projects focused on environmental monitoring and the sustainable management of marine resources, the findings indicate that embedded systems are a promising tool for environmental conservation. Their capability to collect and analyze data in real time not only facilitates rapid responses to critical events but also supports the development of evidence-based conservation strategies. Thus, these technologies prove indispensable for the sustainability of marine ecosystems, aiding in the identification of changes and providing the necessary support for adaptive conservation strategies.

Keywords: Marine Bioindicators; Environmental Monitoring; Sustainability; Remote Sensing; Arduino.

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APLICAÇÕES PRÁTICAS DE SISTEMAS EMBARCADOS PARA A CONSERVAÇÃO DE ECOSSISTEMAS MARINHOS

RESUMO: Os sistemas embarcados fornecem uma variedade abrangente de informações que contribuem para a observação, preservação e administração dos ambientes marinhos. A integração dessas tecnologias com métodos de sensoriamento, coleta e análise de dados capacita pesquisadores, conservacionistas e responsáveis pela gestão ambiental ao aprimorar sua compreensão na salvaguarda dos ecossistemas marinhos de forma mais eficiente. Ademais, ao fornecer informações precisas e em tempo real sobre o estado dos ecossistemas, os sistemas embarcados permitem uma gestão mais eficiente e adaptativa dos recursos naturais. Isso possibilita a implementação de estratégias de conservação direcionadas e baseadas em evidências, contribuindo para a proteção da biodiversidade marinha, a manutenção da saúde dos mares e a promoção da sustentabilidade ambiental. Este artigo explora o uso de sistemas embarcados como ferramentas para a conservação dos ecossistemas marinhos, com foco no monitoramento ambiental e na gestão sustentável dos recursos, com base em uma revisão bibliográfica, investigando o potencial dos sistemas embarcados como ferramentas de conservação em ecossistemas marinhos. Foram realizadas leituras de artigos científicos e análises de projetos voltados para o monitoramento ambiental e a gestão sustentável de recursos marinhos. Os resultados indicam uma ferramenta promissora para a conservação ambiental. Sua capacidade de coleta e análise de dados em tempo real facilita respostas rápidas a eventos críticos e apoia estratégias de preservação baseadas em evidências. Dessa forma, essas tecnologias surgem como indispensáveis para a sustentabilidade dos ecossistemas marinhos facilitando a identificação dessas alterações e fornecendo subsídios para estratégias de conservação adaptativas.

Palavras-chave: Bioindicadores Marinhos; Monitoramento Ambiental; Sustentabilidade; Sensoriamento Remoto; Arduino

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APLICACIONES PRÁCTICAS DE SISTEMAS EMBEBIDOS EN LA CONSERVACIÓN DE ECOSISTEMAS MARINOS

RESUMEN: Los sistemas embebidos proporcionan una amplia variedad de información que contribuye a la observación, preservación y gestión de los entornos marinos. La integración de estas tecnologías con métodos de sensado, recopilación y análisis de datos capacita a investigadores, conservacionistas y gestores ambientales, mejorando su comprensión para salvaguardar los ecosistemas marinos de manera más eficiente. Además, al proporcionar información precisa y en tiempo real sobre el estado de los ecosistemas, los sistemas embebidos permiten una gestión más eficiente y adaptativa de los recursos naturales. Esto facilita la implementación de estrategias de conservación dirigidas y basadas en evidencias, contribuyendo a la protección de la biodiversidad marina, el mantenimiento de la salud de los océanos y la promoción de la sostenibilidad ambiental. Este artículo explora el uso de sistemas embebidos como herramientas para la conservación de los ecosistemas marinos, con un enfoque en el monitoreo ambiental y la gestión sostenible de los recursos. Basado en una revisión bibliográfica, se investiga el potencial de los sistemas embebidos como herramientas de conservación en ecosistemas marinos. Se realizaron lecturas de artículos científicos y análisis de proyectos enfocados en el monitoreo ambiental y la gestión sostenible de recursos marinos. Los resultados indican que los sistemas embebidos son una herramienta prometedora para la conservación ambiental. Su capacidad para recopilar y analizar datos en tiempo real facilita respuestas rápidas a eventos críticos y respalda estrategias de preservación basadas en evidencias. De esta manera, estas tecnologías surgen como indispensables para la sostenibilidad de los ecosistemas marinos, permitiendo la identificación de cambios y proporcionando fundamentos para estrategias de conservación adaptativas.

Palabras clave: Bioindicadores Marinos; Monitoreo Ambiental; Sostenibilidad; Sensado Remoto; Arduino.

INTRODUCTION

Brazil boasts a rich heritage of marine biodiversity, distributed among sandy beaches, rocky shores, mangroves, estuaries, coastal lagoons, reefs composed of calcareous algae and endemic corals, islands, and oceanic banks. This physiographic complexity harbors a repository of genetic resources that are invaluable and yet underexploited. The utilization of these resources is primarily focused on fisheries, oil and gas exploration, mariculture, tourism, and leisure activities. The conservation of marine ecosystems represents a critically important issue, especially in light of the mounting challenges these habitats encounter due to human interference and global environmental changes.

In this context, the practical applications of embedded systems have emerged as a promising instrument for the protection and preservation of these fragile ecosystems. An Embedded System is defined by the IEEE as "a computer system that is part of a larger system and implements some of the requirements of that system". Although this definition was established over two decades ago, it remains pertinent. Nonetheless, the revolution in software engineering in recent years has prompted some authors to expand upon this definition (Zurita 2014). The deployment of embedded technologies has gained prominence as an innovative and efficient methodology for the monitoring and management of marine protected areas, sensitive habitats, and endangered species. The capability of these systems to collect data in real time and remotely furnishes a more comprehensive and nuanced understanding of marine ecosystems, thereby enabling a swifter and more effective response to events of environmental degradation.

Given the pressing necessity to formulate and implement strategies for the protection and preservation of marine ecosystems against increasing human and environmental pressures, this chapter will delve into the practical applications of embedded systems in the conservation of these ecosystems. It will highlight how this technology can assist in monitoring, preserving, and restoring these environments.

A BRIEF JOURNEY THROUGH EMBEDDED SYSTEMS

According to Vahid and Givargis (1999), embedded systems are devices with data processing capabilities that are integrated into specific equipment or products to perform a function or cater to a particular application. The cornerstone of these systems is microcontrollers, essentially processing units characterized by their flexibility in use and ease of application. An embedded system intrinsically comprises a processor and software, necessitating memory to store both the executable code and temporary data generated during operation. This memory can take the form of ROM or RAM, though most embedded systems incorporate both. If the memory requirement is minimal, it resides on the same chip as the processor. Conversely, substantial memory needs dictate the use of external memory chips. Smartphones, or cell phones, furnish a prime example of embedded systems in application, offering a plethora of applications pivotal to the conservation of marine ecosystems.

Emerging in the 1960s with the development of NASA's Project Apollo, embedded systems underwent significant evolution in the 1970s, primarily driven by the military defense industry. However, as embedded systems proliferated, their development was further propelled by various sectors, including the gaming industry, medicine, and aviation. Another catalyst for the spread of embedded systems was the establishment of the PC/104 Consortium by Ampro, RTD, and other manufacturers. This consortium standardized a format for Intel microprocessors, featuring a motherboard approximately four inches square and less than an inch high, thereby enhancing operational response times.

Since their initial applications, embedded systems have experienced a decline in price and an escalation in processing power and functionality, particularly post-1980s when various external components were consolidated into the same processor chip, yielding integrated circuits known as microcontrollers. This cost reduction has rendered embedded systems more accessible, spurring innovation and the development of novel applications and functionalities.

One notable application is the monitoring of marine environmental quality, increasingly threatened by human activity and global environmental change. The deployment of remote sensing technologies and embedded systems enables the precise collection of data on water quality, coral reef health, marine species distribution, and other environmental parameters. Such data is crucial for assessing marine ecosystem statuses, identifying concerning trends, and facilitating informed conservation decision-making. Additionally, promoting scientific research and the development of innovative solutions to marine conservation challenges is imperative. Investment in research and technology can unearth significant insights into marine ecology, habitat restoration, genetic conservation, and climate change adaptation, thereby fostering more effective and sustainable conservation efforts. In essence, embedded systems are indispensable tools for supporting the conservation of marine ecosystems, providing essential data and information.

BIOGENIC COMPONENTS AND MARINE ICHTHYOFAUNA AS BIOINDICATORS OF MARINE ECOSYSTEM HEALTH

In recent decades, the extensive changes to the marine environment have become increasingly apparent. These changes include rising global temperatures, marine pollution, the destruction of coastal habitats, overfishing, and illegal fishing, all primarily due to anthropogenic activities. These activities not only put sensitive species at risk of extinction and produce diseases in humans but also significantly impact ecological processes (Brown and McLachlan, 1990). According to the latest Global Biodiversity Outlook published by the UN Convention on Biological Diversity (CBD), coastal and marine ecosystems continue to diminish in size, threatening valuable ecosystem services.

Given these challenges, the search for efficient methods to monitor and evaluate marine ecosystems has become critical for conservation and recovery efforts. In this context, biogenic components have emerged as potential bioindicators of marine health (Ginsburg, 1956). The physiological and behavioral responses of these components to death reflect the environmental conditions of their habitats, including water quality, the presence of pollutants, eutrophication phenomena, and other health-related aspects of the seas (Purdy, 1963). The analysis of the marine environment is facilitated by the fact that biogenic sediments generally remain at their origin, enabling accurate assessments of local conditions (Ginsburg, 1956; Ginsburg et al., 1963; Purdy, 1963; Swinchatt, 1965).

Healthy marine ecosystems are vital, not only for their biological diversity but also for their role in regulating Earth's temperature, cycling nutrients, and providing food. However, these ecosystems have not been adequately preserved, leading to impacts on biodiversity and coastal ecosystem damage. Despite their resilience, marine environments are subject to pollution rates that exceed their capacity for regeneration (Leon et al., 2020). The most significant pollution issues in marine ecosystems arise from domestic and industrial pollutants and the presence of vessels, which primarily affect marine life, causing ecological imbalances, contamination of seafood, water quality degradation, death of birds and animals feeding on contaminated ichthyofauna, mangrove degradation, and the closure of swim-friendly beaches (Oliveira et al., 2002; Leon et al., 2020; Tommasi, 1989; Santos et al., 2005).

Beach sediments, composed of biogenic components such as decomposing organic matter, remains of marine organisms, and microorganisms, are crucial for the structure of coastal ecosystems and the biogeochemical processes within these environments (Illing, 1954; Wilson, 1979; Halfar et al., 2000; Farina and Amado Filho, 2009). These sediments act as vital reserves of organic carbon, helping to mitigate atmospheric CO_2 concentrations and, consequently, global warming (Perry, 1996; Suguio, 2003). The decomposition of organic matter releases essential nutrients like nitrogen and phosphorus, fostering the growth of organisms at the base of the trophic chain, including algae and marine plants. This provides a critical habitat for benthic fauna, comprising various organisms such as isopods, bivalves, and polychaetes, and supports higher trophic levels. These organisms play a fundamental role in the coastal trophic chain, maintaining ecological balance, engaging in biogeochemical cycles, promoting nutrient recycling, and contributing to the biological productivity of coastal ecosystems.

Changes in the marine ecosystem have implications for various organisms that are interconnected primarily through trophic relationships and ocean currents. Considering this, onboard technologies enable the monitoring of changes affecting various scales, and investigations can even identify catastrophic shifts, since information on the abundance of one species can provide insights into others. The trophic structure of a marine zone can include organisms from the bottom to the top of the food chain (Levinton, 1982). These zones are interconnected through feeding behaviors and, notably, nesting habits, due to the availability of food and environmental conditions that support species in their early life stages.

The trophic structure of fish is essential to the dynamics and equilibrium of ecosystems and plays a vital role in maintaining marine life. Alterations in species composition and habitat structure impact the regenerative ability of these ecosystems (Pauly, 2009). Higher trophic levels influence lower levels (top-down), through both direct and indirect effects of interactions between consumers and resources, as well as the influence of lower trophic levels. Similarly, species at the apex of the trophic chain can be affected from the *bottom up (bottom-up*), that is, by changes at the lowest levels of the trophic chain, which can initiate a degradation of the entire food chain.

Arduino sensors as tools for monitoring seawater quality are critical in assessing the health of marine ichthyofauna since the distribution of species and the structure of fish communities are affected by a variety of abiotic factors operating at different scales (Albieri, 2016). Changes in the trophic structure patterns of fish can indicate environmental issues, such as pollution, temperature fluctuations, and limited food availability (Pauly et al., 2000).

In addition to Arduino sensors' contribution to studying marine ichthyofauna, the employment of bioindicators by researchers to evaluate the marine environment's condition, including the biogenic components found in beach sediments, is crucial for monitoring and assessing the health of coastal ecosystems. The amalgamation of bioindicator approaches with other monitoring techniques is pivotal for the development of effective conservation strategies and the proper management of natural resources (Ricklefs, 2003; Ponzi, 2004; Wright and Burgess, 2005).

Environmental bioindicators, which are organisms that respond sensitively to environmental changes, play an essential role in assessing the quality and integrity of ecosystems. Their behavioral, physiological, or biochemical responses mirror the conditions of their environment, assuming a significant role in ecology. These biological indicators offer valuable information on environmental status, including pollutant presence, ecological disturbances, and climate change (Arias et al., 2007), which is crucial for the sustainable management and conservation of beaches and coastal areas. The capacity of these biological indicators to reflect responses to multiple environmental stressors makes them instrumental for the early detection of ecological disturbances, anthropogenic impacts, and changes within ecosystems. The growing interest in evaluating ecosystem health has driven the utilization of bioindicators as effective tools for monitoring environmental quality.

Research on bioindicators includes identifying species most suitable for assessing specific environments. Data collection occurs in the field, and laboratory analysis is sometimes necessary to detect chemicals or elements indicative of the health of the organism and its environment. Continuous research and monitoring are essential to address emerging challenges and ensure the sustainability of coastal areas amid global change.

EXPLORING THE POTENTIAL OF EMBEDDED SYSTEMS WITH ARDUINO

To enhance the efficacy of biogenic bioindicators, it is imperative to integrate biological and environmental data gathered through diverse sampling and analytical methods. This integration may encompass traditional monitoring techniques, such as field sampling and visual observation, as well as more sophisticated approaches, including genetic analysis and remote sensing. When embedded systems are combined with biogenic components as bioindicators, they significantly broaden their practical applications and effectiveness. Integrated sensors are capable of measuring parameters such as temperature, salinity, pH, and dissolved oxygen levels, thus providing essential information about marine ecosystems. These technologies are crucial for the comprehensive and detailed monitoring and understanding of marine ecosystems. The system's sensors are intended to be connected to Arduino, an open-source platform (both hardware and software) that was developed in 2005 by Massimo Banzi and other collaborators in Italy, as reported by the Embarcados website.

The primary objective of creating an open-source system was to offer a cost-effective platform, enabling students to develop prototypes at minimal expense. Temperature sensors are utilized to monitor variations in water temperature, which is vital for understanding ocean circulation patterns and the impacts of climate change on ecosystems. Salinity sensors can offer insights into water salinity, which influences the distribution of marine species and water density. The pH level is a critical indicator of environmental acidity or alkalinity, affecting the health of marine organisms like corals and mollusks. Turbidity sensors are employed to assess water clarity, shedding light on sunlight penetration and its role in photosynthesis and organism distribution. This aspect is particularly pertinent in coastal areas and estuaries, where turbidity may be affected by factors such as freshwater runoff and human activities.

Ocean acidification poses significant risks to marine organisms including corals, mollusks, and crustaceans, which may experience shell and skeleton dissolution in more acidic conditions. pH sensors incorporated into onboard systems can monitor water acidity changes and their impact on marine ecosystems. Given its status as a low-cost, open-source platform, Arduino's integration with embedded systems facilitates its application in a wide range of projects, including environmental monitoring. Its versatility and ease of programming allow for project customization and adaptation to the specific requirements of different environmental monitoring tasks. This amalgamation of accessibility and computational capability renders it an invaluable resource for researchers dedicated to understanding, protecting, and preserving the environment.

THE EFFECT OF CHANGING SEASONAL PATTERNS ON THE PHYSICOCHEMICAL ASPECTS OF MARINE ICHTHYOFAUNA: CHALLENGES FROM THE CONTINENT TO THE SEA

Evidence indicates that species exploit specific habitats, which leads to characteristic distribution patterns according to local conditions (Gatz, 1979; Uieda, 1984). Accordingly, changes in environmental conditions lead to a restructuring of eclectic assemblies, reflecting the prevailing environmental conditions (Fausch et al., 1990; Onorato et al., 1998). Some habitats offer beneficial conditions for species at certain life stages, such as increased metabolic efficiency for heat acquisition, facilitated by the abundance of food concentrated by the action of currents. Artificial factors can abruptly alter these rates, resulting in predominantly juvenile depletion in the environment (Lasiak, 1983).

Teleost fishes exhibit interspecific differences in terms of the ideal temperature, salinity, oxygen content, pH, and luminosity for their development. The action or interaction of these environmental factors affects all physiological systems of the fish. The physiological processes essential for reproduction include stages such as gonadal differentiation, gametogenesis, gamete release, fertilization, and egg hatching. These critical phases are tightly regulated by a complex network of endocrine factors operating along the Hypothalamus-Pituitary-Gonads axis. Beyond their intrinsic significance, these reproductive events significantly interact with other vital physiological functions such as nutrition and growth (Izquierdo et al., 2001), osmoregulation (Haffray et al., 1995; Le François and Blier, 2003), and stress responses (Schreck et al., 2001).

Moreover, the influence of abiotic factors, which can directly impact all stages of the fish reproductive process, is crucial to recognize (Cossins and Crawford, 2005). These factors, through various forms of pollution including oil spills, lead to changes in water oxygenation and other damages, as well as ocean acidification, causing a reduction in water pH, contributing to catastrophic effects.

The high number of oil spills, such as the 2019 incident on the northeastern coast, has left a toxic trail extending thousands of kilometers into the sea, damaging various ecosystems like mangroves and coral reefs, posing a high contamination risk for years (Uchôa, 2019). Routine spills, resulting from the dense flow of vessels in oceans and coastal regions, present additional challenges, leading to 'orphan spots' of pollution with no identifiable sources.

Furthermore, ongoing pollution from domestic sewage and plastics, with the latter accounting for 85% of anthropogenic waste in marine ecosystems (UNEP, 2021), represents a significant threat. A study by *Ocean Conservancy* found that around 90% of sampled foods contained plastic particles, identifying microplastics in the bloodstream and hearts of humans, highlighting their pervasive presence in the food chain.

Economically, the sea is a vital source of animal protein for coastal populations, with artisanal fishing serving as a primary income source (De Santana, 2019). However, fishing can alter fish population structures, with biomass loss indicating reduced income for artisanal fisheries.

The destruction of natural forces in aquatic ecosystems disproportionately affects small-scale fishermen, with the sea as their fundamental means of subsistence (Diegues, 1974). The loss of fish species is attributed to changes in seasonal patterns of physical and chemical aspects and overfishing, exacerbated by the introduction of predatory machinery and urban waste pollution.

Pollution can diminish species diversity in marine ecosystems through direct mortality of sensitive organisms or habitat quality degradation, affecting the health and quality of life of nearby communities or artisanal fisheries.

Artisanal fishing, characterized by Chuenpagdee et al. (2006) as comprising individuals with deep knowledge of marine ecosystem dynamics (Hall, 2010), holds ecological knowledge beyond the capacity of formal science to produce (De Santana, 2019). The sustenance derived from this activity is crucial for the survival of coastal ecosystems and artisanal fishing communities (Gladstone, 2009). Countless maritime populations consider the sea a living entity, essential for their subsistence (Diegues, 1974), underlining the need to sustain fisheries by preserving their supporting ecosystems.

The modern concepts of wilderness, biodiversity, and primitive ecosystems are insufficient to explain the complex relationships between traditional communities and their environments. Diegues (2021) supports this assertion, arguing that in the perspectives of these communities and cultures, the diversity of species is perceived not solely as a natural occurrence but also as a cultural one, emerging from enduring interactions between humans, their habitats, and other non-human entities. Overfishing leads to a decline in these three aspects of interaction. The costliness of meat and the use of eggs for caviar production make pregnant females particularly valued targets, and they are often killed before they can reproduce, further escalating the critical depletion of fish stocks (Pough et al., 2003). The principle of 'supply and demand' dictates the price of fish; that is, the scarcity of commercially valuable species, particularly those of significant commercial interest, enhances their economic value. This dynamic, however, does not favor the artisanal fisherman who 'loses' his customers to markets dominated by industrial fishing operations. The precariousness afflicting many of the wealthiest fishing corporations prompts inquiries regarding the fate of coastal communities reliant on this animal protein for their sustenance. Notably, among fish species, the most endangered tend to have the narrowest distribution among vertebrates. This downturn jeopardizes the cultural legacy of 'artisanal fishing,' portending a grim scenario of acute poverty and vulnerability. Consequently, there's an imperative to reorient the labor market, as the dearth of employment opportunities leads to marginalization (De Santana, 2013). Evaluating abiotic factors is crucial for enhancing the sustainability of regional fishing practices and for safeguarding the ecosystems and biodiversity they depend on. This assessment can also pinpoint areas requiring special protection and guide the development of management strategies to conserve these resources. Marine ecosystems deliver vital services crucial for human survival, offering not only food but also maintaining climate equilibrium, purifying water, controlling floods, protecting coastlines, and enabling recreational activities (Marques, 2001). A comprehensive understanding and monitoring of the marine ecosystem—through biological dynamics, physicochemical parameters, and human ecology aspects—are pivotal, not only for grasping the biology of species but also for supporting future evaluations of species exploited by artisanal fishing across various Brazilian regions.

CONCLUSION

The continuous impact of human activities, including pollution and climate change, has led to significant alterations in various aspects of the marine ecosystem. Among the visible evidence of these changes, biogenic sediments not only reflect the biological diversity of the marine environment but also provide crucial insights into the influence of anthropogenic actions on the environment. Changes in the dynamics of the trophic structure of marine ecosystem ichthyofauna—when noticeable—initially and directly affect the fishing community, as they increasingly fail to find fish in their gear or on their tables.

Mitigating the impacts of human activities on the marine ecosystem is essential, given that the ocean offers valuable information on the health and integrity of coastal ecosystems and aids in the development of conservation strategies and sustainable management of marine resources. In this context, the application of embedded technologies has emerged as an innovative and effective approach to monitor and manage marine protected areas, sensitive habitats, and endangered species. The capability of these systems to collect data in real time and from remote locations provides a more comprehensive and detailed understanding of marine ecosystems, enabling a faster and more effective response to environmental disturbances.

REFERENCES

Arias, Ana Rosa et al. **Utilização de bioindicadores na avaliação de impacto e no monitoramento da contaminação de rios e córregos por agrotóxicos**. Ciência e Saúde Coletiva, [s. l.], p. 61-72, 2007.

Brown, A. C. & Mclachlan, A. **Ecology of Sandy Shores**. Amsterdam: Elsevier, 327p. 1990.

CONFERÊNCIA DAS NAÇÕES UNIDAS SOBRE O DIREITO DO MAR,3., New York, abr. 1982. Declaração do Embaixador Carlos Calero Rodrigues, Chefe da Delegação do Brasil. In: DOCUMENTO A/CONF.62/SR 170. United Nations, New York, 1982

Albieri, R. J., & Rebelato, F. (2016). **Uso de Plataforma Arduino para**

Monitoramento de Variáveis Ambientais em Aquicultura. IX Workshop de Tecnologias de Computação Aplicadas à Educação (WTA), 29-34.

Barbieri, Edison. **Biodiversidade: a variedade de vida no planeta terra**. APTA. São Paulo, p1-19, 2010.

Barbieri, E. **Biodiversidade: a variedade de vida no planeta Terra**. In: Instituto de Pesca, Agência Paulista de Tecnologia dos Agronegócios, Secretaria de Agricultura e Abastecimento do Estado de São Paulo. 16 p. 2010.

Batista, J. da S. Estimativa da variabilidade genética intra-específica da dourada – Brachyplatystoma rousseauxii Castelnau 1855 (Pimelodidade – Siluriformes) no sistema Estuário-Amazonas-Solimões. Biota Neotrop., Campinas, v. 6, n. 1, 2006. Disponível em: Acesso em: 16 / Nov / 2012.

Claydon, John. **Spawning aggregations of coral reef fishes: characteristics, hypotheses, threats and management**. Oceanography and Marine Biology: An Annual Review, v. 42, p. 265-302, 2004.

De Santana, I. 2001. **A Pesca Artesanal na APA Litoral Norte da Bahia: um olhar sobre a exploração comercial da ictiofauna marinha e estuarina e sobre as relações pesca – pescador**. João Pessoa: UFPB. 2001. xvi + 106p il. Mestrado.

De Santana, I. O Mar de Fora: Peixes e Pessoas no Manejo da Pesca de Linha no Litoral Norte da Bahia. 1. ed. Salvador: EDUNEB, 2019. 121p. DE SANTANA, I. **Os peixes de Subaúma: Uma visão preliminar das espécies desembarcadas pela pesca artesanal na APA do Litoral Norte da Bahia**. 1999.Monografia (Aperfeiçoamento/Especialização em Zoologia) – Departamento de Ciências Biológicas, Universidade Estadual de Feira de Santana, Feira de Santana, 1999.

De Santana, I.; Santos, G. O.; Nogueira, E. M. S.; Saborido-Rey, J. F.. Riqueza e diversidade de peixes explorados pela pesca artesanal na APA Litoral Norte, Bahia, Brasil. In: José Marcos de Castro Nunes; Mara Rojane Mattos. (Org.). **Litoral Norte da Bahia: Caracterização ambiental, biodiversidade e conservação**. 1ed.Salvador: EDUFBA, 2017, v. 01, p. 331-356.

Dulvy, Nicholas K.; Sadovy, Yvonne; Reynolds, John D. **Extinction vulnerability in marine populations**. Fish and fisheries, v. 4, n. 1, p. 25-64, 2003.

Begon, M.; Harper, J.; Townsend, C. **Ecology. New York: Blackwell**, 1996.

COSTA, Monica F. et al. **Poluição marinha**. Clube de Autores, 2015.

Pauly, D., Christensen, V., & Walters, C. (2000). **Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries.** ICES Journal of Marine Science: Journal du Conseil, 57(3), 697-706.

Nagelkerken, I., 2009**. Ecological Connectivity Among Tropical Coastal Ecosystems. Springer**, Dordrecht, p. 615.

Gibson RN, Robb L, Burrows MT, Ansell AD (1996). **Mudanças de maré, diel e de**

longo prazo na distribuição de peixes em uma praia arenosa escocesa. Mar Ecol Prog Ser 130:1–17.

Levin, S.A. (1999). **Towards a science of ecological management**. Conservation Ecology, 3, 6. (http://www.consecol.org/vol3/iss2/art6/).

Levinton, J. S. 1982. **Marine Ecology**. Englewood Cliffs, Prentice-Hall Inc.526p.

Fairbridge, R. W. 1980. The Estuary: its definition and geodynamic cycle. **In**: Olausson, E.; Cato, I. (Eds). **Chemistry and Biogeochemistry of Estuaries** New York, John Wiley and Sons, p. 1-35.

IEEE Standard Glossary of Software Engineering Terminology, em *IEEE Std 610.12-1990*, vol., no., pp.1-84, 31 de dezembro de 1990, doi: 10.1109/IEEESTD.1990.101064.

Mclusky, D. S. & M. Elliott, 2007. **Transitional waters: a new approach, semantics or just muddying the waters?** Estuarine, Coastal and Shelf Science 71: 359–363.

Monteiro-Neto, C.; Tubino, R.A.; Moraes, L.E.S.; Neto, J.P.M.; Esteves, G.V.; Fortes, W.L. 2008. **Associações de peixes na região costeira de Itaipu, Niterói, RJ**. Iheringia, Série Zoologia, 98(1): 50-59.

Pauly, D., and R. Watson. 2009. **Spatial dynamics of fisheries**. p. 501-509 + plate 14 In: S. Levin (ed.) The Princeton Guide to Ecology. Princeton University Press, Princeton, N.J.Pauly, Daniel et al. **Fishing down marine food webs**. Science, v. 279, n. 5352, p. 860-863, 1998.

Farina M & Amado Filho GM 2009. **Biomineralização em organismos marinhos.** Capítulo 7. In: RC Pereira & A Soares-Gomes (Ed.). Biologia Marinha. 2ª Edição, Interciência, p. 155-182.

Ginsburg RN 1956. **Environmental relationship of grains size and constituent particles in some South Florida carbonates sediments.** American Association Geological of Petroleum Geologists Bulletin 40: 2381-2427.

Ginsburg RN, Lloyd RM, Stockman KW, Mccellum JS 1963. **Shallow- water carbonates sediments**. In: MN HILL (Ed.). The sea: ideas and observations on progress in the study of the seas. The earth beneath the sea history, Vol.3. Interscience publishers, p. 554-582.

Halfar J, Godinez-Orta L, Ingle JR. JC 2000. **Microfacies analysis of Recent Carbonate Environments in the Southern Glf of California, Mexico** – A model for warm-temperate to subtropical carbonate formation. Palaios 15: 323-342.

Illing LV 1954. **Bahaman calcareous sands. American Association Geological of Petroleum Geologists** Bulletin 38: 1-95.

Leon, Lucas et al. **Poluição dos ecossistemas marinhos brasileiros: Uma breve revisão sobre as principais fontes de impacto e importância do monitoramento ambiental. Biociências**, [s. l.], v. 9, ed. 3, p. 166-173, 202

Oliveira EC, Horta PA, Amâncio CE, Sant'anna CL (2002). **Algas e angiospermas marinhasbênticas do litoral brasileiro: diversidade, exploração e conservação**. In: Workshop sobreAvaliação e ações prioritárias para a conservação da Biodiversidade das zonas costeiras e marinha, Brasília, Ministério do Meio Ambiente (1): 411-416

Perry CT 1996. **The response of reef sediments to changes in community composition: implications for time-averaging and sediment accumulation.** Journal of Sedimentary Research 66(3): 459-467.

Ponzi VRA 2004. **Sedimentologia marinha.** Cap. 9. In: JA Baptista Neto, VRA Ponzi & SE Sichel (Org.). Introdução à geologia marinha. Interciência, p. 217-241.

Ricklefs RE 2003. **A economia da natureza**. Guanabara-Koogan SA, RJ, 5ª edição, 503p.

Sistemas Embarcados: Conceitos e Aplicações. Pernambuco, 2009. Disponível em: https://www.cin.ufpe.br/~rfp3/2009.1/IC/se%20-%20completo.docx. Acesso em: 15 abr. 2024.

Souza, Fábio. **Introdução ao Arduino:** Primeiros passos na plataforma. 2013. Disponível em: https://embarcados.com.br/arduino-primeiros-passos/. Acesso em: 15 abr. 2024.

Suguio K 2003. **Geologia Sedimentar**. Editora Blücher, São Paulo, 400p.

Tommasi LR (1989). **Tendências da poluição dos oceanos**. Boletim IG-USP: PublicaçãoEspecial (6): 94-99.

Vahid, Frank; GIVARGIS, Tony. **Embedded System Design**: A Unified Hardware/Software Approach. Riverside, CA: [s. n.], 1999. 103 p.

Wilson JB 1979. **Biogenic carbonate sediments on the Scottish continental shelf and on Rockall bank**. Marine Geology 33: M85-M93.

Wright VP & Burgess PM 2005**. The carbonate factory continuum, facies mosaics and microfácies: an appraisal of some of some of the key concepts underpinning carbonate sedimentology.** Facies 51: 17-23

Zurita, Marcos E. P. V. Projeto de Sistemas Embarcados. **Researchgate**, Teresina - PI, 20 nov. 2014.

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