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Investigating the biodiversity-supporting function of buffer zones through benthic macroinvertebrate composition: A case study in Tram Chim National Park, Vietnam

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ABSTRACT: Buffer zones are critical for protecting biodiversity and ensuring the variety and stability of plant and animal populations. The objective of this study is to evaluate the diversity of benthic macroinvertebrates in the buffer zone of Tram Chim National Park and examine their ecological interconnections with the core zone. This investigation intends to understand the role of the buffer zone in supporting biodiversity in the core zone. The study examined 37 species of benthic macroinvertebrates in the buffer zone surrounding Tram Chim National Park. The Mollusca category had the greatest degree of diversity, accounting for 68.42% of the recorded species. The Crustacea category represented 15.79% of the species, while insect larvae made up 10.53%. The Oligochaeta group has the lowest representation, accounting for only 5.26%. The study also discovered 10 species in Tram Chim's buffer zone that had previously been unrecorded in the core zone. These species include *Hyriopsis bialatus, Margaritifera auricularia, Pomacea diffusa, Stenomelonia* sp., *Brotia* sp., *Clea* sp., *Melanoides tuberculata, Tylomelania* sp., *Tylomelania sinobarfeld, and Tylomelania wallacei*. The IUCN Red List for 2022 lists 18 of the 37 observed species, particularly *Margaritifera auricularia* and *Hyriopsis bialatus*, commonly found in canal habitats within the buffer zone. These species are significantly decreasing in population around the world. This demonstrates that the buffer zone of Tram Chim National Park has a high level of biodiversity, necessitating protection and impact mitigation to sustain biodiversity support functions in the park's core zone.

KEY WORDS: benthic macroinvertebrate, biodiversity support function, buffer zone, Tram Chim national park.

INTRODUCTION

A buffer zone, situated beyond the boundaries of national parks and reserves, imposes limitations on resource utilization or necessitates certain development strategies to enhance the area's conservation significance. (Martino, 2001). In modern times, a buffer zone within a nature reserve serves the dual purpose of acting as both an ecological and social buffer. Buffer zones serve multiple purposes, including protecting against human effects and pollution, providing a migration corridor for wildlife, and serving as a base for research and monitoring (Yu and Jiang, 2003). Buffer zones boosted conservation coverage by 50–100%, depending on the planning scenario, and supported regional conservation efforts. Local conservation practices rarely match regional planning; therefore, programs should be assessed using both landscape-scale and site-specific approaches. Conservation should go beyond Biosphere Reserve cores. Managing buffer zones requires equal or more attention due to the higher anthropogenic footprint. Invertebrate losses are linked to anthropogenic global change drivers; therefore, land use planning must address conservation. Due to a lack of research on diversity, conservation efforts disregard invertebrates, which make up most animals (Schoeman, 2021). According to Decision No. 08/2001/QĐ-TTg, the primary objective of all activities within the buffer zone is to facilitate the preservation, administration, and safeguarding of the special-use forest. Buffer zones have a crucial and varied function in safeguarding and preserving biodiversity in places requiring protection, such as national parks and nature reserves. Buffer zones play a vital role in providing additional habitats for numerous species. They establish protected areas where plants and animals can safely move, search for food, and reproduce. This is particularly crucial for species with extensive distributions that necessitate diverse environments at different times of their life cycles. Buffer zones play a crucial role in preserving the diversity and stability of plant and animal populations. They provide essential biological resources and minimize the danger of extinction caused by habitat fragmentation. Buffer zones create ecological corridors that facilitate species movement and genetic exchange across isolated areas, preserving genetic flow and critical ecological processes (Ebregt and Greve, 2000; McGray, 2003; Gray, 2016; Kubacka, 2022).

Tram Chim National Park is a wetland environment in the Mekong Delta, with a core area of 7,313 hectares and a buffer zone of 16,858 hectares (as stated in Decision No. 1037/QĐ-UBND dated October 5, 2015). This location is a globally significant wetland for the preservation of waterbird habitats, primarily because it is home to the Sarus Crane, scientifically known as *Grus* *antigone sharpii* (Triet et al., 2002; Truyen et al., 2014). A multitude of animal species often migrate between the central and surrounding areas of Tram Chim National Park. Several fish and waterbird species utilize the environments found in both the core and buffer zones for their survival and feeding activities (Vinh and Wyatt, 2006).

Benthic macroinvertebrates are crucial in the aquatic food chain as they provide the principal food supply for fish, waterbirds, and amphibians. The nutrient cycles and structure of this aquatic community are influenced by the feeding habits and activities of fish and waterbirds (Napier et al, 2010; Melcher et al., 2018; Jadhav et al., 2022, Pinna et al 2024). Benthic macroinvertebrates control the overall structure and function of the ecosystem by regulating primary production and nutrient cycles. Since 1993, research on the richness of macroinvertebrates in Tram Chim National Park has been undertaken; yet the studies are incomplete and predominantly concentrated on the core zone of the park. In 1993, four species of crustaceans and twelve species of mollusks were documented, comprising five gastropods and seven bivalves (Hung, 1993). A separate investigation documented seven species of crustaceans and eight species of mollusks, comprising four gastropods and four bivalves (Hung and Minh, 1997). A further survey revealed eleven species. Among them, seven were categorized as bivalves and three as gastropods. *Sinotaia basicarinata, Sinotaia dispiralis*, and *Pomacea canaliculata* were the predominant species (Dung et al., 2008). The water environment within the park contains 29 reported benthic species, categorized into three groups: mollusks (15 species) and crustaceans (six species) (Triet et al. 2002). Seventeen benthic species have been found, with the potential to document seven additional species (An, 2011). Thus far, there is limited published literature regarding the species composition and biodiversity of benthic macroinvertebrates in the buffer zone of Tram Chim National Park, despite its recognized significance in sustaining biodiversity in the core zone through the ecological linkage between the two areas. The park's water management system has been upheld since 2005, influencing the macroinvertebrate fauna in the core zone of the national park. Consequently, we undertook this study to evaluate the richness of macroinvertebrates in the buffer zone of Tram Chim National Park, aiming to determine the buffer zone's capacity to support biodiversity in the core zone of the national park. The findings will provide a scientific foundation for the efficient management of the buffer zone, therefore fostering conducive conditions for the sustainable development of this national park in coming years.

MATERIALS AND METHODS

In the buffer zone of the national park, samples were collected at 15 locations, dividing them into two types of ecosystems: lentic ecosystems (fishponds, rice fields), and lotic ecosystems (irrigation canals) (**Figure 1**). Lentic ecosystems: TC1 – TC9 with different habitats (fishponds, three-crop rice fields, traditional two-crop rice fields, two-crop ecological rice fields). Lotic ecosystems: TC10 – TC15 with irrigation canals surrounding the national park.

At the sampling stations, samples were collected using a $0.1m^2$ Ponar grab with 3 replicates per station. Sampling was conducted at 15 locations (TC1 – TC15) during both the rainy and dry seasons. The obtained samples were then sieved using a mesh screen with a mouth diameter of 30 cm and a mesh size of 0.5 mm to eliminate mud and debris (Bingham et al 1982, Thai et al 2018, Hien et al 2023). The samples were enclosed in nylon bags, documented, and marked with details such as the location and date of sampling. In addition, a wide range of sampling methods were employed, including the use of nets, hand collection, and the procurement of specimens from local fishermen (using bottom nets, stake traps, and mechanical dredges), as well as from small markets (Quang et al 2020). These methods were used to assess the abundance and diversity of commercially important species.

The samples were placed in plastic containers and treated with either 10% formalin or 70% alcohol for preservation. In addition, the study involved conducting interviews with local residents to gather further information about the composition of the species and the amount of catch obtained for qualitative sample. Abundances were expressed in individuals/$0.1m^2$. The classification of the large invertebrate samples was conducted by utilizing a microscope with a magnification range of 7.5–45x. The specimens were then identified and named in accordance with the international nomenclature system. The classification references encompassed works by Fauchald (1977), Thanh (1980), Abbott (1983), Springsteen (1986), Hayward (1995), Quynh (2004), Thanh and Chau (2005), Xuan (2010), and Ting Hui Ng (2016).

The data analysis was performed with SPSS 20.0 software on a Windows operating system. Permanova and t-test statistical approaches were used to analyze significant differences in species composition at sample sites, habitat types throughout the two seasons. All values were evaluated for statistical significance at a threshold of α=0.05. The composition and density data of species were analyzed using Primer 6.0. Graphs were generated utilizing Microsoft Excel 2010.

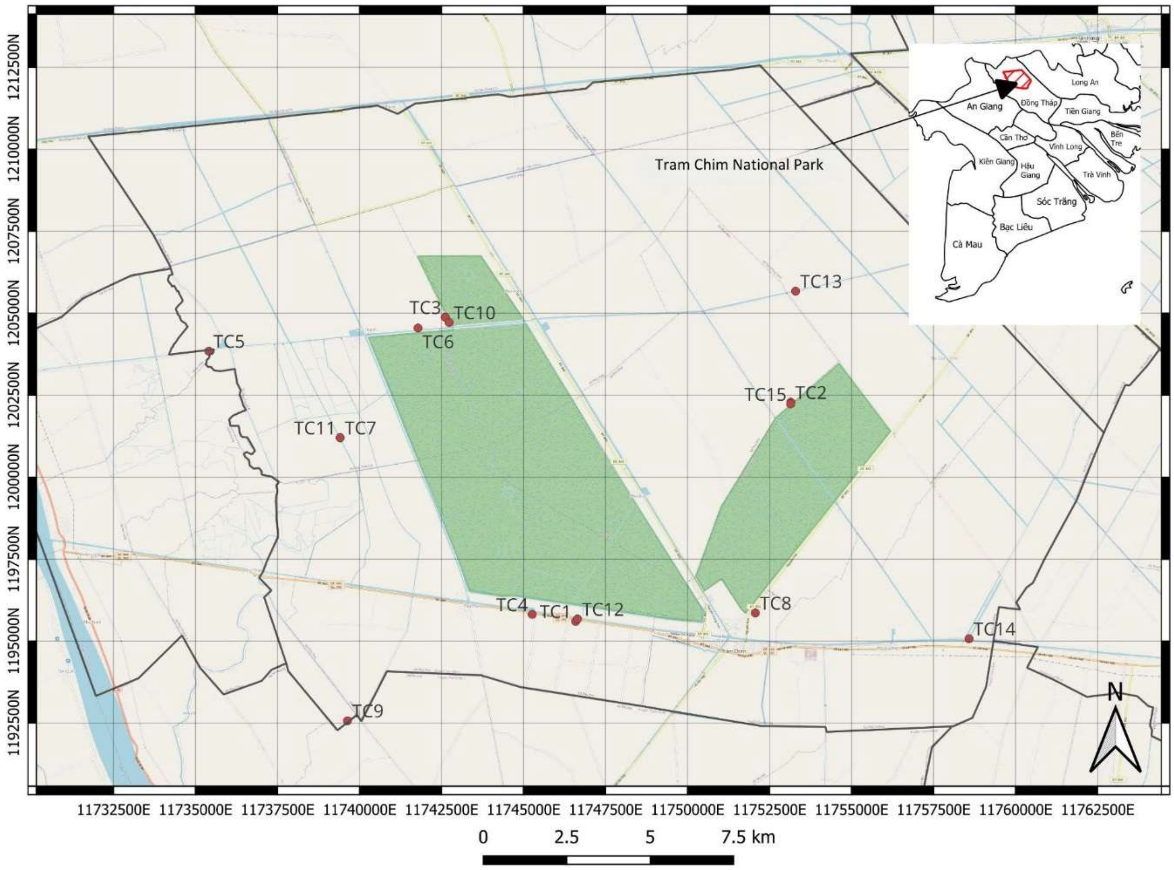

Fig.1. Sampling sites at Tram Chim National park

RESULTS

The study recorded a total of 37 species of benthic macroinvertebrates in the aquatic habitats of the buffer zone of Tram Chim National Park, including both the rainy and dry seasons. The benthic species can be classified into four groups: Mollusca (25 species), Crustacea (6 species), Oligochaeta (2 species), and insect larvae (4 species) (**Table 1**). The Mollusca group had the highest level of diversity, constituting 68.42% of the documented species. The Crustacea group accounted for 15.79%, while the insect larvae group constituted 10.53% of the species. The Oligochaeta group was the least represented, making up only 5.26%. Among the Mollusca group, the class Gastropoda consisted of 19 species, whereas the class Bivalvia contained 7 species (**Figure 2**).

Rainy season research revealed the presence of 25 benthic macroinvertebrate species in the sampling locations within the buffer zone of Tram Chim National Park. The benthic species can be classified into three groups: Mollusca (consisting of 17 species), Crustacea (consisting of 6 species), and Oligochaeta (consisting of 2 species). Conversely, the study documented a total of 27 species from three distinct groups during the dry season: Mollusca (22 species), Crustacea (5 species), and four varieties of larvae from the Insecta group. The Mollusca category has the highest species count, making up around 70% of the total documented species in both seasons. The Mollusca group consists of the Gastropoda class, which contains 10 species during the rainy season and 17 species during the dry season. The Bivalvia class, on the other hand, has 7 species during the rainy season and 5 species during the dry season. Certain species within the Gastropoda class tend to inhabit the flora found along the banks and canals, which accounts for this phenomenon. The Pilidae family, widely distributed and typically found in various water bodies, serves as one such example. Other families are commonly found on canals' lower substrates. Typically inhabiting bottom substrates, bivalvia species exhibit a limited geographic range, exclusively found in specific areas adjacent to water management sluice gates. Bivalvia species are unable to thrive in areas with abundant plant debris on the on the substrate due to their poor or non-existent mobility. This hampers their ability to restore or replenish their populations unless their habitats are enhanced.

The findings demonstrate disparities in species composition between the rainy and dry seasons in lotic and lentic ecosystems inside the national park buffer zone. The number of species seen in lentic ecosystems is greater

Table 1. Species composition of macroinvertebrates recorded in the buffer zone of Tram Chim National Park.

Phyllum: Mollusca
Class: Gastropoda
Order: Architaenioglossa
Family: Viviparidae
1. *Bellamya filosa* Haas, 1952
Family: Ampullariidae
2. *Pila polita* Deshayes, 1830 **
3. *Pomacea canaliculata* Lamarck, 1819
4. *Pomacea diffusa* Linnaeus, 1785
5. *Sinotaia dispiralis* Heude, 1890**
6. *Sinotaia aeruginosa* Reeve, 1893 **
Order: Cerithioidea
Family: Thiaridae
7. *Stenomelania* sp.
8. *Stenomelania reevei* Barot, 1874
Order: Caenogastropoda
Family: Thiaridae
9. *Thiara scabra* O.F.Muller, 1774**
10. *Melanoides tuberculata* O.F. Muller, 1774 **
Order: Hygrophila
Family: Lymnaeidae
11. *Lymnaea viridis* Quoy&Gaimard, 1832 **
12. *Gyraulus convexiusculus* Hutton, 1894 **
Order: Littorinimorpha
Family: Assimineidae
13. *Assiminea lutea* Adams, 1861
Order: Sorbroconcha
Family: Pachychilidae
14. *Brotia* sp.
15. *Tylomelania* sp.
16. *Tylomelania sinobartfeldi* von Rintelen &Glaubrecht, 2008
17. *Tylomelania wallacei* Reeve, 1860
Order: Neogastropoda
Family: Nassariidae
18. *Clea* sp.
Class: Bivalvia
Order: Venerida
Family: Corbiculidae
19. *Corbicula baudoni* Morlet, 1886 **
20. *Corbicula moreletiana* Prime, 1867 **
21. *Corbicula blandiana* Prime, 1864
Family: Mylitidae
22. *Limnoperna siamensis* Morelet, 1866
Order: Unioida
Family: Unionidae
23. *Nodularia douglasiae* J.E. Gray, 1833 **
24. *Hyriopsis bialatus* C.T.Simpson, 1900 **
Family: Margaritiferidae
25. *Margaritifera auricularia* Spengler, 1793 **
Phyllum: Arthropoda
Class: Malacostraca
Order: Decapoda
Family: Atyidae
26. *Caridina serrata serrata* Stimpson, 1860
27. *Caridina subnilotica* Dang, 1975
28. *Caridina flavilineata* Dang, 1975 **
Family: Palaemonidae
29. *Macrobrachium rosenbergii* De Man, 1879 **
30. *Macrobrachium mammillodactylus* Thallwitz, 1892 **
Family: Gecarcinucidae
31. *Somanniathelphusa sinensis* H.Milne-Edwards, 1853 **
Class: Insecta
Order: Diptera
Family: Canacidae
32. Canacidae larvae
Family: Chironomidae
33. Chironomidae larvae
Family: Rhagionidae
34. Rhagionidae larvae
Order: Odonata
Family: Anisoptera
35. Anisoptera larvae
Phyllum: Annelida
Class: Clitellata
Order: Oligochaeta
Family: Naididae
36. *Limnodrilus hoffmeisteri* Claparede, 1862
37. *Tubiflex tubiflex* Lamarck, 1816

** IUCN Red Listed Species

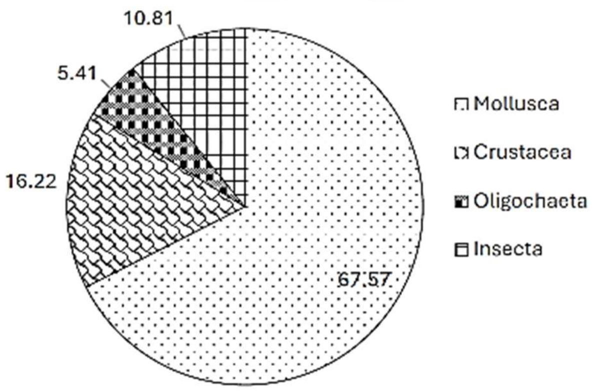

Fig. 2. Species composition of benthic macroinvertebrates in the buffer zones of Tram Chim National Park.

during the rainy season compared to the dry season (p = 0.034). Allowing rice fields used for two crops to remain uncultivated during the rainy season allows floodwaters to enter and deposit silt. This process also introduces aquatic species and larvae into the fields. In rice fields that grow three different crops, the water level is intentionally kept high and protected by dikes. This high-water level, along with the nutrients and surface runoff that flow into the fishponds, creates ideal conditions for the growth and development of bottom-dwelling creatures. In contrast, the number of species observed in a lotic habitat is higher during the dry season compared to the rainy season (p = 0.01) (**Figure 3**). During the dry season, the decrease in water levels in the canals causes slower water flow and allows aquatic plants to invade. These conditions are favorable for snail species reproduction, particularly Melanoides snails. In contrast,

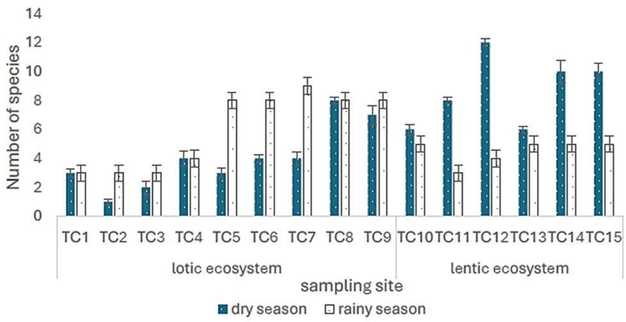

Fig. 3. The number of benthic macroinvertebrate species at sampling sites in two seasons

during the rainy season, higher water levels and strong currents prevent the dispersion of organisms in the water body. The decreased water levels in the canals also promote local bottom-scraping activities, resulting in a greater abundance of species recovered from scraping boats during the dry season compared to the rainy season.

DISCUSSION

Macroinvertebrate species composition

The previous research conducted by Hung, 1993, Hung et al., 1997, Triet et al., 2002, and An, 2011 in the central area of Tram Chim National Park documented the presence of 10–29 benthic species. The investigation indicated that the macroinvertebrate species composition in the buffer zone of Tram Chim National Park showed a 50% similarity to that of core zone, based on prior studies conducted in the core zone. There are six species that are common in the area. They are *Bellamya filosa, Corbicula baudini, Pila polita, Sinotaia dispiralis, Macrobrachium mammilodactylus,* and *Somanniathelphusa sinensis sinensis.* These species have been found in most studies over the past 30 years.

Several benthic species, including the giant freshwater prawn *Macrobrachium rosenbergii, Caridina flavilineata, Somanniathelphusa sinensis, Pila conica, Pila polita, Pomacea diffusa, Caridina subnilotica, Assimiea lutea, Margaritifera auricularia, and Limnoperna siamensis*, have economic value and are commonly consumed as food. Several diminutive mollusks and crustaceans, while not inherently valuable to humans, serve a crucial function in the food webs of Tram Chim's freshwater ecosystems. Local inhabitants also use these organisms as livestock and shrimp feed. The species involved include *Tylomelania* spp*., Brotia* sp*., Clea* sp*., Stenomelania* spp*., Sinotaia* spp*., and Corbicula* spp. Furthermore*, Pomacea caniculata*, an invasive species, poses a significant threat to rice cultivators.

While the quantity of benthic macroinvertebrates species remains relatively consistent between the rainy and dry seasons, there is a discernible variation in the specific types of species present. During the rainy season, groups such as Bivalvia, apple snails, and rice snails experience growth and development. In contrast, the dry season is characterized by the expansion of snail groups like *Melanoides* and *Cerithidea*. Eight species, namely *Lymnaea viridis, Stenomelania* sp., *Brotia* sp., *Clea* sp., *Melanoides tuberculata, Tylomelania* sp., *Tylomelania abendanoni*, and *Tylomelania wallacei* (all belonging to the Melanoides and Cerithioidea groups), as well as four varieties of larvae from the Insecta group, exclusively emerge during the dry season. During the rainy season, the following seven species are exclusively present: *Stenomelania reevei, Thiara scabra, Corbicula baudoni, Margaritifera auricularia, Macrobrachium mammillodactylus, Limnodrilus hoffineisteri,* and *Tubifex tubifex*. This outcome is also distinctly evident from discussions with local fishermen who engage in bottom-scraping. During the rainy season, the majority of the 7 boats that dock each day for purchase will gather rice snails, apple snails, clams, mussels, and other similar species. However, during the dry season, most boats will be searching for Melanoides snails. Furthermore, during the dry season, there is a scarcity of golden clams (*Corbicula baudoni*), river mussels (*Margaritifera auricularia*), and only a small number of *Hyriopsis bialatus* mussels in the canals. This is in contrast to their abundance during the rainy season, as evidenced by the boats that scrape the bottom.

Biodiversity support functions of the buffer zone of the national park

Macroinvertebrates, particularly waterfowl and migratory birds, depend on big invertebrates as their main source of nourishment. Aquatic areas, such as ponds, streams, and wetlands, are often home to large invertebrates, making them suitable homes for numerous bird species. Wetland-dwelling birds, such as herons, egrets, and shorebirds, consume a variety of aquatic invertebrates, including aquatic insects (such as mayflies, dragonflies, and damselflies), mollusks (such as snails and clams), crustaceans (such as crabs and crayfish), and aquatic worms.

Macroinvertebrates and fish: A significant number of fish species, especially those found in freshwater environments, rely heavily on consuming big invertebrates as their main source of food. Fish commonly devour insects, tiny crustaceans, and plankton, which are huge invertebrates. The nutritional interdependence between macroinvertebrates and fish is a crucial component of the aquatic food chain, facilitating the transmission of energy and nutrients from lower to higher trophic levels. Consumption of large invertebrates by fish can impact the size and composition of the invertebrate populations in the environment, as it influences the growth and reproduction of these fish. Furthermore, the periodic opening of water regulation sluice gates can disperse the eggs and larvae of sizable invertebrates carried by the water current (plankton), thereby facilitating the spread of species both within and beyond the National Park's boundaries. While mature individuals do not actively migrate with the water current, human activities can potentially aid in the spread of species. While doing fieldwork, we witnessed avian species foraging in rice fields, fishponds, alongside canal banks, and inside natural aquatic habitats.

The study also found 10 species that had not been recorded in the core zone of Tram Chim. These species are *Hyriopsis bialatus, Margaritifera auricularia, Pomacea diffusa, Stenomelonia* sp., *Brotia* sp., *Clea* sp., *Melanoides tuberculata, Tylomelania* sp., *Tylomelania sinobarfeld,* and *Tylomelania wallacei*. Previous investigations have not documented the presence of these species within the national park's core zone. These findings suggest that the canals and flooding in the rice fields have the potential to add to the inventory of benthic species in the core zone of the National Park during specific periods of water circulation throughout the year. In contrast, the National Park can provide 22 species for the buffer zone, which has flowing water habitats that are conducive to the establishment and development of benthic macroinvertebrates. This enhances the ecological role of reserves and promotes biodiversity in the buffer zone.

Out of the 37 species seen in the studied locations, a total of sixteen species are included in the IUCN Red List 2022. In this, *Margaritifera auricularia* is classified as Critically Endangered (CR), and *Hyriopsis bialatus* is classified as Endangered (EN). The two species, *Margaritifera auricularia* and *Hyriopsis bialatus*, frequently inhabit canal habitats within the buffer zone of the National Park, despite their global rarity and dwindling populations. This highlights the necessity for increased focus on their influence on their habitats, as the majority of these species predominantly inhabit canals (samples were mainly obtained through bottom-scraping conducted by local individuals). Regular bottom-scraping activities in the canals surrounding the National Park persist, particularly during the dry season. Implementing conservation techniques for IUCN-listed species in the national park buffer zone, particularly for two species facing a substantial decrease in population, will also enhance the overall value of this wetland system.

Overall, the buffer zone of Tràm Chim National Park has the potential to support biodiversity by providing habitat for species that are rarely or not yet recorded in the park's core zone. However, strong impacts from aquaculture activities, fishing, intensive farming, and environmental pollution in the buffer zone could lead to a severe decline in the biodiversity of large invertebrates, affecting this supporting function.

CONCLUSION

The buffer zone of Tram Chim National Park demonstrates considerable macroinvertebrate richness, with 37 documented species, including 2 species listed on the IUCN Red List and 10 species not previously recorded in the park's core zone. The buffer zone significantly enhances biodiversity, as around fifty percent of the species identified there were not documented in previous core zone surveys. The extensive variety of species will enhance the various food supplies accessible to several bird species residing in the core zone. Consequently, mitigating fragmentation or overexploitation in the buffer zone will be essential for preserving the diversity and stability of macroinvertebrate ecosystems. This effort will support the restoration and biodiversity enhancement of Tram Chim National Park by using the biodiversity support capability of the buffer zone. This effort would improve the restoration and enhancement of biodiversity in Tram Chim National Park by using the biodiversity support capacity of the buffer zone.

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