NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Assessment of Services of the Hau River in the Mekong Delta, Vietnam

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Article information

Article History
Received 21 November 2022
Revised 6 December 2022
Accepted 7 January 2023
Available online 16 March 2023

Keywords:
river, ecosystem services, ecotourism, water regulation

https://doi.org /10.5281/zenodo.7741013
https://nipesjournals.org.ng

Abstract

This study investigated ecosystem services on the Hau River provinces (An Giang, Can Tho, Vinh Long, Soc Trang) of Mekong Delta of Vietnam. It is found that the river has directly and indirectly provided various regulation and support services. Moreover, the river is the place where many festivals and traditional beliefs activities take place featuring with different eco-tourism and experiential activities. However, hydrological changes, reduced river's water quantity and quality, and river-related development policies have degraded the river's ecosystem services. The change in water quality and quantity has been considered the main causes of ecosystem services changes. Therefore, action plans for the restoration, protection and sustainable development of river ecosystem services are needed.

1. Introduction

Water represents a basic component of the economy in the Vietnamese Mekong Delta, in addition to domestic consumption, water is also used for agriculture, industry/services. Rivers and riparian areas also contribute to the landscape for the area and the development of other tourism services [1]. Besides, the river is also a connection and creator of the river environment for many terrestrial and aquatic creatures and it also creates other aesthetic and recreational values. Therefore, Hau river's ecosystem services could play crucial role in socio-economic development. In the Mekong Delta, the Mekong River is considered the most important source of water and ecosystem services. The section of the Mekong River flowing in the territory of Vietnam is about 220 km long. Before flowing into Vietnam, the Mekong River divides into two branches called Tien and Hau rivers.

According to the report of the National Center for Planning and Investigation of Water Resources (2021) [2], the statistics in the period 2000 - 2020 show that the average annual discharge measured at Tan Chau and Chau Doc is 12,571 m^3/s, of which in Tan Chau about 10,142 m^3/s and in Chau Doc about 2,430 m^3/s. The total annual average volume of water entering the MD area at Tan Chau and Chau Doc stations is 398 billion m^3 (12,620 m^3/s), of which at Tan Chau is 321 billion m^3, Chau Doc is 77 billion m^3. The total volume of water in the dry season (from December to May) is 94.3 billion m^3 (accounting for 23.7% of the whole year).

About 90% of water flow into the Mekong Delta is from upstream; especially in the dry season, the amount of water completely depends on the upstream area [3]. Therefore, ecological resources and socio-economic development in the Mekong Delta depend greatly on water resources, especially from upstream. In which, the section of Hau River flows through An Giang (upstream), Can Tho (middle source), Vinh Long (middle source) and Soc Trang (upstream), the widest section of the river belongs to Long Phu district, Soc Trang province [2]. This is also one of the survey areas of the project. From there, it is possible to determine that the water source on the Hau River along with the services related to the river is an issue that needs attention in order to be able to plan, develop the riverside areas, and use it rationally.

2. Materials & Methods

The study was carried out in several areas near the Hau River (a tributary of the Mekong River), the section of the river flowing from the upper Hau River to the estuary area, including the provinces of An Giang, Can Tho, Vinh Long and Soc Trang (Figure 1). One hundred twenty households were interviewed using a pre-designed questionnaire to assess the change of ecosystem services from past to present, including provisioning services, regulatory services, culture and support services. Besides, the questionnaire was also designed to be able to collect the current status of water quality in the survey area. Specifically, information is collected such as water quality expression, pollution level, pollution duration, main effects and causes in the area.

The identification of indicators for assessing the change of ecosystem services on the river is considered based on the field survey and the characteristics of the Mekong Delta in the use of river water. Through analysis and discussion, the research team selected two factors including (1) For service provision (water supply, food, raw materials, genetic resources, electricity); (2) Regulatory services (erosion control, self-cleaning capacity, amount of sediment deposited, level of acid sulfate soil washing, freight transport, climate regulation). Meanwhile, cultural services are analyzed through recreational activities on the river, using the river for education, poetic composition, symbolic species, cultural beliefs or traditional festivals; Support services include assessment factors such as river habitat, river nutrients, soil accretion capacity.

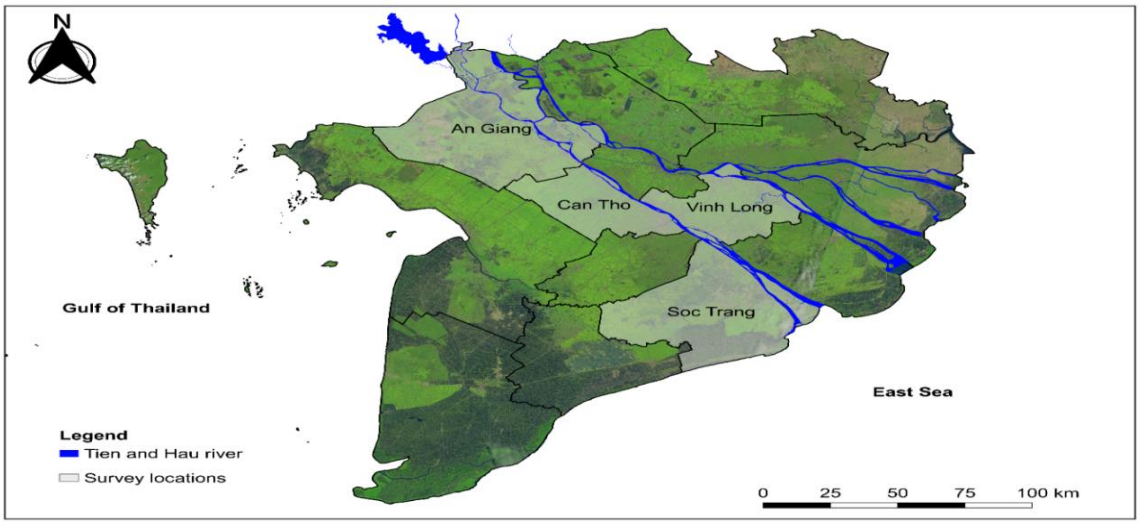

Figure 1. Map of survey loactions (An Giang, Can Tho, Vinh Long and Soc Trang provinces)

The collected data was entered into Excel software. Then, the simple calculations including minimum, maximum and percentage analyses were carried out regarding the river's ecosystem services.

3.0 Results and Discussions

3.1 Characteristics of households participating in the survey

The characteristics of 120 households participating in the assessment of changes in ecosystem services are presented in Figure 2. In which Figure 2a shows that 60.5% of the surveyed people are male, the remaining 39.5% are female. During the survey, men were found to provide more information than women. The actual reason is explained by the fact that women are often afraid to share information. This shows that the gender chosen for the interview also affects the results of the survey more or less; Therefore, the study chose to collect more information from men than from women. In terms of age, most of the respondents are over 41 years old (89.5%) (Figure 2b) and have lived in the locality for more than 15 years (accounting for 96.49%).

This makes the assessment highly reliable because they have seen and felt the change of the river over a long time. In addition, the interview results show that the education level of the respondents in the research area is quite low. Specifically, there are about 48.2% at the primary level, and 32.5% at the lower secondary level (Figure 2c). However, the level of education did not affect the assessment results because the assessment was only based on information surrounding their life with the river.

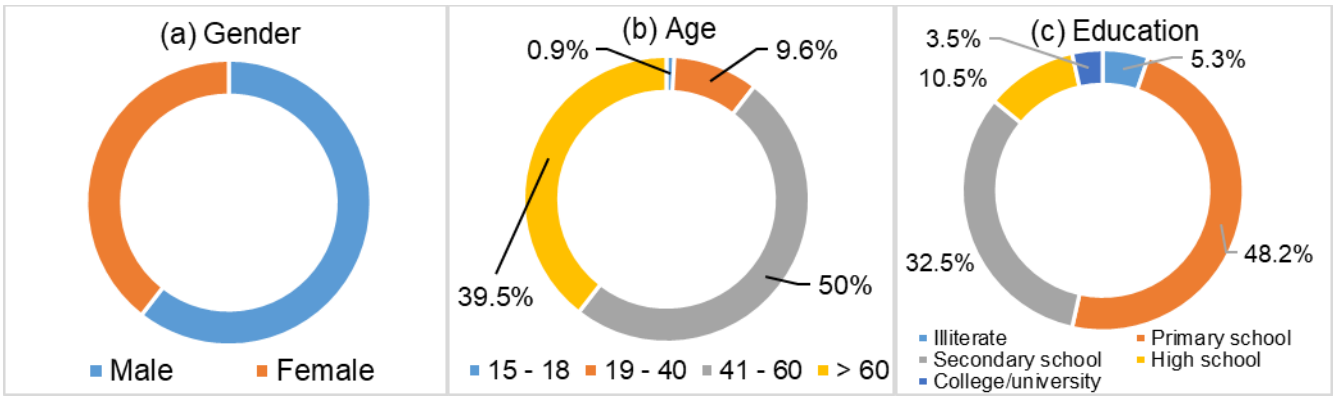

Figure 2. Characteristics of (a) gender, (b) age and (c) education level of surveyed households

Regarding the livelihoods of the interviewed households, most of them were found in other groups (40.7 - 60.6%). The main activities are growing fruit trees (plums, coconuts, longans, star apple, mango) and vegetables on the river (coastal area). Next is rice farming (accounting for 4.0 - 31.1%), the lowest recorded in Can Tho and the highest in Vinh Long. Meanwhile, aquaculture on rafts is recorded mainly in Can Tho. A variety of income-generating activities were recorded during the survey and all of these activities depend on river water (except for administrative work), especially floating fish farming in the river in Can Tho.

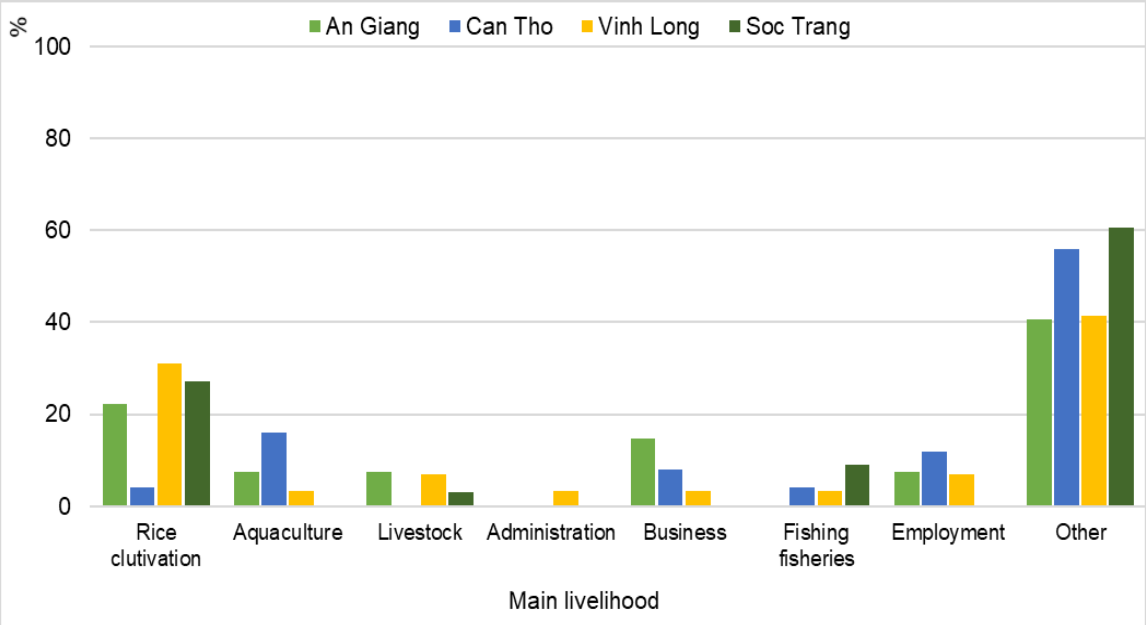

Figure 3. Main livelihood activities in riparian areas

Figure 4. Crop farming and fishing in the river

3.2 Characteristics of water quality in the study area

All interviewed households said that the river is very important for their daily activities. The households said that they only assessed the water quality in the survey area through the senses, especially water color, smell and garbage. Some main manifestations such as a lot of garbage (packages of plant protection drugs, animal carcasses), discolored water, bad smell, especially for Soc Trang area and part of Vinh Long province are affected by salt water. There were 38 survey participants (accounting for 33.3%) who assessed that the water quality in the water bodies they live in is polluted at a high to very high level (corresponding to 4 points and 5 points) (Table 1) and provide habitat for low-lying aquatic species, the period of pollution started about 4-5 years ago (2017 - 2018) with the most polluted month being January - March of the year. Meanwhile, more than 100 people (accounting for about 87%) said that water quality was not polluted or very little polluted in the past. This has also been reported in the past on pollutant concentrations in the Hau River section at An Giang and Can Tho;

This study has recorded signs of organic pollution and an increasing trend over the years (2016 - 2018) [3-4]. This may have limited the use of river services, typically provisioning and cultural services. According to the survey results, up to 78.95% (corresponding to 90 people out of 114 people) respondents will not use it if they feel the water quality is polluted.

Table 1. Level of water pollution

Pollution level	Present	Proportion (%)	In the past	Proportion (%)
No idea	11	9.65	10	8.77
Very little	20	17.54	44	38.60
Little	12	10.53	55	48.25
Moderate	13	11.40	0	0.00
High	38	33.33	5	4.39
Very high	20	17.54	0	0.00
Ranking	4 – 5		0 – 3	

Note: Levels are classified into 5 levels, including 1 – Very little, 2 – Little, 3 – Moderate, 4 – High and 5 – Very High.

The maximum discharge on the river is around September, October and the minimum discharge is in March and April every year [2]. Moreover, people in the Hau riverside area in An Giang have said that water reserves have decreased by about 20-30% compared to 10 years ago. The cause of the difference in discharge was explained by the majority of people as flood water; however, the respondents in households in Soc Trang have said that this difference depends on the mode of opening and closing the sluice to prevent salinity. In Soc Trang, due to the impact from the process of closing culverts, trade and flow activities lead to many impacts on people; Specifically, after about a month of freezing, the water environment begins to decline in both quantity and quality. Variation in quality and quantity may be the main factor leading to changes in the use of ecosystem services related to the Hau River in the study areas.

*3.3 **Evaluation of ecosystem services***

3.3.1 Supply services

The ecosystem services are evaluated, the service provided is considered as one of the four indispensable services created by the river. Through the survey, the water supply service of Hau River is mainly for agricultural and domestic activities. Figure 6 shows a significant decrease in water supply for domestic activities; Water supply for agriculture is still prioritized using river water. However, in Vinh Long and Soc Trang areas, people have said that the use of this service for agriculture is limited in the dry season, because of the problem of saline intrusion. In contrast, the demand for river water for aquaculture tends to increase, households using services for this purpose are mainly concentrated in Can Tho area. The main aquatic resources raised on Hau River are traditional fish species such as Red-tailed Heli, Ca Lang and some households raising Carp and Snakehead, Pangasius. Among the people surveyed, water supply for industrial and service activities has not been recorded in both the present and the past. As previously mentioned in section 3.1, other activities in the study area still use water to supply farming. Therefore, it can be seen that the water source on the Hau River is one of the main factors for the sustainable development of agriculture in the Mekong Delta.

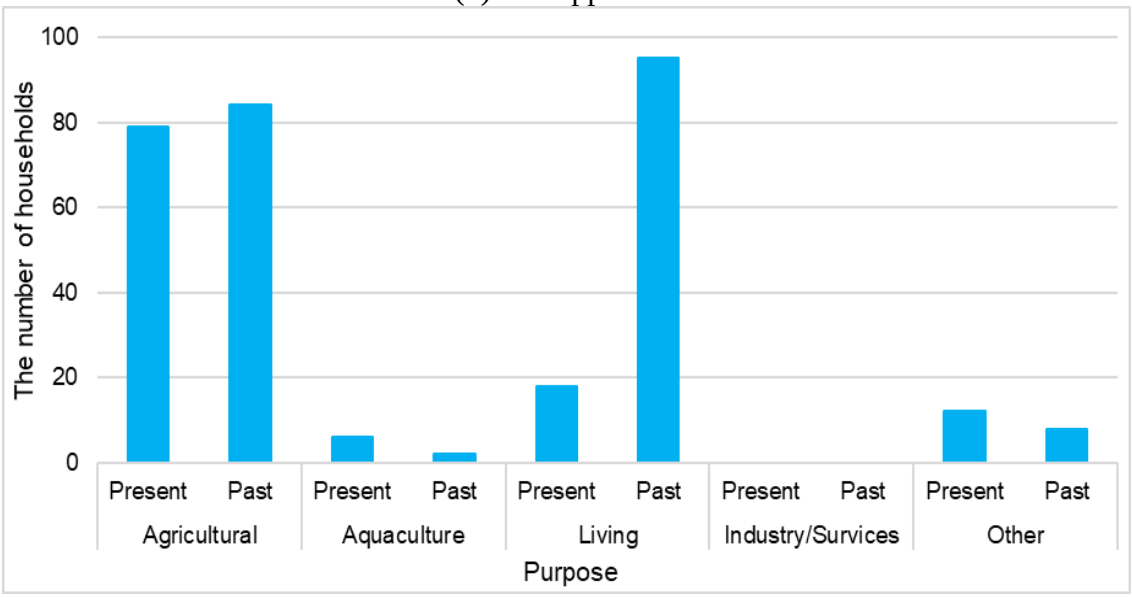

Figure 6. Percentage of people using river water for activities

Through the survey results, people believe that fishing activities is especially high in the period from September to October of the Hau River and its tributaries; at the same time as the flood season, around 96% of the surveyed people said that fishery production in the river at the moment is assessed to be declined; meanwhile, in the past, the service of providing aquatic products on the river was considered to be high (accounting for 86.84% of the surveyed people) (Table 2).

In the past, the composition of fish species caught in the river was very diverse, such as Linh fish (*Henicorhynchus siamensis*), Vinh catfish (*Barbonymus gonionotus*), Long fish (*Leuciscus cephalotaenia*), snakehead fish (*Channa striata*), Anchovies (*Stolephorus commersonnii*), Perch (*Anabas testudineus*), Silver Shrimp (*Metapenaeus brevicornis*), Crayfish (*Macrobrachium rosenbergii*), Dolphin (*Botia modesta*), Sliced Sprout (*Notopterus notopterus*), Australian fish (*Arius arius*), Crayfish (*Pangasius krempfi*),... However, the number of fish caught and the diversity of species composition has decreased significantly compared to 5 years ago (decreased by about 60-80%). The fish species that have been caught recently are only about 3 to 4 species, including the giant salmon (*Hypostomus plecostomus*), Tilapia (*Sarotherodon melanotheron*), Snakehead (*Channa striata*), Catfish (*Clarias gariepinus*), and some fish species. During the survey in An Giang province, many households thought that they had caught fish with the size of a few dozen pounds before, but in recent years, it has disappeared.

The cause of the decline was identified by survey participants in An Giang province as being low flood levels and overfishing; while in Soc Trang area, it is recorded that it is affected by the saltwater prevention sluice and the use of prohibited fishing gear (rake boats). In Vinh Long, the area is polluted by industrial zone water and pulse fishing are the main causes of the decline. However, when asked about the solutions to this change, people said that they still use traditional fishing methods.

Table 2. Food delivery services (aquatic and wild plants) on the river

Food	Evaluating criteria	Present		In the past	
		Level	Proportion (%)	Level	Proportion (%)
Aquatic fish species	Aquatic production	1	95.61	4	86.84
	Species composition	About 60-80% reduced. Some fish species often appear such as: Suckermouth catfish, Tilapia, Snakehead, Catfish and some other small fishes.		Very high. Some fish species regularly present include: Henicorhynchus, Silver barb, Yellow rasbora, Snakehead, Anchovies, Climbing perch, Giant River prawn, fresh river dolphin, Flounder, Giant salmon catfish, Chinese Pangasid-catfish, and some other river fish.	
	Frequency and production	Seldomly. Average weight: 1-3 kg/time/day		Regularly. Average weight: 1-15 kg/time/day	
Wild plants	Species composition	Moderate. Some species appear frequently such as water spinach, dandelion flower and water hyacinth (this is an invasive alien species).		Diversity. Species such as spinach, Sesbania flower, water lily, water coconut, and other river vegetables	
	Frequency of use	Sometimes		Frequently	

Note: Levels are classified into 5 levels, including 1 – Very little, 2 – Little, 3 – Moderate, 4 – high and 5 – Very high.

In addition to fish species, the riparian area also offers a number of edible wild plants that are mainly harvested during the flood season, such as morning glory, poppy, water lily, water hyacinth and other wild plants. However, the frequency of using this service has decreased significantly in recent years, due to the appearance of some invasive alien species such as water hyacinth in some river sections. In general, most of the variation in service delivery is due to poor water quality, namely the diffusion of pollutants, chemicals (pesticide), garbage, saline water (in the dry season). In which, saline water is the time factor affecting fresh water supply in Soc Trang and part of Vinh Long province. Several studies on water quality in the Hau River have demonstrated that water quality is lower than previously reported [4]. These negative changes have had an impact on the use of services provided related to the Hau River.

The Hau River flows through the Vietnamese Mekong Delta provinces and the flows has not been used for electricity generation. Furthermore, the use of other raw abiotic materials has been limited or no longer permitted (sand), as this has greatly affected the river's regulatory services, especially the river erosion control. While bottom mud, is often used to improve soil in agricultural cultivation and used as a raw material for leveling ground to make traffic routes [5]. From the above analysis, it shows that the services provided from the river have decreased a lot compared to before; This has contributed to limiting the benefits that the river can bring to people, typically people living along the river banks.

Figure 7. River fishing activities

3.3.2 Regulating services

Regulatory services play an important role in ecosystem survival and maintenance of basic biophysical processes, including climate regulation and water purification [6-8]. Therefore, the research team focused on surveying and discussing self-cleaning, flood regulation, water level, erosion and climate. In the Mekong Delta, most people tend to prefer to live along the riverside because of the cool climate and easy access to water, as an example in An Giang in Figure 8. As for sedimentation of alluvium, about 47.37% thought that the deposition of alluvium was high in the field (3 – 4 cm) in the past; however, sedimentation of alluvium have now been declined because of flow in the upstream disturbed. This is explained by the people because the water environment is very clear even during the flood season. In the period of 1979 - 1982, in the flood season, the suspended sediment content of the Mekong in the Hau River in Chau Doc was on average 250 g/m^3 and the Tien River in Tan Chau was 550 g/m^3. During the dry season, the concentration of suspended alluvium in the Tien and Hau rivers ranges from 30 to 80 g/m^3. During the period 2009 - 2015, in the flood season, the suspended sediment concentration in Chau Doc was nearly 200 g/m^3; in Tan Chau about 300 g/m^3. In the dry season, the suspended sediment concentration in Chau Doc and Tan Chau is about 30-80 g/m^3. Moreover, the Hau River in An Giang and Vinh Long sections is assessed by people as having more erosion than before [2,5].

The cause is thought to be due to the flow and the content of silt is relatively less than before (Table 3). Besides, sand mining also significantly changes river morphology in Can Tho area. According to information collected from the survey results, a few years ago the area near the dunes of Vinh Long province had sand mines mined with high frequency, this mining process lasted for several years. This is one of the reasons some households believe that landslides are more severe in recent years. The flow of water supplied to the operations is also affected by flow regulation, quantity and frequency (dam, water extraction, irrigation). Therefore, this may affect regulation services as well as support services, limiting the sedimentation in other areas [9].

Table 3. Alluvial deposition and transport in the river

Tiêu chí	Time	Very little	Little	Normal	High	Very high
Alluvial deposition	Present	27	35	46	6	0
	Proportion (%)	23.68	30.70	40.35	5.26	0.00
	In the past	0	23	31	54	6
	Proportion (%)	0.00	20.18	27.19	47.37	5.26
Transport	Present	11	64	18	20	1
	Proportion (%)	9.65	56.14	15.79	17.54	0.88
	In the past	11	1	9	74	19
	Proportion (%)	9.65	0.88	7.89	64.91	16.67

With a dense network of rivers and canals, accounting for 60% of the area and density of 0.62 km/km^2, the Mekong Delta has a great advantage in water transport; this has been confirmed by people in the past (accounting for more than 80% of the people surveyed). Even so, the use of this service has declined due to the developed and convenient foot traffic system. However, in Vinh Long, because the locality has a policy of developing cultural services based on the river; Therefore, the transportation by water increased compared to other survey areas.

Figure 8. Commodity trade and population distribution in An Giang province

3.3.3 Supporting services

Supporting services such as water and food are important for dwellers along the river in their daily activities and production. Supporting service from the Hau River can also be observed as sedimentation in the dune areas, because this service has an indispensable indirect role in maintaining and stabilizing the ecosystem of the river. The Hau River is known to provide nutrients, form soil, and restore many ecosystems. Nutrient availability in rivers is closely related to food webs at different nutrient levels. However, only about 50% of survey respondents are aware of support services, especially nutrient cycling and soil formation. In the Mekong Delta, the increase in nutrient supply after flooding is explained by farmers adding water to fields before rice cultivation so that nutrients can be added to the soil. Besides, this can also be used as a regulatory service for disease control.

In addition, Hau River has also created a lot of habitats for aquatic species, including humans. Specifically, the habitat of wild fish in Phu Tan, An Giang was recorded during the investigation (Figure 9). With favorable environmental characteristics, rich in food sources from plankton, Hau River is a feeding place and river environment for many freshwater fish species. According to the report of Lien et al. [10], Lien et al. [11], Quy et al. [12], the aquatic ecosystem in the river has 97 species of benthic, 106 species of protozoa, and 128 species. phytoplankton. Moreover, many households consider Hau River as "home" in the past. However, the living environment on the river is also considered to be narrower than before (about 72.81% of the total surveyed people) (Figure 10). The decline in regulatory services has contributed to negatively impacting support services on the Hau River.

Figure 9. Creating a natural habitat

The results of the analysis and survey show that support services can be affected by changes in flows, overexploitation of services provided and changes in climate such as temperature and precipitation. Overexploitation affects the biodiversity of the ecosystem, which plays a huge role in stabilizing, creating primary productivity, maintaining balance and stability in the ecosystem. Climate can directly affect support services in several ways including modulating surface hydrothermal conditions [1,6] that limit habitat of aquatic organisms. In addition, aquatic characteristics have also been shown to affect the productivity, sustainability and stability of ecosystem services in the studies by Zavaleta et al. [7] and Lavorel et al. [8].

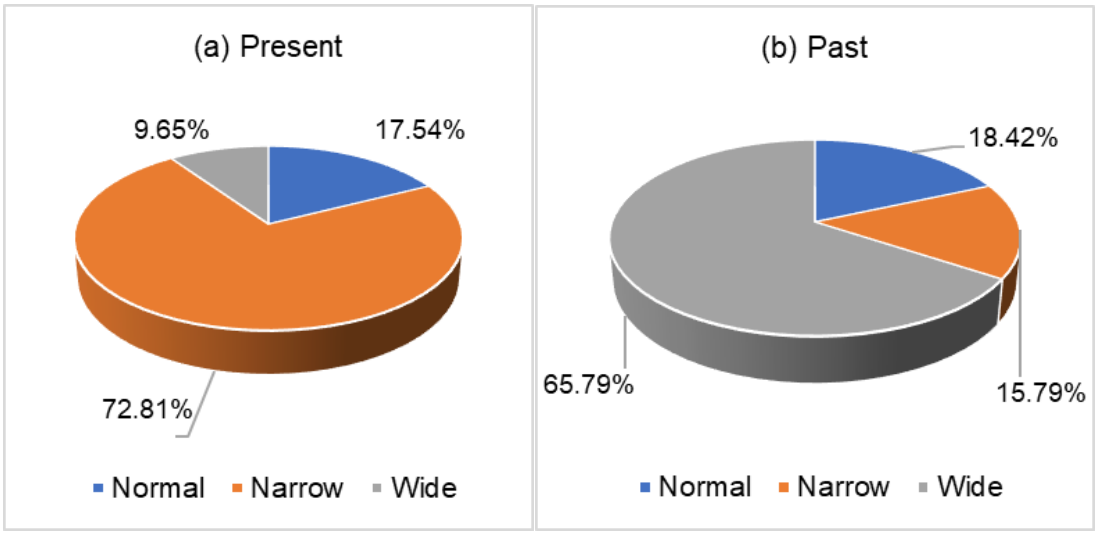

Figure 10. Changes in river environment characteristics on rivers

3.3.4 Cultural services

Cultural services are the most discussed of the service groups. Cultural services include recreational, educational, aesthetic and spiritual activities. Specifically, the study evaluated the cultural services of the Hau River through the indicators of entertainment, experience tourism, education, inspiration for art creation, symbolic species and valuable characteristics. attraction, social relationships thanks to the river, cultural activities, festivals, and beliefs (Table 5). All survey respondents considered the important role of integrating river activities in the Mekong Delta region. Among surveyed households, recreational activities on the river and river embankments or fishing activities, mud bathing and experiential tourism associated with Hau River are discussed as the main services when referring to current cultural services of the Hau River. About 85.96% of people said that they used the river as a recreational activity (swimming, fishing, canoeing, riverside coffee...). In addition, the use of the river to teach children to swim also accounts for 83.33% (Table 4). In addition, due to the characteristics of the topography of the river, the exchange and trade on the river was very busy in the past; this has created many social relationships thanks to the exchange on the river, about 49.12% of the surveyed people have had social relationships on the river. At present, the circulation and exchange of goods is more convenient than by road, so people have limited trade on the river. This has indirectly degraded this cultural service of the river.

For fishermen and people who work in the river industry, although they are not the ones who directly catch the fish, those who "take the boat as their home" and take the "river as their homeland", consider boats and boats as close friends. Therefore, people who go on boats and ships all have the same belief of worshiping the Water God, namely Ca Ong, Ba - Uncle, Quan Am Nam Hai ... to express their prayers for peace and good fishing (Figure 11).

Some of the religious activities and festivals, as well as the folk tales associated with the river, also gradually disappeared. Even so, residents also pointed out that low water quality and riverbank accessibility also affect the ability to use these cultural services. However, activities in cultural services can negatively affect the use of provisioning, regulatory and support services, especially the quality of water supplies. Therefore, an appropriate management plan for this service of the river is needed.

Figure 11. Religious activities and festivals on the river

Table 4. Value of cultural services provided by rivers in Hau River basin

Activities	Proportion (%)		Description
	Present	In the past	
Entertaining	43.86	85.96	Swimming, fishing, canoeing, riverside coffee...
Experiential travel	13.16	27.19	Mud bathing on the river, raising fish to visit, traveling by boat/ferry sightseeing on the river, visiting fruit gardens, eating, singing on the ferry.
Education	15.79	83.33	Teaching swimming, boating/boating, student research activities.
Inspiration in art creation	16.67	16.67	Some songs related to fishing tools and rivers such as Cham boating, My hometown's river, Ong Nuoc, The story of the river fork, On the Hau River, My hometown Luc Si Thanh, etc.
Iconic species and features of attractive value	42.98	64.91	Some species of flora and fauna on the river are appreciated by the people as having attractive value such as *Henicorhynchus lineatus*, *Pangasius krempfi*, *Catlocarpio siamensis*, *Platanista gangetica gangetica*, *Hampala macrolepidota*, *Systomus orphoides*, Sesbania flowers, etc.

Activities	Proportion (%)		Description
	Present	In the past	
Social relationships relating to the river	26.32	49.12	Create many new relationships between traders and farmers, neighbors on both sides of the river; - In the upstream area, people often have activities to release fish; - The annual festival of May 18 (lunar year) of Buddhists, formerly held a flower boat show to represent the old stories; - The ceremony to release the corvette is intended to dispel bad things, bad luck, and calamities in the past year and pray for a good new year. Nghinh Ong ceremony prays for peace, good weather; - Using the symbol of a folk story "Ma da" (local word) to educate children; - Boat racing festival is held every year on the river; - In fishing, carp species are often released because of the belief in prosperity, praying for the growth and development of the ancient Vietnamese; - The story of Ca Ong (also known as Ong Nuoc) about helping people when fishing in the river; - Fishermen and river goers have beliefs to worship Ca Ong, Ba Uncle, Ba Chua Xu, etc. to express their prayers for peace and productive fishing.
Cultural activities, festivals, beliefs	29.82	56.14	

4. Conclusion

The ecosystem services on the Hau River are diverse and play a very important role in the development of the whole Mekong Delta. It is the source of water and food for many of the region's activities. Hau River has directly and indirectly provided various regulation and support services, such as climate regulation, nutrient supply, etc. Moreover, this is considered the place where many festivals and beliefs activities take place on the river, featured with many eco-tourism activities and types of experiential tourism.

As can be seen that the roles of the river's services are very important for nature and human being. However, these services have been increasingly degraded by a variety of factors such as hydrological changes, quality, reduced water resources, and river-related development policies. In which, the change in water quality and quantity is one of the main causes leading to the change of ecosystem services on the river. Therefore, action plans on the restoration, protection and sustainable development of river ecosystem services are needed in the current period.

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