Impacts of Livelihood Activities on the Environment and Natural Resources of Can Gio Mangrove Forest, Ho Chi Minh City

Lam Vinh Son¹,²*, Nguyen Vu Phong¹, Ta Trung Kien¹, Nguyen Thi Phuong Chau², Le Thanh Hoa³,⁴, Vo Le Phu³,⁴*

¹HUTECH Institute of Applied Sciences, HUTECH University, Ho Chi Minh City, Vietnam
²Faculty of Geography, University of Social Sciences and Humanities – VNU HCM, Ho Chi Minh City, Vietnam
³Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology (HCMUT) 268 Ly Thuong Kiet street, District 10, Ho Chi Minh City, Vietnam
⁴Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam

*Corresponding authors: lv.son@hutech.edu.vn; volephu@hcmut.edu.vn

Abstract. In recent years, local livelihood activities in the Can Gio district have increased significantly, including aquaculture practices, aquaculture cultivation, salt-works, forest guard, farming, livestock, tourism, and etc. These livelihood activities have contributed remarkably to the local economy and the improvement of living conditions for local people. However, the burgeoning development of these activities have posed negative impacts on the mangrove ecosystem in Can Gio. In which, the use and exploitation of existing human and natural resources are paid inadequate attention. The purpose of this study is to identify livelihoods by conducting a survey with 536 questionnaire samples in both the buffer and transition zones in Can Gio Mangrove Forest. In addition, the quality of surface water sources was examined by collecting 70 surface water and wastewater samples. The results show that the quality of surface water meets the allowable limits of QCVN 08-MT:2015/BTNMT. The extent of the impact from livelihood activities on the environment of mangrove forest is at the medium level. However, the livelihood of aquaculture cultivation practices has the most affect on the environment and natural resources and is posing negative impacts on the quality of water sources in Can Gio Mangrove Forest. Therefore, these findings will be useful information for decision makers of the local authority in building an appropriate planning for aquaculture cultivation area. Further, irrigation and drainage systems for aquaculture practices need to be invested to control and handle wastes from aquaculture cultivation areas.

1. Introduction

Can Gio is a coastal district, located in the Southeastern area of Ho Chi Minh City, consisting of Can Thanh town and 6 villages namely Binh Khanh, An Thoi Dong, Ly Nho, Tam thon Hiep, Long Hoa, and Thanh An [1-3]. Can Gio Mangrove Forest was recognised as a World Biosphere Reserve Area by UNESCO in 2000. It plays a vital role in providing the local communities with specific livelihoods, including aquaculture practices, aquaculture cultivation, salt-works, farming, livestock, tourism, and etc. [4]. Over the past 20 years, the development and expansion of immigrants’ livelihoods, associated with
supporting policies of the local authority enabled residents to diversify livelihoods. These diverse livelihoods are attached to specific characteristics of the mangrove ecosystems and encompass onshore-offshore fishing, aquaculture cultivation (shrimp, crab, fish, and other aquatic products), salt-works, forest guarding, farming and livestocks, and tourism services [5-6]. However, these livelihoods have had adverse impacts on the environment and natural resources of Can Gio Mangrove Forest (CGMF). Therefore, zoning and assessing the impacts of livelihood activities on the mangrove environment is an imperative requirement to formulate measures for the management, use, and exploitation practices appropriately and sustain the existing natural resources in CGMF.

2. Study Area and Methods

2.1. Study area
The study area is Can Gio Mangrove Forest, Ho Chi Minh City, Vietnam, covers 3 zones that include core zone, buffer zone, and transition zone. This study examined the impacts of the following livelihood activities: aquaculture cultivation (shrimp farming, crab, fish, and other aquatic products), aquaculture practices, salt-works, farming and livestocks. The location of livelihood areas is depicted in Figure 1.

Figure 1. Administrative map and livelihood activities zones of Can Gio District

2.2. Methods

2.2.1. Site Investigation and Survey
There are 9,960 households with above-mentioned livelihoods in CGMF. About 536 out of 9960 households were surveyed and interviewed through a questionnaire set. These households depend on the following livelihoods: aquaculture cultivation (shrimp farming, crab, fish, and other aquatic
products), aquaculture practices, salt-works, farming and livestocks. Surveyed households were allocated randomly in buffer and transition zones. The number of households surveyed is inequally distributed depending on the concentration of these livelihood activities. The survey data was calculated by Yamane formula (1), with standard deviation 0.4% as below.

\[ n = \frac{N}{1 + N \left( \alpha^2 \right)} \]  

(1)

Where as, \( n \) is sampling size, \( N \) is total households attached with livelihoods in the study area, \( \alpha \) is standard error (%). In addition, 54 households were face-to-face interviewed as an additional qualitative information on existing practices of local livelihood activities.

2.2.2. Simple addition weight method – radar graphs

A multi-criteria approach was deployed by using the simple addition weight method. Collected data was converted from qualitative expression (%) with the extent of scale is very poor – poor – average – good – very good to quantitative expression scaling as impact level (extent) from 1 to 5 (corresponding as Non-impact – 5 points, minor impact – 4 points, medium impact – 3 points, considerable impact – 2 points, serious impact – 1 point). Average point of each impact level is calculated by the below formular (2).

\[ \text{Average point} = \frac{\sum m_i a_i}{\sum m_i} \]  

(2)

In which, \( m_i \) is the rate (%) of household’s livelihood corresponding to the scale (\( m_i = 0 – 100 \)); \( a_i \) is the value corresponding to the extent of scale (\( a_i = 1 – 5 \)). Then, total point of each impact level for each livelihood is calculated and aggregated to livelihood activities and affected entities corresponding impact level (extent) from 1 to 5. Calculated aggregate results are depicted by Radar graph to expressing the level of impact from each livelihood activity.

Further, aggregate data technique is deployed to aggregating similar information and data in the same group (homogeneity).

### Table 1. Types of livelihood activities in Can Gio district

| Non-aggregation information | Aggregate information |
|-----------------------------|-----------------------|
| 1 1. Shrimp farms/cultivation | Shrimp farming |
| 1.1. Fish cultivation | |
| 1.2. Floating fish cultivation (Cobia fish) | |
| 2.3. Fish farms (Pineapple fish, butterfish) | Fish, crab cultivation |
| 4. Crab cultivation | |
| 3.1. Oyster cultivation | |
| 3.2. Clam, shell cultivation | |
| 3.3. Shellfish cultivation | Other aquatic products cultivation |
| 3.4. Fishing pond cultivation | |
| 4.1. Aquaculture exploitation | |
| 4.2. Beding net fishing | Aquaculture exploitation |
| 4.3. Crab burrowing (catching) | |
| 4.4. Crabling | |
| 5.1. Salt making | Salt making |
| 6.1. Rice cultivation | |
| 6.2. Fruit trees cultivation (mango, custard apple) | Farming and livestocks |
| 6.3. Vegetables | |
| 6.4. Livestock / fowls | |
| 6.5. Swallow nests | |
2.2.3. Water Sampling and Analysis
A total of 35 wastewater samples and 35 surface water samples at receiving water bodies of wastewater discharging from aquaculture cultivation activities (shrimp, crab, fish, and other aquatic products) were analysed to assess the extent of impacts from livelihood activities on water environment. Water samples were collected in the dry and rainy seasons of 2020. Water sampling and storing were conducted in accordance with TCVN 6631-1:2011 and transported to the lab at HUTECH within 24 hours.

Table 2. Analysis methods for water quality parameters

| Parameter     | Analysis method/protocol                      | Permissible limits (B1) | Measurement and analysis instruments |
|---------------|-----------------------------------------------|-------------------------|-------------------------------------|
| pH            | TCVN 6492:2011 Water quality – pH             | 5.5 – 9                 | Model Seven Compact S220-K           |
| DO (mg/L)     | TCVN 7324:2004 Water quality – DO measurement, Electrode probe. | 4                      | Model Oxi 7310                      |
| BOD₅ (mg/L)   | TCVN 6001-2:2008 Water quality – Non-dilution protocol | 15                     | Model Oxi 7310                      |
| COD (mg/L)    | TCVN 6491:1999 Water quality – COD analysis  | 30                      | Elox portable meter                 |
| NH₄⁺-N (mg/L) | TCVN 6179-1:1996 Water quality – Spectrometer | 0.9                    | AmmoniTor                           |
| NO₂⁻-N (mg/L) | TCVN 6180:1996 Water quality – UV Vis         | 0.05                   | UV Vis 730                          |
| NO₃⁻-N (mg/L) | TCVN 6178:1996 Water quality – UV Vis         | 0.3                    | UV Vis 730                          |
| PO₄³⁻-P (mg/L)| TCVN 6202:2008 Water quality – UV Vis (amoni molipdate) | 6                      | UV Vis 730                          |
| TOC           | TCVN 6634:2000 Water quality – UV Vis (amoni molipdate) | 4 (A1)                | TOC Ultra                            |
| Colifrom (MPN)| TCVN 6187-2:1996 Water quality – Most probable number | 7500                  | Most probable number                |

The quality of surface water was compared with QCVN 02-19:2014/BNNPTNT – National Technical Regulation on Brackish Water Shrimp Culture Farm - Conditions for Veterinary Hygiene, Environmental Protection and Food Safety and QVCN 08-MT:2015/BTNMT – National Technical Regulation on Surface Water Quality. The quality of wastewater was compared with QCVN 40:2011/BTNMT – National Technical Regulation on Industrial Wastewater.

3. Results and discussion
3.1. The Situation of Livelihood Activities
Given the mangrove ecosystem characteristics, local people maintain traditional livelihood activities which play a crucial role in improving their living conditions, including aquaculture practices (shrimp, crab, fish, and other aquatic products cultivation), seafood and aquaculture exploitation, salt-making, farming and livestocks. Each household (corresponding to its livelihood) was surveyed and interviewed
by filling one questionnaire set. A total of 536 households was surveyed corresponding to existing livelihood activities, the distribution of different activities surveyed was presented in Table 3.

Table 3. Number and ratio of livelihoods surveyed

| Livelihoods                           | Number of households surveyed | Percentage of livelihoods surveyed (%) |
|---------------------------------------|------------------------------|----------------------------------------|
| 1 Shrimp farming                      | 124                          | 23.0                                   |
| 2 Fish, crab cultivation              | 40                           | 7.0                                    |
| 3 Other aquatic products cultivation  | 118                          | 22.0                                   |
| 4 Aquaculture exploitation            | 106                          | 20.0                                   |
| 5 Salt making                         | 105                          | 20.0                                   |
| 6 Farming and livestocks              | 43                           | 8.0                                    |
| **Total**                             | **536**                      | **100**                                |

Aquaculture cultivation is the highest livelihood activity, accounting for 52%, followed by salt-making and seafood and aquaculture exploitation, 20% for each. Meanwhile, farming and livestocks is the lowest proportion, contributing 8%.

**Figure 2.** Proportion of Livelihood Activities in Can Gio district

**Figure 3.** Aquaculture cultivation in CGMF

**Figure 4.** Aquaculture exploitation in CGMF
3.2. Impacts of Livelihood Activities on Water Quality

The extent of impact from each livelihood activity was calculated by addition weight analysis, an aggregation of impacts from livelihood activities on the quality of water sources in CGMF was depicted in Table 4 below.

| Water Quality Issue                      | Scale of extent | Shrimp farming | Fish, crab cultivation | Other aquatic cultivation | Aquaculture exploitation | Salt making | Farming and livestocks |
|------------------------------------------|-----------------|----------------|------------------------|--------------------------|--------------------------|-------------|------------------------|
| Water Quality – 10 years ago             | Very poor       | 0.04           | 0.00                   | 0.00                     | 0.00                     | 0.01        | 0.10                   |
|                                          | Poor            | 0.67           | 0.29                   | 0.15                     | 0.51                     | 0.46        | 0.05                   |
|                                          | Medium          | 0.56           | 0.50                   | 1.25                     | 1.24                     | 1.54        | 0.90                   |
|                                          | Good            | 1.45           | 1.70                   | 1.68                     | 1.65                     | 0.81        | 1.97                   |
|                                          | Very good       | 0.85           | 0.81                   | 0.22                     | 0.15                     | 0.17        | 0.06                   |
| **Total**                                |                 | **3.57**       | **3.30**               | **3.30**                 | **3.55**                 | **2.90**    | **3.08**               |
| Water Quality ¬-10 years recently        | Very poor       | 0.02           | 0.00                   | 0.00                     | 0.00                     | 0.00        | 0.06                   |
|                                          | Poor            | 0.51           | 0.41                   | 0.14                     | 0.34                     | 0.02        | 0.24                   |
|                                          | Medium          | 0.37           | 0.79                   | 0.37                     | 0.69                     | 1.00        | 1.51                   |
|                                          | Good            | 1.55           | 1.23                   | 2.00                     | 1.50                     | 1.57        | 1.23                   |
|                                          | Very good       | 1.20           | 0.69                   | 0.80                     | 0.65                     | 0.44        | 0.25                   |
| **Total**                                |                 | **3.65**       | **3.12**               | **3.31**                 | **3.18**                 | **3.03**    | **3.29**               |
Additionally, the quality of surface water at receiving water bodies was also identified by analysing 35 water samples collected at discharging sites of aquaculture cultivation practices (shrimp, crab, fish, and other aquatic products) in CGMF is presented in Table 5.

**Table 5. The quality of surface water at receiving water bodies of aquaculture practices**

| Sample Code | Coordinates          | BOD₅ | DO     | COD    | TOC   | NH₄⁺-N | PO₄³⁻ | NO₃⁻-N | NO₂⁻-N |
|-------------|----------------------|------|--------|--------|-------|--------|-------|--------|--------|
| NM1         | 10°38'09.8"N; 106°48'20.5"E | 8    | 5.21   | 15.0   | 6.25  | 0.184  | 0.010 | 3.67   | 0.012  |
| NM2         | 10°37'43.2"N; 106°47'11.4"E | 9    | 5.64   | 10.0   | 5.19  | 0.21   | 0.070 | 3.15   | 0.026  |
| NM3         | 10°37'34.5"N; 106°47'40.5"E | 4    | 5.38   | 12.0   | 5.26  | 0.146  | 0.060 | 3.20   | 0.013  |
| NM4         | 10°37'08.4"N; 106°47'20.4"E | 5    | 5.61   | 12.6   | 2.48  | 0.245  | 0.048 | 2.46   | 0.024  |
| NM5         | 10°37'12.8"N; 106°48'35.9"E | 10   | 5.45   | 14.7   | 5.26  | 0.289  | 0.150 | 2.35   | 0.017  |
| NM6         | 10°36'20.0"N; 106°49'09.7"E | 8    | 5.68   | 15.9   | 5.26  | 0.222  | 0.052 | 3.05   | 0.025  |
| NM7         | 10°35'04.5"N; 106°49'22.5"E | 6    | 5.92   | 8.5    | 3.47  | 0.192  | 0.060 | 2.95   | 0.012  |
| NM8         | 10°35'03.2"N; 106°48'23.6"E | 7    | 5.35   | 16.0   | 2.21  | 0.234  | 0.020 | 2.45   | 0.016  |
| NM9         | 10°35'29.0"N; 106°47'57.6"E | 9    | 6.08   | 16.8   | 2.57  | 0.215  | 0.057 | 3.28   | 0.012  |
| NM10        | 10°37'06.8"N; 106°50'49.4"E | 10   | 5.42   | 22.3   | 6.29  | 0.111  | 0.030 | 3.33   | 0.019  |
| NM11        | 10°37'07.0"N; 106°51'05.9"E | 9    | 5.62   | 15.4   | 6.24  | 0.128  | 0.030 | 2.24   | 0.023  |
| NM12        | 10°36'26.3"N; 106°51'42.9"E | 7    | 6.13   | 10.0   | 6.28  | 0.146  | 0.050 | 2.41   | 0.010  |
| NM13        | 10°36'08.1"N; 106°51'27.1"E | 14   | 6.08   | 16.8   | 6.28  | 0.134  | 0.010 | 2.05   | 0.021  |
| NM14        | 10°36'23.0"N; 106°51'14.4"E | 10   | 6.06   | 12.0   | 5.23  | 0.201  | 0.050 | 3.16   | 0.023  |
| NM15        | 10°35'15.8"N; 106°50'29.4"E | 6    | 5.29   | 10.6   | 2.48  | 0.167  | 0.013 | 3.82   | 0.012  |
| NM16        | 10°35'14.5"N; 106°50'08.8"E | 13   | 5.35   | 28.0   | 8.18  | 0.149  | 0.150 | 2.16   | 0.012  |
| NM17        | 10°35'03.9"N; 106°49'42.4"E | 8    | 5.24   | 14.0   | 2.18  | 0.182  | 0.100 | 3.05   | 0.024  |
| NM18        | 10°33'51.8"N; 106°48'38.1"E | 9    | 5.67   | 14.6   | 4.70  | 0.167  | 0.200 | 3.14   | 0.023  |
| NM19        | 10°23'50.8"N; 106°54'26.2"E | 9    | 5.88   | 13.6   | 2.28  | 0.165  | 0.050 | 3.26   | 0.031  |
| NM20        | 10°27'46.0"N; 106°46'24.6"E | 5    | 5.60   | 19.2   | 5.1   | 0.164  | 0.030 | 2.16   | 0.016  |
| NM21        | 10°28'07.3"N; 106°46'05.7"E | 7    | 5.27   | 25.6   | 2.18  | 0.142  | 0.020 | 2.22   | 0.018  |
| NM22        | 10°28'46.9"N; 106°45'42.6"E | 6    | 5.40   | 14.0   | 5.29  | 0.136  | 0.050 | 2.31   | 0.023  |
| NM23        | 10°27'48.3"N; 106°46'49.8"E | 4    | 5.17   | 8.2    | 4.64  | 0.227  | 0.080 | 3.61   | 0.020  |
| NM24        | 10°28'40.8"N; 106°46'27.2"E | 8    | 6.22   | 21.5   | 5.81  | 0.213  | 0.060 | 2.54   | 0.016  |
| NM25        | 10°28'51.6"N; 106°46'08.7"E | 8    | 5.64   | 20.6   | 2.18  | 0.152  | 0.06  | 2.31   | 0.02  |
| NM26        | 10°29'14.8"N; 106°45'57.6"E | 15   | 5.21   | 27.0   | 9.00  | 0.139  | 0.07  | 2.31   | 0.012  |
The results showed that the contents of DO, BOD₅, COD, NH₄⁺-N, NO₃⁻-N, NO₂⁻-N from most of water samples meet the allowable levels of surface water quality – QCVN 08-MT:2015/BTNMT (Class B1) and the quality of shrimp farming water – QCVN 02-19:2014/BNNPTNT (see Fig. 8 – 9). However, the concentration of total organic carbon (TOC) at the same sampling sites exceeds permissible limits of QCVN 08-MT:2015/BTNMT (> 4 mg/L) (Fig. 8). The content of PO₄³⁻-P at sampling site NM34 is the highest (0.45 mg/l) exceeding the permitted level of QCVN QCVN 08-MT:2015/BTNMT (with PO₄³⁻-P < 0.3 mg/L) (Fig. 9). This is caused by the fact that the sampling site at NM34 closes to many intensive and large shrimp farms which discharges a huge volume of organic wastes.

This result is similar to previous study conducted by Nguyen Van Trai and Momtaz (2006) on the assessment of water quality at shrimp farms of three communes, namely Binh Khanh, An Thoi Đong, and Long Hoa. Nguyen Van Trai and Momtaz (2006) claimed that the higher production of shrimp farming the worse water quality, in which COD was 1.51 times higher than the allowable limit of QCVN 08-MT:2015/BTNMT (B1). This caused by the decomposition of organic matter in shrimp ponds which consumed a great deal of oxygen content leading to the depletion of DO level.

Similarly, the content of NO₂⁻-N is 2.34 folders higher than permissible level of QCVN 08-MT:2015/BTNMT (B1) although the concentration of NH₄⁺-N at three sampling sites is lower than the permitted limit (< 0.5 mg/L). This condition of water quality coupled with increasing temperature and pH may poison aquatic ecosystems [7]. However, Swann (1997) suggested that the safe level of NH₄⁺-N for aquaculture cultivation should be less than 0.02 mg/L [8].
Figure 8. The Content of DO, BOD$_5$, COD and TOC from Surface Water at Receiving Water Bodies

![Graph showing the content of DO, BOD$_5$, COD, and TOC](image)

Figure 9. The content of NH$_4^+$-N, PO$_4^{3-}$-P, NO$_3^-$-N and NO$_2^-$-N from surface water at receiving water bodies of aquaculture cultivation practices

Importantly, direct and indirect impacts on the mangrove aquatic ecosystems are the causes for the spread of epidemic diseases and the reduction of aquacultural yields and incomes of local people [9-11]. Apart from shrimp farming, other aquacultural practices have been burgeoning recently such as oyster, clam, and shell cultivation, etc. with areas ranging 800 – 1000 ha [12]. However, these kinds of aquaculture cultivation are facing some barriers, including low production yield, low experience and techniques, and unstable incomes. Thus, the extent of impacts from these aquaculture practices is not considerable.

Figure 10. Site visit and investigation of livelihood activities in Can Gio Mangrove Forest

Further, 35 samples of wastewater from shrimp farms were collected to assess the quality of wastewater discharging into the receiving water bodies (Table 6). The results showed that most of samples has the contents of BOD$_5$, COD, NH$_4^+$-N, Total P meet the permissible limits of QCVN 40:2011/BTNMT (B1) (Fig.11). However, the content of Coliform in most of samples exceeds the allowable level of QCVN 40:2011/BTNMT (<5,000 MPN/100ml) and QCVN 02-19:2014/BNNPNTNT (Fig.12). The sampling site of NT19 has the highest Coliform content (27,384 MPN/100ml) owing to the high contents of organic matter from wastewater.
Figure 11. The content of BOD₅, COD, NH₄⁺-N and total P of wastewater samples from shrimp farms

The quality of surface water and wastewater from sampling sites suggested that the extent of impact from livelihood activities, in particularly in aquacultural practices, is minor impact. Nevertheless, the quality of water sources is likely threatened by aquacultural cultivation practices if the local government does not make a master plan for livelihood activities properly. In addition, farmers do not usually comply with adequate techniques for cultivation practices as regulated resulting in the degradation of surface water sources, increasing aquatic epidemic diseases, and leading the deterioration of the environments and mangrove ecosystems.

Table 6. The quality of wastewater from shrimp farms

| Sample Code | pH  | BOD₅ (mg/L) | COD (mg/L) | NH₄⁺-N (mg/L) | Total P (mg/L) | Coliform (MPN/100Ml) |
|-------------|-----|-------------|------------|---------------|----------------|---------------------|
| NT1         | 7.24| 16.80       | 50.60      | 0.190         | 3.65           | 14,436              |
| NT2         | 6.81| 13.25       | 48.70      | 0.067         | 1.78           | 20,244              |
| NT3         | 6.97| 27.60       | 52.80      | 0.150         | 0.69           | 24,360              |
| NT4         | 6.83| 18.50       | 48.13      | 0.100         | 0.90           | 6,702               |
| NT5         | 7.32| 16.01       | 62.70      | 0.059         | 1.04           | 20,634              |
| NT6         | 7.36| 22.70       | 55.12      | 0.250         | 1.09           | 15,402              |
| NT7         | 6.72| 12.40       | 46.20      | 0.071         | 2.17           | 20,463              |
| NT8         | 7.10| 16.60       | 53.80      | 0.250         | 2.00           | 26,583              |
| NT9         | 6.83| 20.40       | 46.14      | 0.106         | 0.61           | 27,384              |
| NT10        | 6.92| 13.87       | 37.00      | 0.062         | 0.32           | 18,753              |
| NT11        | 6.61| 17.06       | 56.30      | 0.167         | 0.21           | 17,205              |
| NT12        | 6.35| 11.48       | 47.10      | 0.055         | 1.23           | 13,158              |
| NT13        | 6.79| 44.17       | 48.20      | 0.145         | 0.99           | 5,256               |
| NT14        | 6.85| 36.01       | 56.80      | 0.422         | 1.67           | 8,907               |
| NT15        | 6.68| 12.80       | 50.70      | 0.146         | 1.13           | 6,693               |
| NT16        | 6.70| 51.20       | 80.00      | 1.146         | 4.20           | 11,334              |
| NT17        | 6.60| 49.23       | 64.30      | 0.122         | 0.77           | 5,592               |
| NT18        | 6.54| 57.17       | 77.00      | 0.263         | 3.89           | 23,223              |
| NT19        | 6.50| 15.16       | 48.00      | 0.219         | 0.45           | 16,353              |
| NT20        | 6.91| 43.80       | 42.68      | 0.052         | 0.78           | 20,157              |
| NT21        | 6.70| 35.60       | 42.17      | 0.122         | 0.56           | 17,166              |
NT22  6.48  42.30  62.01  0.164  0.54  17,244  
NT23  5.48  27.80  57.40  0.250  1.01  17,748  
NT24  6.65  36.61  65.20  0.066  1.24  19,836  
NT25  5.72  44.50  59.30  0.290  0.88  10,284  
NT26  6.85  61.01  85.00  0.371  3.56  6,804  
NT27  6.68  47.20  64.10  0.868  0.65  10,947  
NT28  6.82  31.62  61.80  1.179  2.78  9,801  
NT29  5.31  44.60  58.90  1.016  0.67  15,333  
NT30  5.43  49.20  58.40  0.860  0.99  15,702  
NT31  6.82  53.17  83.00  0.226  3.10  2,883  
NT32  6.84  30.08  60.10  0.400  1.47  7,371  
NT33  6.90  49.62  63.20  0.195  0.66  25,257  
NT34  6.78  42.84  47.20  0.256  0.79  14,283  
NT35  6.77  29.70  67.80  0.500  0.72  6,967  
QCVN  5.5 – 9  50  150  10  6  7,500  
40:2011/BTNMT

*Notes: NT is the coding of wastewater samples; QCVN 40:2011/BTNMT – National Technical Regulation on Industrial Wastewater.

![Graph](image.png)

**Figure 12.** The content of Coliform in wastewater samples from shrimp farms

### 3.3. Impact of Livelihood Activities on Food Sources and Aquatic Fauna Biodiversity

The extent of impacts from livelihood activities was calculated and analyzed by aggregation of addition weight factor of each livelihood type, an aggregation of impacts from livelihood activities on the diversity of food sources and aquatic fauna in Can Gio Mangrove Forest was presented in Table 7.
Table 7. Impacts of livelihood activities on the diversity of food sources and aquatic fauna

| Issues                                      | Scale of extent | Livelihood Activities |          |          |          |          |          |
|---------------------------------------------|-----------------|-----------------------|----------|----------|----------|----------|----------|
|                                              |                 | Shrimp farming        | Fish, crab cultivation | Other aquatic cultivation | Aquaculture exploitation | Salt making | Farming and livestocks |
| Natural food sources – 10 years ago         | Very poor       | 0.04                  | 0.00     | 0.00     | 0.00     | 0.03     | 0.29     |
|                                             | Poor            | 0.54                  | 0.34     | 0.02     | 0.20     | 0.25     | 0.13     |
|                                              | Medium          | 0.81                  | 0.40     | 1.42     | 1.50     | 2.30     | 0.50     |
|                                              | Good            | 1.55                  | 2.00     | 1.65     | 1.80     | 0.75     | 0.80     |
|                                              | Very good       | 0.51                  | 0.63     | 0.31     | 0.30     | 0.12     | 0.77     |
| **Total**                                   |                 | **3.45**              | **3.37** | **3.40** | **3.80** | **3.45** | **2.49** |
| Natural food sources – 10 years recently    | Very poor       | 0.01                  | 0.00     | 0.00     | 0.00     | 0.01     | 0.29     |
|                                              | Poor            | 0.43                  | 0.45     | 0.20     | 0.13     | 0.04     | 0.19     |
|                                              | Medium          | 0.6                   | 0.87     | 0.62     | 1.04     | 1.51     | 1.44     |
|                                              | Good            | 1.42                  | 1.40     | 1.60     | 1.98     | 1.25     | 0.71     |
|                                              | Very good       | 0.64                  | 0.68     | 0.78     | 0.45     | 0.21     | 0.35     |
| **Total**                                   |                 | **3.10**              | **3.40** | **3.20** | **3.60** | **3.02** | **2.98** |
| Diversity of aquatic fauna – 10 years ago   | Very poor       | 0.07                  | 0.00     | 0.00     | 0.00     | 0.00     | 0.27     |
|                                              | Poor            | 0.37                  | 0.45     | 0.12     | 0.37     | 0.36     | 0.13     |
|                                              | Medium          | 1.35                  | 0.78     | 1.43     | 1.30     | 1.97     | 0.46     |
|                                              | Good            | 0.85                  | 1.35     | 1.70     | 1.71     | 0.72     | 0.64     |
|                                              | Very good       | 0.65                  | 0.62     | 0.05     | 0.05     | 0.36     | 0.50     |
| **Total**                                   |                 | **3.29**              | **3.20** | **3.30** | **3.43** | **3.41** | **2.00** |
| Diversity of aquatic fauna – 10 years recently | Very poor   | 0.01                  | 0.00     | 0.00     | 0.04     | 0.00     | 0.29     |
|                                              | Poor            | 0.40                  | 0.45     | 0.12     | 0.31     | 0.06     | 0.60     |
|                                              | Medium          | 1.07                  | 1.64     | 1.05     | 0.74     | 1.41     | 0.82     |
|                                              | Good            | 0.90                  | 0.7      | 1.49     | 2.11     | 1.43     | 0.45     |
|                                              | Very good       | 0.67                  | 0.62     | 0.66     | 0.70     | 0.10     | 0.14     |
| **Total**                                   |                 | **3.05**              | **3.41** | **3.32** | **3.90** | **3.00** | **2.30** |
Livelihood activities also influence the natural food chain and the biodiversity of aquatic fauna at medium level (Fig. 13 and 14). In fact, aquaculture resources are declining not only due to an over-exploitation of crowded local fishing farmers but also fishermen from neighbouring provinces of Long An and Tien Giang at the same fishing ground of Can Gio district [5, 13-14]. This is similar to the same findings reported by previous studies by Pham Van Tuan et al. (2019), in which aquaculture cultivation and fishing imposed negative impacts on the environment and ecosystems of the mangrove forest [14] as summarised in Table 8.

### Table 8. Impacts of different fishing exploitation on the aquaculture resources

| Livelihoods            | Impacts on aquaculture resources                                                                 | Aquaculture/ Fishing equipment                                                                 |
|------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Net fishing            | Negative impacts, harming and exterminating coastal aquaculture resources and damaging bedding ecosystems, etc. | Very small mesh size, 15 – 30 mm (catching small fish, accounting 25 – 40% of production)       |
| Pa kua fishing         | Exacerbating adjacent fish pollution mining due to over-exploitation of fish at immature stage   | Small mesh size, 15 – 20 mm (catching more small and immature fish)                             |
| Te xiep fishing        | Posing considerable impacts on shrimp, prawn, and aquatic species                                | Very small mesh size ranging from 10 mm to 15 mm, which attached with small boats or vessels. This kind of fishing equipment is so-called te xiep locally. |
| Beding net fishing     | This is a kind of exterminate fishing which was forbidden by Ministry of Agriculture and Rural Development (MARD). This destroys spawns, larvae, and aquatic ecosystems. |                                                                                                 |

3.4. Impacts of Livelihood Activities on Mangrove Landscape and Alluvial Grounds

The extent of impacts from livelihood activities was calculated and analysed by aggregation of addition weight factor of each livelihood type, an aggregation of impacts from livelihood activities on the landscape of mangrove forest and alluvial grounds in Can Gio Mangrove Forest was depicted in Table 9 below.

### Table 9. Impacts of livelihood activities on mangrove landscape and alluvial grounds

| Issues                        | Extent of Scale | Shrimp farming | Fish, crab cultivation | Other aquatic cultivation | Aquaculture exploitation | Salt making | Farming and livestocks |
|-------------------------------|-----------------|----------------|------------------------|--------------------------|--------------------------|-------------|------------------------|
| Mangrove landscape – 10 years ago | Very poor       | 0.03           | 0.05                   | 0.00                     | 0.00                     | 0.01        | 0.14                   |
|                               | Poor            | 0.15           | 0.10                   | 0.00                     | 0.03                     | 0.04        | 0.05                   |
|                               | Medium          | 1.50           | 0.67                   | 1.04                     | 0.75                     | 1.23        | 0.73                   |
|                               | Good            | 1.31           | 2.25                   | 2.19                     | 1.52                     | 2.14        | 1.23                   |
|                               | Very good       | 0.81           | 0.56                   | 0.27                     | 0.90                     | 0.11        | 0.75                   |
| Total                         |                 | **3.80**       | **3.63**               | **3.50**                 | **3.20**                 | **3.53**    | **2.90**               |
| Mangrove landscape            | Very poor       | 0.00           | 0.00                   | 0.00                     | 0.00                     | 0.01        | 0.12                   |
|                               | Poor            | 0.18           | 0.12                   | 0.02                     | 0.03                     | 0.12        | 0.23                   |
Table 1. Impact of aquaculture cultivation activities on mangrove-poor landscape

| Level of Mangrove Coverage | 10 years ago | Currently |
|---------------------------|-------------|-----------|
| Very poor                | 0.00        | 0.00      |
| Poor                      | 0.15        | 0.09      |
| Medium                    | 1.11        | 1.36      |
| Good                      | 1.37        | 1.75      |
| Very good                 | 1.05        | 0.40      |
| **Total**                 | **3.68**    | **3.60**  |

The livelihoods of agriculture cultivation and practices have posed direct impacts on the coverage of mangrove and the landscape of alluvial grounds, but at the minor level (level 4). In parallel with an increase in aquaculture production, the area of aquaculture practices and changes in land use were also expanded. The shift of mangrove areas to aquaculture cultivation areas is a major cause for the diminution of landscape and area of mangrove forest. Phan Nguyen Hong (2000) argued that “the area of mangrove forests in Vietnam was declined sharply from 400,000 ha in 1940 to 150,000 ha at present; just one-third of the original mangrove area, mainly re-forested and secondary mangrove forests” [9]. The loss of mangrove forest was due to land use changes in aquaculture practices, including intensive cultivation, semi-intensive farms, and extensive farming [4, 15]. Aquacultural practices deteriorated aquatic ecosystems and plankton species, and deprived living conditions of reptile, avian [3-4, 16]. These adverse impacts were addressed in previous studies on the construction of mega farms for aquacultural practices along the coastline and estuaries [9-10]. Phan Nguyen Hong (2000) and Nguyen Van Trai and Momtaz (2006) claimed that these engineering aquaculture cultivation practices declined areas for tidal exchange and allocation. Particularly, high tides coupled with northeast winds induce intrusion of seawater into further land causing salt intrusion.
3.5. Aggregated Impacts of Livelihood Activities on the Environments of Can Gio Mangrove Forest

The extent of impacts from livelihood activities was calculated and analysed by aggregation of addition weight factor of each livelihood type, an integrated impacts from livelihood activities on water environment; food sources and biodiversity of aquatic fauna; landscape of mangrove forest and alluvial grounds in Can Gio Mangrove Forest was presented in Table 10.

Table 10. Integrated impacts of livelihood activities on Can Gio Mangrove Forest

| Issue                  | Livelihood Activities     |
|------------------------|---------------------------|
|                        | Shrimp farming            | Fish, crab cultivation | Other aquatic cultivation | Aquaculture exploitation | Salt making | Farming and livestocks |
| Integrated impacts – 10 years ago | 3.464                    | 3.222                   | 3.362                      | 3.523                   | 3.221       | 2.616                   |
| Integrated impacts – 10 years recently | 3.469                    | 3.265                   | 3.374                      | 3.471                   | 3.048       | 2.647                   |

Figure 17. Integrated Impacts of Livelihood Activities on Can Gio Mangrove Forest

Integrated impacts of livelihood activities are described in Figure 17. Generally, the extent of integrated impacts is medium level (ranging from 3 to 4). However, the livelihood of aquaculture cultivation is posing negative impacts on the quality of water sources of Can Gio Mangrove Forest (CGMF).

4. Conclusion

Can Gio Mangrove Forest, a coastal district of Ho Chi Minh City, has been burgeoning over the past 20 years with many aquacultural practices. However, the lack of planning for cultivation areas has resulted in a crowded development of aquacultural cultivation practices (shrimp farming, crab, fish, and other aquatic products) both the scale and area of cultivation. This has posed an unstable condition on water environment and exacerbated the quality of surface water at receiving water bodies. The contents of phosphorus (PO₄³⁻), total organic carbon (TOC) and Coliform from wastewater exceed the allowable limits of water sources for aquaculture cultivation.
The livelihood activity of aquacultural practices (shrimp farming, crab, fish, and other aquatic products) has a minor impact (level 4), though this is the highest proportion of livelihood activities in Can Gio (over the past 20 years). Nevertheless, this kind of livelihood activity is posing negative impacts on water environment. Therefore, an appropriate planning for aquaculture cultivation area is an imperative. Further, irrigation and drainage systems for aquaculture practices need to be invested to control and handle wastes from aquaculture cultivation areas.

**Acknowledgement**

We acknowledge the support of time and facilities from Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

**References**

[1] UNESCO/MAB 2000 Valuation of the Mangrove Ecosystem in Can Gio Mangrove Biosphere Reserve Vietnam. Final report, Hanoi Vietnam.

[2] Vien Ngoc Nam Le Van Sinh Miyagi T Baba S Chan T H An 2014 Overview of Can Gio District and Mangrove Biosphere Reserve. ISME Mangrove Ecosystem Technical Report No.6.

[3] Vo Quoc Tuan and Kuenzer C 2012 Can Gio Mangrove Biosphere Reserve Evaluation 2012 Final report of UNESCO/MAB Project implemented by the Vietnam MAB National Committee.

[4] Clough B 2013 Continuing the journey amongst mangroves ISME Mangrove Educational Book Series No 1 International Society for Mangrove Ecosystems (ISME) Okinawa Japan and International Tropical Timber Organization (ITTO) Yokohama Japan.

[5] Ngo Thi Phuong Lan 2016 Livelihood Activities in Can Gio, Ho Chi Minh City: An Interaction of Political and Market Factors *Science and Technology Development Journal* 19(X3) 95-113 (in Vietnamese).

[6] Nguyen Dang Hiep Pho An 2016 Approach to Sustainable Livelihood Framework of DFID in Assessing the Livelihood Activity of Ma ethnic in Cat Tien National Park *Journal of Science Development – Dong Nai University* 2 101-112 (in Vietnamese).

[7] Boyd C E and Tucker C S 1992 Water quality and pond soil analysis for aquaculture 173-176

[8] Swann L 1997 *A fish farmer’s guide to understanding water quality*

[9] Phan Nguyen Hong 2000 Effects of mangrove restoration and conservation on the biodiversity and environment in Can Gio District *Mangrove Management and Conservation Workshop 21st May 2000 Okinawa Japan* 111-137

[10] Nguyen Van Trai and Momtaz S 2006 Water pollution concerns in shrimp farming in Vietnam: A case study of Can Gio, Ho Chi Minh *City International Journal of Environmental, Cultural, Economic & Social Sustainability* 3(2) 129-137

[11] Le Manh Tan 2006 Assessment of impacts on water quality of shrimp farming in Can Gio *Science and Technology Development Journal* 9(4) 77-84 (in Vietnamese).

[12] Nguyen Van Trai 2008 The Influences of Shrimp Farming and Fishing Practices on Natural Fish Conservation in Can Gio Ho Chi Minh City Vietnam (PhD Thesis) University of Newcastle, Australia.

[13] Nguyen Van Trai 2016 Small-scale of fishing, managing and conserving aquaculture resources in Can gio, Ho Chi Minh City *Journal of Agriculture and Development* 2 353-361 (in Vietnamese).

[14] Pham Van Tuan 2019 Impacts of some aquaculture practices on aquaculture resources *National Forum on Biology and Sustainable Development* Hai Phong 70 – 79 (in Vietnamese).

[15] White A T and Cruz Trinidad A 1998 Values of Philippine coastal resources: Why protection and management are critical *Coastal Resource Management Project* Cebu city, Philippines, 96 p.

[16] Hamilton S E and Collins S 2013 Livelihood responses to mangrove deforestation in the northern provinces of Ecuador *Bosque* 34(2) 143-153.