Science on Natural Resources and Environment
Journal homepage: hunre.edu.vn/hre/d16216

COMMUNITY - BASED HAZARD IDENTIFICATION ON AQUACULTURE OF THE NORTHERN COASTAL AREA, VIETNAM

Nguyen Xuan Trinh, Nguyen Thanh Tung, Lai Thi Thuy, Do Hong Van, Pham Khanh Chi
Vietnam Institute of Fisheries Economics and Planning,
Ministry of Agriculture and Rural Development

Received 18 September 2018; Accepted 20 November 2018

Abstract

This study focuses on identifying natural hazards affecting aquaculture using Rapid Rural Appraisal (RRA) and community surveys in the Northern coastal area of Vietnam. Analytic Hierarchy Process (AHP) method was then applied to calculate the weight of single hazards affecting aquaculture. The community based approach also provides information from a stakeholder and farmers' experiences about the hazards of seasonal aquaculture. The results identify that the total of single hazards for cage, clam and white - leg shrimp aquaculture are 6,6 and 7 respectively. The weights of single hazards identified in this study are the initial results for quantifying risk indicator and loss assessment in aquaculture.

Key words: Community; RRA; AHP; Aquaculture; Hazard.

Corresponding author. Email: nguyenxuantrinh2003@yahoo.com

1. Introduction

In the last 10 years, natural disasters have caused approximately 760 deaths of missing people every year. Particularly, in 2017, it caused the property loss of 60,000 billion VND, equivalent to 1.2% of GDP. According to the statistics of Central Steering Committee for Natural Disaster Prevention and Control, about 49,800 ha of aquaculture in 2016 and 5,500 ha of aquaculture in 2015 were affected by natural disasters nationwide. Aquaculture is one of the specialized production areas, which are highly dependent on natural conditions (e.g. climate, water environment, soil) and are difficult to be managed (as aquatic species live in water). Therefore, the level of risk in aquaculture is greater than that in other agricultural sectors. In addition to the risks easy to be recognized (such as storms, floods, salt intrusion, etc.), there are potential risks within the sector itself. For example, a prolonged period of hot weather and sudden rain alter the water environment, which results in the increasing amount of alum in the soil of the area.

Hazard Risk Management provides policies and strategies that aim to mitigate risks, prevent new disaster risks, reduce existing ones and manage the remaining risks in order to strengthen the resilience and reduce loss. In Vietnam, the State has issued supporting mechanisms and policies to reduce and share risks in aquaculture such as Decision No. 49/2012/QD-TTg (amended from Decision No. 42/2009/

QD-TTg) on assistance in the form of plant seeds and seedlings, breed animals and aquatic organisms for restoration of production in areas suffering damage from natural disasters or epidemics; or Decision No. 315/QD-TTg on the pilot provision of agricultural insurance during 2011 - 2013, including fisheries sector,... However, these policies are either ineffective or unfeasible. After three years of pilot implementation, the rate of loss in fisheries insurance was more than 300%. Besides the insurance, sharing disaster risks also faces the lack of specific regulations and sanctions on the integration of natural disaster prevention and control into socio - economic development plans. In addition, policies on disaster risk sharing are no longer suitable with the development and there is lack of researches which set the foundation for proposing solutions to risk management; in which the role of the State, community and members of the seafood chain has not been clearly defined.

This article aims to identify natural disasters including single and multiple natural disasters. The research team uses the method of identifying disaster risks based on the knowledge and experience of the local people in combination with the Analytic Hierarchy Process (AHP) method to obtain the relative weight of the risks. Results of the study will provide a theoretical basis for identifying types of natural disaster risks and assessing damages in aquaculture to quantify disaster risk indicators and integrate solutions towards stable and sustainable development in order to create a solution for the effective disaster risk management.

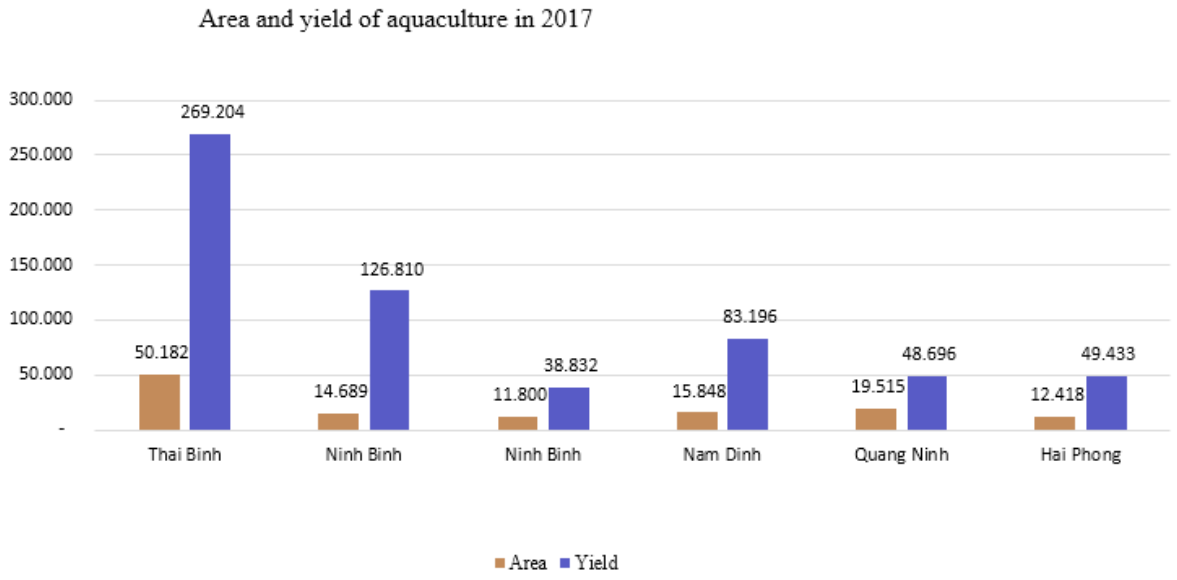

Figure 1: Area and yield of aquaculture in the northern coastal provinces in 2017

2. Methodology

2.1. Study area

The study area consists of coastal districts in 5 provinces of Quang Ninh, Hai Phong, Thai Binh, Nam Dinh and Ninh Binh. This area is the mountainous terrain interspersed with plain or the low and flat valley. It slopes from the Northwest to the Southeast, has the large sea area with many lagoons favourable for aquaculture development. This area has the monsoon tropical climate all year round, with four distinct seasons: spring, summer, autumn and winter. The annual average temperature is about 25°C. In the past 50 years, the temperature in the Northeast

has increased by an average of 0,6°C, in which the temperature mainly increases in January and July. Annually, this area is influenced by the Northeast monsoon and Southeast monsoon, the average precipitation is from 1,700 to 2,400 mm. The Northern area is often affected by bad weather; an average of 6 to 10 storms and tropical low pressure occur every year, which causes floods, directly threatening to life and agriculture of the whole area. Most storms with the strongest intensity often occur in the Tonkin Gulf, especially from Quang Ninh to Ninh Binh.

The natural conditions of this area are suitable for developing diverse forms of aquaculture including open sea areas, islands, estuaries and submerged areas. The main species are white-leg shrimp, marine fish, mollusk, and seaweed. The common farming methods are extensive, improved extensive, intensive and semi-intensive.

2.2. Community approach

Identifying disaster risks based on people's perception/assessment of natural disaster risks; determining the impact of natural disaster risks and the extent of damage caused by natural disasters to aquaculture.

- Identifying the location of aquaculture area, crops of cultured species; techniques to cope with natural disaster risks,…

- Collecting knowledge of farmers about natural disasters, crops, frequency and intensity of natural disasters (single disasters such as precipitation, temperature, cold weather, salt intrusion, hoar frost, storms, flood,… and multiple disasters such as hot weather accompanied by rain, storm accompanied by heavy rain, rain accompanied by flood,…) and assessing the negative impact on aquaculture (increasing diseases, reducing productivity, suffering crop failure, affecting facilities of aquaculture area). That is the basis for assessing the extent of damage caused by disaster risks to aquaculture.

Commune selection for a survey: Communes are selected based on their natural conditions, terrain, environment, features of natural disasters, typical cultured methods and species including:

- Van Ninh commune - Mong Cai town - Quang Ninh province: white - leg shrimp, aquaculture model along - dyke

- Dai Hop commune - Kien Thuy district - Hai Phong province: culturing clam in tidal flats.

- Cat Hai town - Cat Hai district - Hai Phong province: rearing fish cage around the island

Each group of the stakeholder about 10 - 12 people including both male and female of different age and ethnic.

2.3. Analytic Hierarchy Process (AHP) application

The results are processed through the AHP method. Assuming that there is x_n disasters need to be determined, a hypothetical matrix is created as below:

$$\begin{array}{c} \\ x1 \\ x2 \\ \cdots \\ xn \end{array} \begin{array}{c} \begin{array}{cccc} x1 & x2 & \ldots & xn \end{array} \\ \begin{bmatrix} a11 & a12 & \ldots & a1n \\ a12 & a22 & \ldots & a2n \\ \ldots & \ldots & \ldots & \ldots \\ an1 & an2 & \ldots & an3 \end{bmatrix} \end{array}$$

The weight is calculated for the different criteria and the AHP starts creating a pairwise comparison matrix. Then weight is always normalized so that the sum of components is equal to 1.

a_{ij}: the level of assessment between the i and j indicators; a_{ij} indicator is determined by local people directly involved in aquaculture.

The coefficient of the matrix is analyzed to calculate the weight (w_{ij}) of the evaluation criteria:

$$W_{ij} = \frac{aij}{\sum_{i=1}^{n} aij} \quad (1)$$

n: number of natural disasters affecting aquaculture is determined by local people.

Table 1. The relational RI scale proposed by Saaty

N	**1**	**2**	**3**	**4**	**5**
RI	0,00	0,00	0,058	0,90	1,12
N	**6**	**7**	**8**	**9**	**10**
RI	1,24	1,32	1,45	1,49	1,51

The consistency of priority factors is tested by the consistency ratio (CR), the ratio of the random consistency index (RI) and the consistency index (CI). The weight of the parameters meets the requirement if CR is less than 10%. If CR is more than 10%, the estimate is random and the re-evaluation is required.

$$CR = \frac{CI}{RI} \quad (2)$$

The consistency index is defined as follows:

$$CI = \frac{\lambda \max - n}{n-1} \quad (3)$$

λ_{max} is defined as follows:

$$\lambda_{max} = \frac{\sum_{j-1}^{n} aij.wj}{wi} \quad (4)$$

3. Results and discussion

3.1. Hazard risk in aquaculture season

- **Shrimp aquaculture**

Based on the results of the interviews and available materials, the research team identified crops by each stage and determining the occurrence time of natural disasters:

Table 2. Hazard identification for Shrimp aquaculture in Van Ninh commune - Mong Cai city

Stages	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
White - leg shrimp aquaculture												
Pond preparation												
Stocking												
Caring												
Harvest												
Disease												
Natural hazards												
High temperature												
Extreme cold												
Storm and tropical low pressure												
Heavy rain												
High temperature & heavy rain consecutiveness												
Heavy rain and High temperature consecutiveness												
Storm with heavy rain												

Source: Survey data of TTTV&QHT, 2017

Commonly, The first shrimp season of the year starts from early April to Jun, and another from August to October, the breeding time is 3 months. The shrimp pond bottom is covered with a big water - resistant fabric. The pond has the area of 2000 m^2 to 4000 m^2 and the average water depth of 1,3 m. The lowest water level is 1 m and the highest level is 1,6 m.

The initial results indicate that this area is usually suffered by such natural disasters as hot weather, heavy rain, storm and tropical low pressure, extreme cold and other multiple disasters like hot weather accompanied by rain, rain accompanied by hot weather, storm accompanied by heavy rain,… The hot weather occurs from May to July, this is the beginning time of the first shrimp crop. Heavy rain occurs from June to October, this is the end of the first shrimp crop and the beginning time of the second one. Storm and tropical low pressure occur from July to October, this is the culturing time of the second shrimp crop. Multiple disasters often occur during the first shrimp crop.

- **Clam aquaculture**

Table 3. Hazard identification for clam aquaculture in Dai Hop commune, Kien Thuy district

Stages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clam culture												
Preparation												
Stocking												
Caring												
Harvest												
Disease												
Natural hazards												
Heavy rain												
Storm and tropical low pressure												
High temperature												
Extreme cold												
Wind from the South												
Salt intrusion												

Source: Survey data of TTTV&QHT, 2017

Normally, the stocking time of a clam crop is from April to May and the breeding time lasts 1 year. Heavy rain often lasts from June until October every year, this is the time when farmers finish stocking. According to the record of local people, natural disasters affecting aquaculture include single and multiple natural disasters such as a prolonged period of heavy rain, hot weather, storm and tropical low pressure, extreme cold, wind from the south, hoar frost and rain accompanied by extreme cold. The extreme cold often occurs from November this year to February next year seriously affecting cultured species. Heavy rain often occurs from June to October and wind from the south often appears from May to July. Rain accompanied by extreme cold often occurs from November this year to February next year.

- **Cage aquaculture**

Cage aquaculture is common in the Northern area, mainly in close gulfs, some parts of islands and open sea areas. Main fish species are grouper, cobia,

greater amberjack, marine crap, red sparidae, Hong My fish, sea bass, mullet, rabbitfish, yellowfin pomfret,… Main mollusk species are babylonia areolata, blood cockle, otter clam, oyster in estuary areas, Pacific oyster, clam,…in which blood cockle, oyster and otter clam are reared in Quang Ninh and Hai Phong. Clam is reared in the middle and low tide areas with the sand area accounting for 70 - 80%, the salinity stabling at 10 - 30‰, the drying time from 4 - 6 hours/day. The stocking season is from April to May and September to October every year, the breeding time lasts 18 - 20 months.

Normally, the stocking time of a clam crop is from April to May and the breeding time lasts 1 year. Heavy rain often lasts from June until October every year, this is the time when farmers finish stocking. Storm often occurs from June to September, seriously affecting clam area especially in open sea areas. In those areas, the highest water level caused by storm is 3.5 m, the storm intensity is recorded at level 15 and level 16, the highest speed of wind is 50 - 60 m/s. If storm occurs during high tide, the water level will climb up to 5.5 - 6 m. The extreme cold often occurs from December this year to February next year, seriously affecting clam culture.

Table 4. Hazard identification for cage aquaculture in Cat Ba town, Cat Hai district

Stages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Duration of Fish cage aquaculture												
Preparation												
Stocking												
Caring												
Harvest												
Natural hazards												
Heavy rain												
Storm and tropical low pressure												
Hot weather												
Extreme cold												
Wind from the South												
Rain with extreme cold												

Source: Survey data of TTTV&QHTS, 2017

3.2. Weight of hazard for aquaculture

Natural hazards were identified by aquaculture farmer's discussion in group and they were then instructed to create pairwise comparison matrix with the following scale of important factors:

Basing on equation (1) for weight factor calculation and equation (2), (3) for checking reciprocal matrix validation, the results of weight factors of hazards to aquaculture is determined as follows:

For commercial white-leg shrimp, the disaster having the highest weight of 0.496 is rain accompanied by hot weather; the weight of hot weather accompanied by rain, heavy rain, hot weather, storm accompanied by heavy rain, extreme cold, storm and tropical low pressure is 0.151; 0.107; 0.091; 0.061; 0.050; 0.044 respectively. The above data shows that multiple disasters cause the greatest impact on commercial shrimp culture. Cultured species are quite sensitive to the sudden change of their habitat caused by disasters, especially disasters that occur at the same time as it causes difficulties for short and long - term forecast.

Rain changes the pH, dissolved oxygen, temperature, alkalinity; causing high density of algae, stratification within ponds, the movement of shrimp to muddy areas; disease and death of shrimp. The hot weather that appears right after rain destroys the ecological environment within ponds as well as creates favourable conditions for strong growth of algae and virus, which makes the shrimp die quicker with a large quantity.

If the hot weather occurs first, farmers can actively supply more water to the pond, decrease the amount of feed and apply other applicable solutions to reduce the impact. Rain occuring after hot weather often lasts for a short time; therefore, its impact on cultured species is considered at lower level.

As aquaculture ponds are often located inside the dyke, the airtight area, the extent of damage caused by storm and tropical low pressure to aquaculture ponds is low.

Scale	Numerical rating	Reciprocal
Extremely importance	9	1/9
Very to extremely strongly importance	8	1/8
Very strongly importance	7	1/7
Strongly to very strongly importance	6	1/6
Strongly importance	5	1/5
Moderately to strongly importance	4	1/4
Moderately importance	3	1/3
Equally to moderately importance	2	1/2
Equally importance	1	1

AHP: Analytic hierarchy process

Sourse: Saaty's pair-wise comparison

Table 5. The weight of disaster risks for white - leg shrimp culture

Disaster	Weight
Heavy rain	0.107
High temperature	0.091
Storm and tropical low pressure	0.044
Hight temperature and heavy rain consecutiveness	0.151
Heavy rain and High temperature consecutiveness	0.496
Storm with heavy rain	0.061
Extreme cold	0.050
Total	1

Parameter	Value
The value of the matrix (λ_{max})	7.47
Number of factors (n)	7
Consistency Index (CI)	0.078
Random consistency Index (RI)	1.32
Consistency ratio (CR)	0.059

The results in Tab. 6 interpret the weight of disasters affecting fish cage culture at sea. Accordingly, the disaster having the highest weight of 0.310 is a storm and tropical low pressure; the weight of rain, extreme cold, salt intrusion, hot weather, wind from the south is 0.270; 0.209; 0.085; 0.078 and 0.049 respectively. This demonstrates that storm and tropical low pressure, heavy rain and extreme cold cause the greatest impact on cage culture at sea as the rearing area is the coastal and estuarine areas around islands where have no obstacles, high tide and are easy to be suffered by storms and the rain from the upstream which sweetens the coastal areas.

The results in Tab. 7 indicated that both single and multiple disasters affect the clam culture in tidal flats, in which the disaster has the highest weight of 0.372 is storm and tropical low pressure; the weight of heavy rain, extreme cold, rain accompanied by extreme cold, hot weather, wind from the south is 0.114; 0.133; 0.214; 0.082 and 0.085 respectively. Accordingly, disasters greatly affecting clam culture in tidal flats are storms and tropical low

pressure, heavy rain, extreme cold, rain accompanied by extreme cold. Storm and tropical low pressure bring about high sea waves. The amplitude of the sea level in this area is quite high, it can sweep out the areas of clam culture, causing damage to farmers. The prolonged period of heavy rain, the large discharge of fresh water sweetens the water in estuaries and the coastal area, causing death of clam.

Table 6. The weight of disaster risks for fish cage culture at sea

Disaster	Weight
Heavy rain	0.270
High temperature	0.078
Storm and tropical low pressure	0.310
Extreme cold	0.209
Wind from the south	0.049
Salt intrusion	0.085
Total	1

Parameter	Value
The value of the matrix (λ_{max})	6.3
Number of factors (n)	6
Consistency Index (CI)	0.07
Random consistency Index (RI)	1.24
Consistency ratio (CR)	0.06

Table 7. The weight of disaster risks for clam culture in tidal flats

Disaster	Weight
Heavy rain	0.114
High temperature	0.082
Storm and tropical low pressure	0.372
Extreme cold	0.133
Wind from the south	0.085
Rain and extreme cold consecutiveness	0.214
Total	1

Parameter	Value
The value of the matrix (λ_{max})	6.6
Number of factors (n)	6
Consistency Index (CI)	0.13
Random consistency Index (RI)	1.24
Consistency ratio (CR)	0.117

4. Conclusion

The results of the survey determined the duration for aquaculture from stocking to harvest as well as identify types of natural disasters and their occurrence time in the locality.

For intensive commercial shrimp farming, it is affected by both single and multiple natural disasters. The most serious damage is caused by heavy rain accompanied by hot weather, hot weather accompanied by rain and hot weather.

For fish cage culture at sea, it is affected by single disasters, in which storm and tropical low pressure, heavy rain, extreme cold cause the most serious damage.

For clam culture in tidal flats, it is affected by both single and multiple natural disasters, in which the most serious damage is caused by storms and tropical low pressure, heavy rain, extreme cold, rain accompanied by extreme cold.

Results of the study will support for the hazard-risk indicator to aquaculture in northern area in Vietnam

Ackwoledgement: This article is based on results from the research under the program of science and technology for environmental protection and natural disaster prevention (KC.08/16-20). The authors would like to present the sincere thank to the survey team and its members.

REFERENCES

[1]. Can Thu Van, Nguyen Thanh Son (2015). *Weighting methodology for vulnerable indicators of flood in Vu Gia - Thu Bon basin*. Journal of Hanoi National University: Natural Science and Technology, No 1S, 93 - 102

[2]. Can Thu Van, Nguyen Thanh Son, Tran Ngoc Anh và Ngo Chi Tuan (2014). *Develop a flood of vulnerability index using a hierarchical analysis process (AHP) - a case study in some communes in lower Thu Bon river, Quang Nam province*. Journal of Meteorology and Hydrology No 643, tr. 10 - 18.

[3]. Nguyen Duc Binh, Nguyen Thi Lan, Phan Thi Van (2011). *Assessment of environmental status in clam culture areas in North Vietnam*.

[4]. Vu Thi Thu Lan, Hoang Thanh Son (2013). *Study on the dynamics of natural disasters (floods and droughts) in Quang Nam province in the context of climate change*. Journal of Earth Sciences, No 3-2013 66-74.

[5]. Quang Ninh Disaster Preparedness and Search, Rescue Steering Committee (2014). *Final Report on Disaster preparedness and Disaster Preparedness in 2014*.

[6]. Quang Ninh Disaster Preparedness and Search, Rescue Steering Committee (2015). *Final Report on Disaster preparedness and Disaster Preparedness in 2015*, *planing for 2016*.

[7]. Directorate of Fishery (2016). *Situation of marine aquaculture*, *orientation and solution for development in 2016.* Conference on marine aquaculture development in Nha Trang 11/11/2016.

[8]. Center for Natural Disaster Prevention and Mitigation (2014). *Document guideline forCommunity-based disaster risk assessment*.

[9]. National Central Committee on natural disaster prevention and control, National Conference on Disaster 3/2018.

[10]. Institute of Agriculture and Environment (2010). *Analyzing the impact of climate change on Vietnam agriculture, proposing adaptation measures and mitigation policies*.

[11]. Institute of Meteorology, Hydrology and Climate Change (2015). *Special Report of Vietnam on Disaster Risk Management and Extreme Events to Promote Adaptation to Climate Change*.

[12]. Ben Wisner, Piers Blaikie, Terry Cannon, and Ian Davis (2003). *At Rish: natural hazards, people's vulnerability and disasters.*

[13]. Carmen Paz Castro, Juan Pablo Sarmiento và Claudio Garuti (2016). *Disaster risk assessment developing a perceived comprehensive disaster risk index: the cases of three chilean cities.*

[14]. Generino P. Siddayao, Sony E. Valdez anhd Proceso L. Fernandez (2014). *Analytic hierarchy process (AHP) in Spatial Modelinh for floodplain rick assessment*. International Journal of Machine leaning and Computing.

[15]. Homeland Security (2013). *Threat and Hazard identification and risk assessment guide*. Second edition August 2013.

[16]. Martínez, M. (2009*). Los geógrafos y la teoría de riesgos y desastres ambientales.* Geographers and the risk and environmental disaster theory 14:241 - 263.

[17]. Rasool Mahdavi Najafabadi, Mohammad Hosein Ramesht, Iran Ghazi, Seyed Jamaleddin Khajedin, Abdollah Seif, Ahmad Nohegar and Atefeh Mahdavi (2016). *Identification of natural hazards and classification of urban areas by TOPSIS model* (case study: Bandar Abbas city, Iran), Geonatics, Natural Hazards anh Risk, Vol 7, No.1, 85 - 100.

[18]. Saaty, T.L., (1980). *The Analytical Hierarchy Process*. McGraw - Hill, New York.

[19]. Saaty T.L, (1995). *Decisions Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World*. RWS Publications, Pittsburgh.

[20]. Yamin, L. E., F. Ghesquiere, O. D. Cardona, and M. G. Ordaz (2013). *Probabilistic modeling for disaster risk management: the case of Bogotá, Colombia*. Banco Mundial, Universidad de los Andes. [World Bank, Universityof the Andes] 188pp. [In Spanish].