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The Study for Proposing Technical Guidance on Identifying the Causes and Economic Losses Caused by Mass Fish Die-off to Resolve Environmental Conflicts

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Mass Fish Die-off (MFD) refers to incidents where an unusually large number of aquatic organisms die suddenly over a short period. This phenomenon, common in rivers, lakes, estuaries, and coastal waters, may arise from natural events or human-induced factors. MFD often leads to serious ecological disruption, economic losses in aquaculture and fisheries, and deterioration of water quality. Globally, water pollution is a widespread problem, with human activities—especially untreated waste discharge—being a leading cause. Usually because MFDs involve multiple interacting factors, identifying the exact cause is complex. Many countries have established technical frameworks for investigating these incidents, including manuals and procedures that outline step-by-step processes for field inspection, sampling, and data analysis. Among them, the investigation systems adopted in Australia and South Africa are considered highly comprehensive. In Vietnam, MFD cases have been recorded in five provinces, including Phu Tho, Hai Duong, Thai Binh, Thanh Hoa, and Dong Nai. Although local authorities have applied procedures for receiving and verifying information, inconsistencies persist due to the absence of national standards. To overcome the problem, based on the scientific basis and the results of the assessment of the practical basis for MFD incidents in Vietnam, the Technical guidelines for Determining the Causes of MFD accidents and the Technical Guidelines for Assessing Economic Damage Caused by MFD accidents have been developed based on principles suited to Vietnam's context. These guidelines aim to improve governmental capacity in evaluating damage, ensuring compensation, and promoting sustainable environmental management.

Key words: Environmental management, Environmental conflicts, Mass Fish Die-off, Technical guideline, Vietnam

INTRODUCTION

Mass fish die-off (MFD) are environmental incidents in which a sudden and unusual number of aquatic animals die in a relatively short period of time. This is a common phenomenon in rivers, lakes, estuaries and coastal areas. Mass aquatic deaths can be a natural phenomenon or caused by human-caused factors. MFD can cause major economic losses to aquaculture, fisheries, recreational activities, and disturbance of food chains and ecosystems (Rao *et al.*, 2018; Hoang *et al.*, 2020). In addition, the large number of fish and MFD species also has a great impact on the quality of the environment in general (Truyen *et al.*, 2019; Brown *et al.*, 1978).

The phenomenon of water pollution is quite common in the world with many different causes: changes in water quality, pollution, epidemics directly or indirectly related to human activities (Lugg, 2000). The causes of environmental pollution related to human activities account for 66.9%, of which environmental pollution due to human waste discharge is the most prominent cause (Godinho *et al.*, 2019; La and Cooke., 2011). A MFD incident can be caused by a single cause or a combination of a group of causes. Determining the exact cause of mass fisheries deaths is often difficult. Many countries around

the world have developed and issued specific guidelines for determining the cause of MFD incidents such as Meyer and Barclay's Manual (1990) technical guidance on investigating mass aquatic deaths in the US; or another process in the state of Minnesota (USA) (Sarah *et al.*, 2015). In Australia, one of the most prominent processes for determining the cause of a MFD incident was written by Commonwealth Australia (2007). In South Africa, a technical manual covers sections in each phase of the mass fish death investigation process for all types of waters. This is considered the most complete process to guide the investigation of cybersecurity incidents developed in the world so far (Grant *et al.*, 2014).

In Vietnam, the phenomenon of MFD has occurred frequently in recent years, causing great damage to fishermen and aquaculture (Ministry of Natural Resources and Environment, 2018). The most prominent of which is the phenomenon of mass fish deaths in 4 central coastal provinces (Ha Tinh, Quang Binh, Quang Tri and Thua Thien Hue) in 2016 where the cause of the incident was determined to be the wastewater of Hung Nghiep Formosa Ha Tinh Co., Ltd. during the trial operation containing phenol and cyanide combined with iron hydroxide to form a mixed complex have a greater proportion of water following the ocean currents moving in the north-south direction (Ministry of Natural Resources and Environment, 2016). The causes of the phenomenon of mass deaths of fisheries recorded in Vietnam over the past time come from a number of sources of impact such

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as (1) natural disasters and natural phenomena; (2) epidemics, (3) environmental pollution caused by industrial production facilities, and (4) environmental pollution caused by agricultural activities (Ministry of Natural Resources and Environment, 2018).

An aquatic disaster can lead to two main problems: (i) economic losses to aquaculture farmers (aquaculture) (ii) environmental damage due to dead aquatic carcasses not being treated in a timely manner. When these problems are not solved in time, it will lead to conflicts and conflicts between stakeholders (Binh & Ha, 2002). Depending on the scale and causes of mass aquatic deaths, environmental conflicts arise between groups of related subjects (Thanh *et al.*, 2016).

In order to limit environmental conflicts between stakeholders in incidents of mass fishery deaths, it is required that state management agencies need to quickly capture and verify information; analyze and determine the cause of the incident; organizing support or compensation for damage to parties involved in the incident; and fix the environmental pollution where the problem occurred. However, up to now, Vietnam has not had a specific technical guidance for the determination of the cause of the accident. This causes difficulties in resolving environmental conflicts between stakeholders in the MFD incident.

Therefore, in order to support the resolution of environmental conflicts caused by environmental incidents, it is necessary to develop (i) technical guidelines for determining the causes of environmental incidents to serve the identification of causes and the investigation of the causes of incidents; (ii) provide technical guidance on assessment of economic damage caused by environmental damage incidents in order to serve the determination of support costs and compensation for damage to aquaculture farmers when incidents occur.

STUDY AREAS AND RESEARCH METHODS

Study area

The subject of this study is the mass death of fisheries in Vietnam. It focuses on incidents of mass fishery deaths caused by man-made causes. The study focused on incidents of mass fishery deaths across the country. In which, the survey was focused on 5 provinces: Phu Tho, Hai Duong, Thai Binh, Thanh Hoa and Dong Nai in the period from October 2020 to the end of December 31, 2022 (Fig. 1).

Methodologies

Secondary information collection

The information collected includes documents related to incidents of mass deaths of fisheries in the world and Vietnam, legal documents related to the management and handling of incidents of mass deaths of fisheries in Vietnam, and technical guidelines/procedures for determining the causes of mass deaths of fisheries.

Primary Information Collection

Conducting a field questionnaire investigation in 5 provinces where incidents of mass aquatic product

deaths often occur and cause great economic losses to aquaculture farmers, namely Thai Binh (dead clams), Hai Duong (dead fish), Thanh Hoa (dead fish, dead clams), Phu Tho (dead fish), Dong Nai (dead fish) to find out the causes of the incidents; economic damage caused by incidents; environmental and social problems arising during and after the incident. The subjects of the survey include: 30 votes for aquaculture managers in localities (provincial, district and commune levels) and 262 votes for aquaculture households (Each province is surveyed 50 votes in aquaculture areas where mass deaths of aquaculture often occur, especially in Dong Nai province, the number of survey votes is 62 votes) and 250 votes for surrounding households (50 votes for each province). The survey households were randomly selected from the aquatic households in the concentrated aquaculture areas where the mass death of aquatic animals occurred and the surrounding households of each province.

The yield change method in the assessment of economic damage to the mass death of fisheries consists of 4 basic steps as follows: 1) It is necessary to find the relationship that exists between changes in environmental quality and the results of such impacts on production through changes in productivity or output. This can be called the dose relationship between amount and influence. Relying on the production function to simulate inputs including environmental factors and considering how these factors affect production results (Q); 2) Determine the change in output (Q) according to environmental characteristics: From the information collected, find out the change in output when environmental factors change $\partial Q / \partial E \rightarrow \Delta Q$; 3) Collect the market price of the affected object (P): When a change in production is indicated, the market price will be used to quantify the economic value of the estimated change in production. Therefore, it is necessary to collect the market prices of the affected objects in the market; 4) Loss calculation is based on the yield change method. In this method, the loss is calculated based on (1) Output/Yield Change and (2) Market Price Information (P);

$$VE = \Delta Q \times P$$

In which: VE – Damage value of the affected object

ΔQ – Fluctuations in the output of the affected subjects

P – The market price of the affected object

Document review method

The document overview aims to synthesize and analyze to clearly indicate the current status and trend of mass aquatic deaths and related environmental conflicts.

Method of consultation with experts

Consultation of environmental and fisheries experts on issues related to technical guidance on determining the causes of aquatic animal deaths and assessing economic damage.

Statistical processing method

The collected data will be statistically processed descriptively using R software.



Fig. 1. Location of the study area on the map of Vietnam.

RESULTS AND DISCUSSIONS

Factors that cause mass deaths of aquatic products

Fisheries are objects that live in the aquatic environment, are very sensitive, and strongly influenced by environmental factors. Some common causes of mass fishery deaths usually include: agricultural production activities, industrial production activities, daily life activities and transportation activities. In fact, many of the causes of mass aquatic deaths are often not affected by a single impact, but by the combined impact of many factors.

Current status of determining the causes of mass aquatic deaths in Vietnam

The study has carried out investigations and surveys in 5 provinces where mass aquatic deaths have occurred including Thai Binh, Hai Duong, Phu Tho, Thanh Hoa and Dong Nai. The questionnaires are designed to find

out information related to mass aquatic death incidents for 3 related subjects: aquaculture households, households around the affected area, and state management officials (commune-level People's Committees, cooperatives, veterinary officials, etc fisheries and environment).

The process of receiving and verifying information on mass deaths of aquatic animals at survey sites

The survey results also show that when there is an incident of mass death of fisheries, the local government (agricultural extension officer; fisheries sub-department; environmental protection sub-department) is the agency to report the incident of mass death of fisheries, with an average rate of 81.68% (ranging from 60% to 96%); followed by other agencies and departments (directors of cooperatives, heads of joint venture groups) with a rate of 14.89%.

The form of reporting information about the incident was mainly through the phone or in person with the rate

of 74.8% and 48.1%, respectively; only a small number of households called the hotline or used other communication channels to report information at a rate of 0.8% and 0.4%, respectively. In particular, the form of reporting via Email is not used by ethnic minority households in all 5 provinces surveyed.

The time for confirming and verifying information about the incident of mass death of aquatic animals depends on the specific situation of the place and time of occurrence: within a day (accounting for 59.5%), in cases of 1–2 days (accounting for 44.3%). However, there are also many cases where the time to verify and confirm information is longer or there may also be no one to verify it (this rate accounts for 7.6%).

Thus, basically, the process of notifying the mass death of aquatic animals in 5 provinces is uniform and summarized.

Current status of environmental sampling methods and aquatic product samples

The results of the investigation show that depending on the level of management, state management officials will have different understandings of sampling activities in incidents of mass death of fisheries. 67.8% of the

respondents said that there are currently guidelines for sampling according to the regulatory documents of the Vietnam's Ministry of Agriculture and Environment such as QCVN 01–83:2011/BNNPTNT – General requirements for sampling, preservation and transportation; TCVN 6663–6:2018 – Guidelines for sampling river water, spring water...(Fig. 2).

How to organize the investigation to determine the causes of mass aquatic animal deaths in the surveyed provinces

The results of the survey from aquaculture households on the role of investigating the causes of mass death of aquatic animals in 5 provinces are shown in Figure 3. The survey results show that for aquaculture households, people think that this investigation role should be assigned to the Fisheries Sub-department/Department with (110 households). Meanwhile, only 26 households answered that the role should be assigned to the Environmental Protection Sub-Department.

However, the results of interviews with officials of the Fisheries Sub-Department and the Environmental Protection Sub-Department in the locality show that the role of the agency in charge of investigating the causes

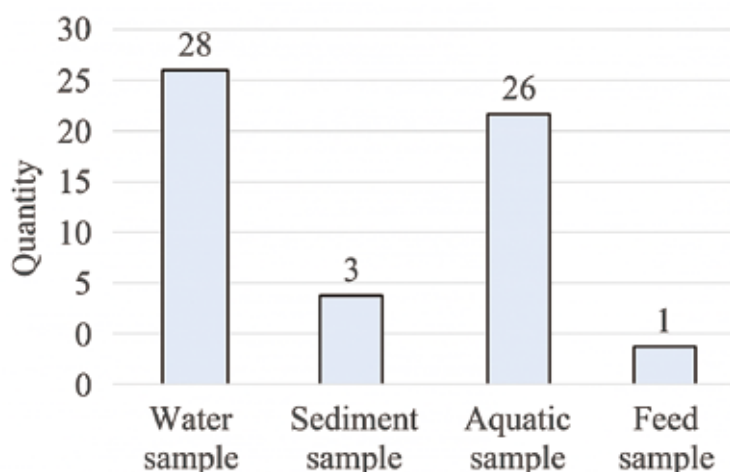


Fig. 2. Results of managers' responses on samples taken in mass aquatic death incidents.

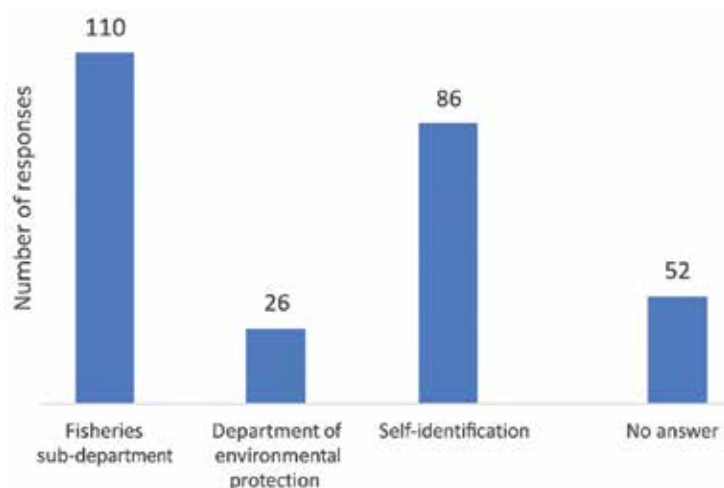


Fig. 3. Results of the investigation into the role of agencies in determining the causes of mass aquatic deaths in 5 provinces.

of mass aquatic deaths in localities depends on the nature of the incident. The investigation of the cause of the incident is usually of an interdisciplinary nature with the coordination of the state management agency in charge of the environment, and veterinary and fisheries.

Formulation of technical guidelines for determining the causes of mass death of aquatic animals

Structural framework for technical guidance on determining the causes of mass aquatic deaths in Vietnam

On the basis of researching the processes for investi-

gating mass fishery deaths in developed countries around the world, we have inherited and proposed technical guidelines for determining the causes of mass fishery deaths for Vietnam. The process of investigating the causes of mass deaths of aquatic animals includes 4 stages: The preparation stage before the incident occurs; Investigation trigger phase/startup phase; Investigation stage; and Investigation Closing Stage (Fig. 4). Contents of technical guidance on determining the causes of mass deaths of aquatic animals

The technical guidance for determining the cause of mass fish deaths is illustrated in Figure 5.

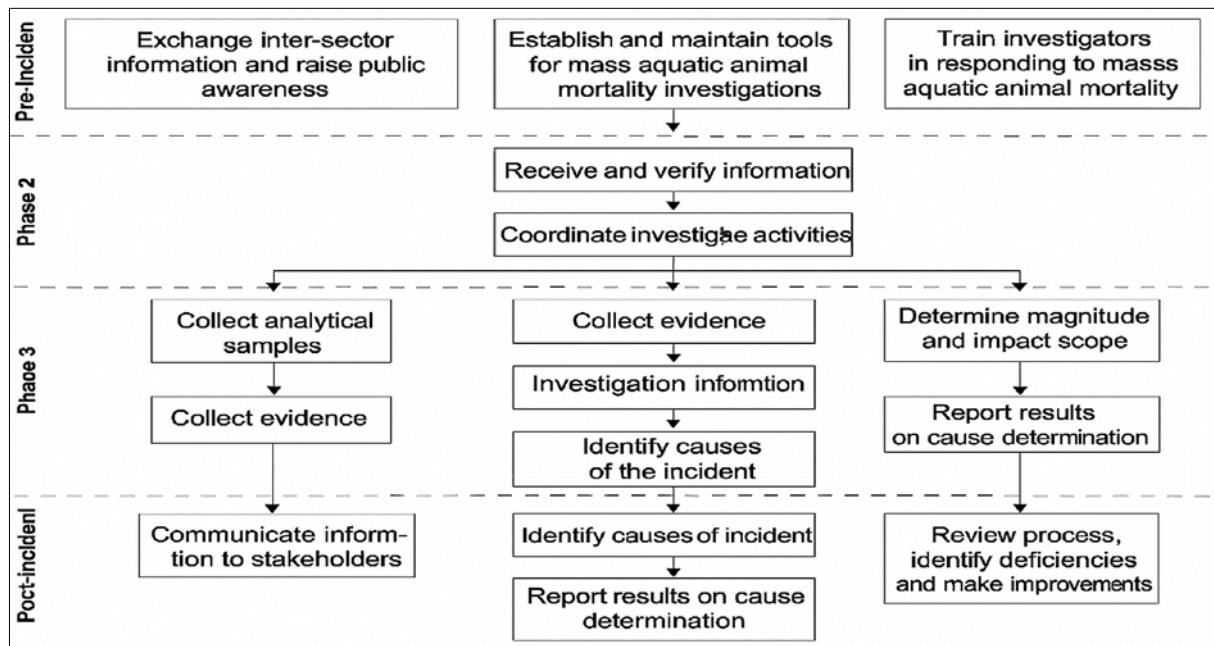


Fig. 4. Diagram of the process for determining the causes of mass deaths of fisheries proposed to Vietnam.

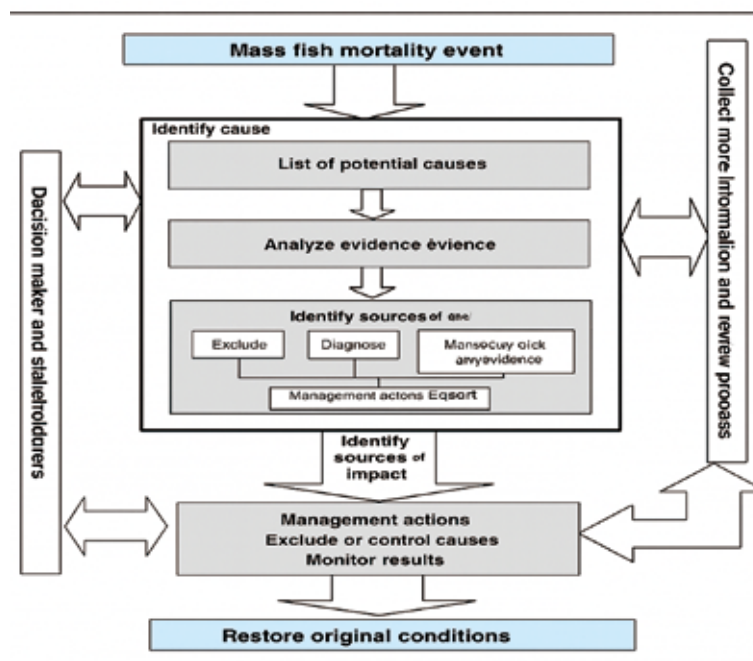


Fig. 5. Guiding diagram for determining the causes of mass death of aquatic animals.

Identification of evidence of listed causes

Conduct an analysis of evidence, including the analysis of information related to the listed potential causes, such as chemical characteristics of waste sources, organisms, sediments, waste source toxicity, water, sediment, etc. Then perform data organization, possible association analysis to support or refute hypotheses about the cause of the problem. Discussions on potential causes and impacted aquatic species; Information on exposure, field measurements and intermediate steps in the chain of causal relationships from the factors influencing the incident. These connections form the basis for the evidence used to describe the causes of the incident.

Identify the probable cause

Use the available evidence to exclude, diagnose, and compare the reliability of the evidence to determine the most likely cause of the incident. The process of determining the cause can be repetitive, starting with a retrospective analysis of the available data. In many cases, it is necessary to collect the additional data necessary to accurately identify the causes.

According to the results compiled by the two authors La & Cooke (2011) From 170 documents (including scientific articles, technical reports) related to mass fish dieoffs in estuaries and rivers in North America, the main causes of mass fish deaths have been pointed out, including: agricultural pollution (19.5%), biological toxins (17.2%) and chemical pollution (7.1%). Other causes include: temperature changes (5.9%), lack of dissolved oxygen (5.3%), gas outbreaks (3.6%), epidemics (3.6%), acidification (1.2%). The authors also point out that 66.9% of mass fish die-offs are caused by anthropogenic agents, while natural causes account for only 10.1%.

Develop technical guidelines for determining economic losses caused by incidents of mass deaths of aquatic animals

Yield Variable Method

Collect all the information of the damaged households, the data will be processed and verified. The steps applied in the yield change method to determine the damage caused by mass aquaculture mortality in the farming environment, when the information is fully collected, are carried out in the following steps:

Step 1: *Determine the relationship between factors in the ecological environment and production results through changes in yield or output.*

Relying on the production function to simulate these input factors that affect production results as follows:

$$Q_i = f(K_i, L_i, Env_i)$$

In which: Q is the output of aquaculture

K is the capital input factor

L is the labor input factor

Env is an environmental input such as BOD, COD, etc

The K and L information is based on information on breeds, food, labor, capital and factors belonging to eth-

nic minorities such as age, qualifications, experience,.. Meanwhile, the Env variable is an environmental attribute that affects aquaculture that is considered damaged. It can be COD, BOD, nitrogen,..

The production function that can be applied to simulate the affected farming yield of the inputs that can be considered is the Cobb–Douglas function as follows:

$$Y = AX_i^{\alpha_i + ui}$$

One of the approaches to best explain the change in output and productivity by the change of input factors is the Cobb–douglas function. Therefore, the above model is rebuilt as follows:

$$Q_i = A Q_i^{\alpha} Env_i^{\beta_i}$$

Where X_i is the usual input element, Env_i is the input factor representing the abnormal change of the environment. To estimate this model, the logarithm of the two sides of the production function we have:

$$\ln Q_i = \ln A + \alpha_i \ln X_i + \beta_i \ln Env_i$$

and completely estimated through OLS (using Excel or STATA, SPSS,.. can find the estimation results for the above model).

Based on the results in the above estimate table, the relationship between output and input factors in aquaculture is shown as follows:

$$\begin{aligned} \ln Q = & -0.17172 + 0.34621 \ln FQ + 0.43926 \ln SD - \\ & 0.20652 \ln CT - 0.86578E - 0.03 \ln Exp + \\ & 0.92513E - 0.01 \ln Edu + 0.19311E - 0.01 \ln Anti \\ & + 0.24352E - 0.01 \ln EC - 0.13744 \ln Env + \\ & 0.13535 \ln NoC \end{aligned}$$

Based on the average values of the input factors (except environmental factors) instead of the equation just estimated, we will obtain the simplified equation:

$$\ln Q = 0.88 - 0.13744 \ln Env \text{ or } Q = e^{0.88} Env^{-0.13744}$$

Step 2: *Determine the change in output (Q) according to environmental inputs*

From the survey information, we can see the impact of environmental factors on the output of aquaculture, we fix the input factors (except environmental factors) and replace the model. From there, find the change: $\partial Q / \partial E$ indicates how the environmental attribute variable affects ΔQ .

In the above example: $Q = 2.41 Env^{-0.13744}$

From there, when we change the values from the normal level where no incident has occurred and the level of observation of environmental factors in Env to have 2 values instead of the above equation. Taking the difference of the result, the yield loss due to fluctuations in environmental quality factors can be calculated.

Assuming that environmental factors change from

Table 1. Results of estimation of factors affecting the production results of specific aquatic species

Get lost	Explain	Influence coefficient	Statistical significance
$\ln(FQi)^*$	Food intake	0.34621	0.000
$\ln(SDi)^*$	Cultivation density	0.43926	0.000
$LNCT$	Time 1 crop	-0.20652	0.161
$\ln(Expi)$	Experience	-0.86578E-03	0.984
$\ln(Edui)^{***}$	Education	0.92513E-01	0.098
$\ln(Antis)$	Probiotics Cost	0.19311E-01	0.505
(ECi)	Environmental Cleanup Costs	0.24352E-01	0.137
$\ln(Envi)$	Environmental Representation Variable	-0.13744	0.018
$Ln(NoC)$	Number of cages	0.13535	0.011
LD1**	Farming Zone 1	-0.14856	0.013
LD2*	Farming Zone 2	-0.25640	0.000
Constant		-0.17172	0.731

Table 2. Results of determination of benefits and costs of aquatic resource exploitation

Turnover	Value	Unit
Yield	350	Ton
Price	10,000	USD/ton
Annual Sales	3,500,000	USD
Cost	Value	Unit
Number of fishing workers	200	Labour
Pay	800	USD/month
Total Labor Costs	160,000 x 12 = 1,920,000	USD/year
Net income from fishing activities	1,580,000	USD

Table 3. Present value of net income from fishing operations

	Year	Net Income
Assuming 50 years of fishing, we will have PV= \$15,665,405	1	\$1,580,000
	2	\$1,580,000
	..	\$1,580,000
	50	\$1,580,000

0.93 kg to 2.8 kg instead of the equation, the yield of aquaculture species will decrease from 2.43 to 2.09 kg/m². Thus, the difference in yield is 0.34 kg or converted to cages/rafts with a corresponding area of 3.8 kg/damaged cage.

Step 3: *Collect the market price of the damaged aquatic species*

As in step 2 in the example section we obtained the ΔQ part. We will survey to find the market price of that damaged fishery (called PQ). Let's say PQ with a selling price of 40.2 USD/kg.

Step 4: *Calculate the damage*

Once the change in production is indicated, the market price will be used to quantify the economic value of the estimated change in production in this step.

$$V_E = \Delta Q \times P_Q$$

In this example, with a loss of 0.34 kg/m² or 3.8 kg/cage x the price of 40.2 USD/kg, it will reduce 152.51 USD/cage.

Total damage = Value just found x Total number of cages/rafts in the damaged area. Thus, the calculation and assessment of economic losses, incidents, and mass deaths of fisheries due to environmental factors have been completed based on the yield change method.

Calculate the flow of benefits and costs of aquatic resource exploitation over time when no incident has occurred. Since the incident is long-term in nature, it is necessary to calculate the present value of net income from fishing operations if there is no operating plant there (50 years) (Table 3).

Net calculation of benefits and costs of aquatic resource exploitation over time when an incident occurs. In the example above, we will calculate the present value of net income from fishing operations if there is a factory operating there (Only 10 years of fishing can be sustained); no net income from year 11 onwards due to pol-

lution (Table 4).

After calculating the two income streams when there is no incident and when there is an incident, the damage will be determined as shown in the difference between the two income streams to determine the damage (Table 5).

Table 4. Net income of fishing activities within 10 years

	Year	Net income attributed to the present
	1	\$1,580,000
	2	\$1,422,000
	3	\$1,264,000
	4	\$1,106,000
Because there are only 10 years of fishing, to simplify, each year is reduced by 158,000 so that after 10 years, the value of fishery exploited=0; PV = \$6,091,584	5	\$948,000
	6	\$790,000
	7	\$632,000
	8	\$474,000
	9	\$316,000
	10	\$158,000
	...	0
	50	0

Table 5. Determination of damage caused by environmental incidents due to plant operations

Summing up the results (N=50; r=10%)	
PV of the fisheries industry without factories	\$15,665,405
PV of the fisheries industry if there is an operating factory	\$6,091,584
Measuring the amount of damage	\$9,573,821

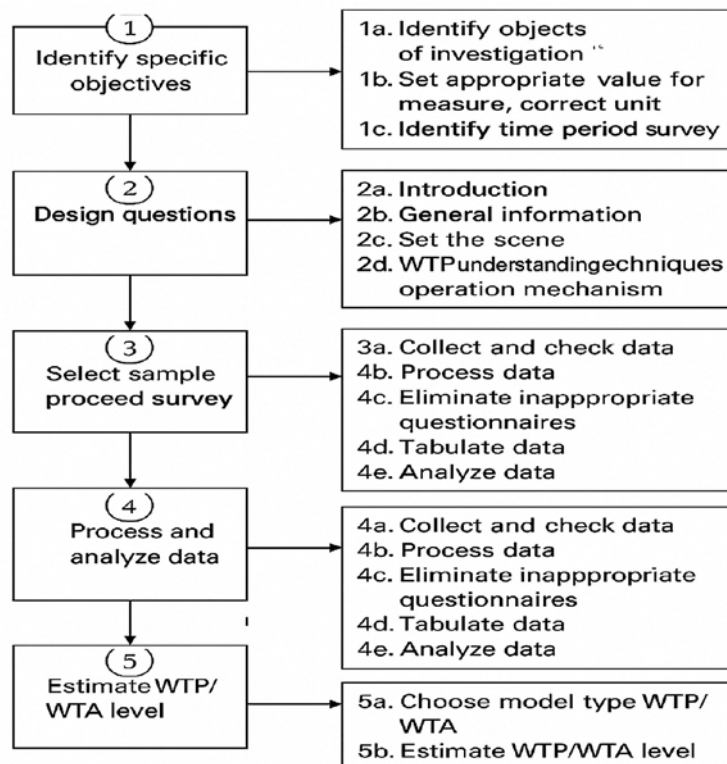


Fig. 6. Sequence of steps to apply the market creation method.

Yield Change Method.

Creating a market in the assessment of economic damage, incidents of mass deaths of fisheries. Measure the level of willingness to pay by applying the Contingent Valuation Method – CVM–market–making. CVM does not pass through an actual market but through a hypothetical market. In this hypothetical market, scenarios are set. The basic point of this method is to identify and understand the willingness to pay (WTP) or willingness to accept (WTA) of the relevant entities on the issue of market attributes. The three basic activities to survey the level of willingness to pay/accept of relevant subjects are shown in the Figure 6.

Practice of determining economic losses of mass fishery deaths in 5 surveyed provinces

Through surveys, evaluate methods of determining economic losses through surveys of relevant officials. The results showed that after an aquatic incident occurred, 78.6% of respondents said that the information to determine the damage would be based on a combination of information from the people and the determination methods of state management agencies and specialized agencies. Because once damage occurs, it is important to identify the parties involved in the incident as well as consult in the most objective way about the damages. The basis for calculating damages, up to 67.8% of the respondents said that the basis for calculating damage is through the market price, only 32.2% of the opinions said that there are cases where the market price is not based on the market price to determine damage such as incidents occurring in complicated cases, take place on a large scale and affect the ecological and interdisciplinary environment.

In localities, investigating and surveying incidents of mass aquatic deaths have generally not caused environmental conflicts between stakeholders. Up to 75.0% of the opinion said that no conflict occurred in the incidents of mass deaths of fisheries. The number of opinions that environmental conflicts arise (i) between aquaculture households; (ii) aquaculture households and surrounding households; (iii) aquaculture households with polluting establishments; (iv) between polluting establishments and state management agencies are 7.1%, 10.7%, 28.6% and 7.1%, respectively.

The impact of the research results on the state management of the field of natural resources and environment is very significant. Currently, in Vietnam, there is no technical guidance to determine the causes of mass death of aquatic animals, and the economic damage caused by the mass death of aquatic products. The study was conducted to develop technical guidelines to help resolve environmental conflicts arising from mass fisheries deaths in Vietnam. The technical guidelines for determining the causes and economic losses caused by mass fishery deaths are based on the inheritance of technical guidelines/processes developed by developed countries, but adapted to Vietnam's conditions and potentials. The research results of the study provide the authorities with documents for the development and issuance of techni-

cal guidelines to determine the causes of mass aquatic deaths and economic losses caused by these incidents in order to support the prevention, resolving environmental conflicts that may arise.

CONCLUSIONS

MFD incidents are quite common in different parts of the world. The causes of natural disasters include both natural (climate change, natural disasters,...) and man-made (environmental pollution from human economic and social activities). MFD incidents occur causing heavy economic losses and creating environmental conflicts for stakeholders. To solve this problem, countries around the world have developed technical guidelines to identify the causes of natural disasters and determine the economic losses caused by these incidents, which is an important basis for minimizing and resolving environmental conflicts arising from natural disasters.

The results of actual investigations and surveys in 5 provinces of Vietnam including Phu Tho, Hai Duong, Thai Binh, Thanh Hoa and Dong Nai show that the process of receiving, verifying information and determining the causes of food safety incidents has been implemented quite well, as shown by the feedback of managers and households. However, because the Managing Ministry has not established and promulgated a process to provide specific guidance for activities of receiving, verifying information and determining the causes of MFD incidents, these activities have not been implemented synchronously between provinces and cities and still reveal some limitations. Based on the scientific bases and the results of the assessment of the practical basis for resolving cyber incidents in Vietnam, the Technical Guidelines for determining the causes of cyber accidents have been developed, including: the process of receiving and verifying information; quick surveys and assessments; method of taking field samples and analyzing indicators; data synthesis and analysis; identify the causes, report the results. The study has also developed a Technical Guideline for Assessing Economic Damage Caused by Accidents based on economic principles and quantification of the value of basic resources along with actual conditions in Vietnam, supporting state agencies to determine, assess the extent of damage to the incidents, thereby using it as a basis for calculating compensation for damage or financial support for parties involved in the incident.

AUTHOR CONTRIBUTIONS

All authors contributed to the study's conception and design. Material preparation, and data collection by Nguyen Xuan HOA, Doan Thanh THUY, Cao Truong SON. Analysis was performed by Doan Thanh THUY, Nguyen Hai NUI, Cao Truong SON and Yoshifumi TAKAHASHI. The first draft of the manuscript was written by Nguyen Xuan HOA, Cao Truong SON, Nguyen Dinh TRUNG, and Yoshifumi TAKAHASHI. All authors

commented on previous versions of the manuscript, and read and approved the final manuscript.

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