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The Socioeconomic Impact of Coastal Environment Changes on Fishing Communities and Adaptation Strategies

Yao-Jen Hsiao

Institute of Applied Economics, National Taiwan Ocean University, Keelung 202301, Taiwan; yjhsiao@mail.ntou.edu.tw; Tel.: +886-2-2462-2192

Abstract: Oysters are one of the main aquatic products produced in Taiwan. However, because of the gradual changes in the environment of the Waisanding Sandbar, the oyster farming environment along the coast of Chiayi is shrinking, leading to greater operational risk and uncertainty. This study adopted a three-stage method to investigate the socioeconomic uncertainty that fishing communities face regarding environmental changes and to understand the environmental risk and fishery management awareness of different stakeholders as well as their views on adaptation strategies. In-depth interviews were used in the first stage. In Stage 2, two-round focus group interviews were conducted to organize views on the environment and climate, the oyster industry and management, and adaptation strategies. In the final stage, the AHP method was adopted to analyze the opinions of different stakeholders. The results showed factors affecting environmental change, oyster industry, and management among different stakeholders as well as the cognitive differences within the corresponding adaptation strategies. Therefore, socioeconomic and ecology complexities and uncertainties should be considered for enhancing social capital and promoting risk communication, more diverse social–ecological system data to assist fishery governance, and oyster industry development and adaptation strategies.

Keywords: coastal environment changes; land cover change; socioeconomic; oyster farming; stakeholders

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1. Introduction

Land use and land cover change (LUCC) is a crucial issue in the study of environmental changes and sustainability. Since the 1950s, LUCC has been the key driving force of ecosystem service values (ESVs) [1]. Land change creates direct economic benefits for humans but at the expense of causing an imbalance in ecosystem services, such as changes in water resources, air quality, disaster prevention capability, and biodiversity, all of which affect the well-being of humans [2]. The coastal ecosystem (including terrestrial and coastal wetlands and shallow water areas) plays an irreplaceable role in organic matter production, climate regulation, water conservation, pollutant removal, and biodiversity maintenance, making it one of the few most valuable natural ecosystems on earth. The combination of climate change impacts, declining fluvial sediment supply, and heavy human utilization of the coastal zone, arguably the most populated and developed land zone in the world, will very likely lead to massive socioeconomic and environmental losses in the coming decades [3].

Coastal zones are among the most critical areas in the world, providing approximately 22% of the global value of ecosystem services (ESSs) [4]. Economic development in coastal zones has negatively affected ecosystem functions and services in recent years. To mitigate or adapt to the impact of such development, it is therefore important to monitor LUCC in coastal zones, evaluate changes in coastal wetlands, predict the demand for land use [5], explore the effects of LUCC on ESSs, and perform multiscenario simulations of future land use changes [2]. The combination of local knowledge and scientific knowledge provides a more

useful evaluation of LUCC and its effects on local land users and administrators. For example, the cause and process of LUCC [6] and its effect on socioeconomic conditions [7] can be better understood and effectively evaluated by combining resident-provided information with remotely sensed LUCC data.

Climate change impacts, declining fluvial sediment supply, and heavy human utilization of coastal zones will likely lead to massive socioeconomic and environmental losses in the coming decades [3]. The environment in coastal zones is changed through natural causes and human activities. Natural causes include waves, ocean currents, northeast monsoons, typhoons, and sediments in rivers. Human activities include groundwater overexploitation, human utilization of tidal lands, construction of harbors and reservoirs, and erosion and transportation caused by longshore drift and waves, leading to reduced coastal sediments [8,9]. Furthermore, Chang et al. [10] suggested using alternative adaptation strategies, such as adjustments to crop combinations, trade liberalization, and technological advancements, to minimize losses resulting from climate change, which likely causes sea level rise and in turn affects socioecological systems. Therefore, coastal communities are increasingly at risk from many chronic and episodic hazards and vulnerable to unforeseen events [11].

The fishery sector in Taiwan has been a stable provider of staple foods for many years and is also a vital player in the international fishing community (in 2019, Taiwan ranked 25th in global capture fisheries production and 21st in global aquaculture fisheries production [12]). Coastal fishing communities are largely dispersed along the coastline. The coastline has been the subject of concern relating to continuous economic development, industry transformation, trade liberalization, open market competition, and changes and waste problems in coastal environments. As a result, some traditional coastal fishers and aquafarmers are compelled to transform their farming practices, consequently leading to an outward movement of the coastal fishing population and a birth rate decline among this population. Therefore, fishing communities are facing a challenge far worse than those of general communities. Aquaculture is a valuable sector that is continuously developing (in 2010, Taiwan's aquaculture production accounted for 23.28% of the total production in quantity and 35% in value. In 2020, the proportion of output in quantity increased to 31.47% and that in value rose to 44.76%.). It is dependent on access to and reasonable utilization of terrestrial, coastal, and marine resources, all of which are common resources pursued by different stakeholders and fishing communities [13]. Nevertheless, finding a suitable ecological economic system to sustain coastal aquaculture activities is key to seeking economic efficiency while ensuring both resource utilization and the carrying capacity of the environment [14].

Oysters have long been an economic product of aquaculture in Taiwan. Between 2010 and 2020, 19,000–30,000 metric tons or NT$4–5 billion worth of oysters were produced annually on average. Oysters are mainly produced along the southwest coast of Taiwan, in Changhua County, Yunlin County, Chiayi County, Tainan City, and Penghu County, with Chiayi County being the largest producer (Figure 1). Oyster farming in Chiayi County typically takes place on the Waisanding Sandbar. Due to the constant building of artificial facilities in rivers, decreased river-borne supply of sediment to the coast, and ocean currents, the shoreline of this sandbar has been shrinking, disappearing, or moving in recent years. If these phenomena persist, the Waisanding Sandbar will eventually disappear completely and severely impact the aquaculture sector and fishing communities in Chiayi County, which is a place that relies on the Waisanding Sandbar as its natural barrier to weather events [15–18].

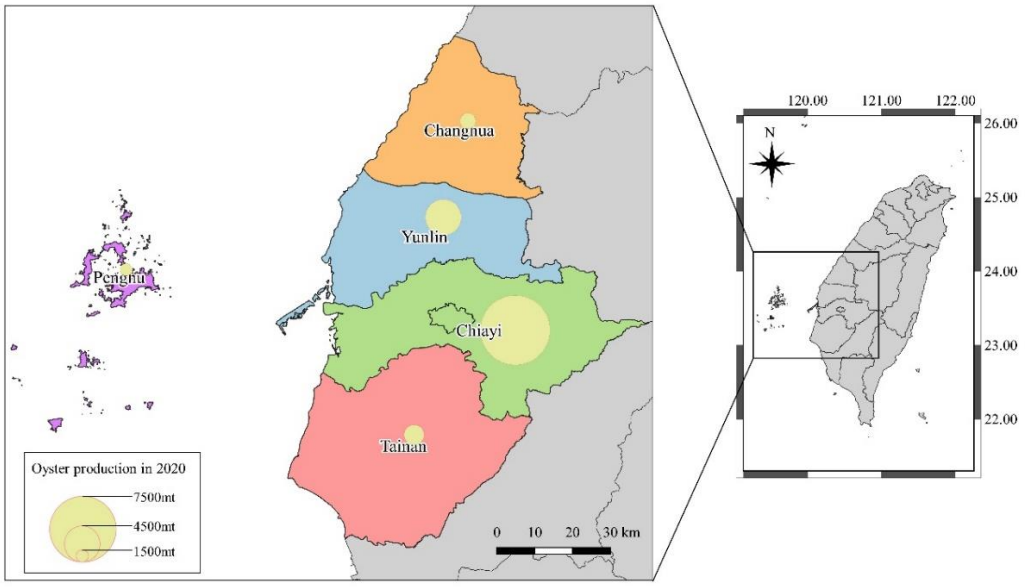


Figure 1. The study area and main oyster farming sites.

Several studies have reported that the Waisanding Sandbar is drifting and shrinking every year. Chang et al. [19] examined changes in the coastline of Taiwan by conducting surveys and taking aerial photographs. They verified that the Budai Harbor in Chiayi City and the Waisanding Sandbar were retreating and showing signs of erosion. Hsiao et al. [15] combined multitemporal remotely sensed satellite image data to analyze the evolution and migration of the Waisanding Sandbar over the past 35 years (1973–2006). Changes in the area (ha) and volume (m^3) of the Waisanding Sandbar between 2004 and 2006 were analyzed as well. The results revealed that the area and volume of the sandbar decreased from 1813.10 ha to 1721.57 ha and from 17.56 million m^3 to 16.24 million m^3, respectively. Chang et al. [17] analyzed the long-term changes in the shoreline and land areas between 1994 and 2015 and determined that the shoreline of the Waisanding Sandbar was retreating landwards at a rate of ≈30.5 m/year to ≈119 m/year, and the rate of land erosion has been increasing in recent years. The investigation and analysis results of the aforementioned studies show that the changes in the environment of the Waisanding Sandbar have been supported by numerous literature studies.

The relevant studies have speculated that the Waisanding Sandbar will eventually become a sunken sandbar or touch the Aogu Wetlands in the coming years. For instance, Tsai et al. [16] analyzed the environmental changes (shoreline, area, and volume) of the Waisanding Sandbar by using 12 sets of topographical data collected between 1993 and 2014. Their results showed that the sandbar was shrinking, with the area and volume decreasing by 40.2% and 52.9%, respectively. At this rate, the Waisanding Sandbar will sit below sea level by 2028. Chang et al. [17] explored the evolution of the Waisanding shoreline by detecting waterlines in satellite images. Based on the rate of land erosion between 2009 and 2015, the dry land area of the Waisanding Sandbar is projected to sit completely below the average tidal level and become a sunken sandbar by 2060. Peng et al. [18] analyzed multitemporal satellite images and determined that the volume of the Waisanding Sandbar decreased from 1.88 × 107 m^3 to 1.03 × 107 m^3 and that the rate of movement across the sandbar was 78.7–221.3 m/year. Specifically, the southernmost tip of the sandbar was moving faster than the northernmost tip, and the sandbar was projected to move toward and touch the Aogu Wetlands by 2048.

The aquaculture sector in Taiwan has been exposed to increased operational risk in recent years due to climate change impacts, such as low temperature, torrential rain, diseases, reduced water quality, and environmental changes. Consequently, coastal fishing communities, whose income is derived mainly from coastal fishing and aquaculture

activities, are struggling to stay afloat [20]. With the goal of helping coastal fishing and aquaculture communities develop sustainably, past studies adopted the perspectives of different stakeholders to examine the differences in aquafarmers' risk perceptions or their adaptation strategies [21]. The Waisanding Sandbar on the west coast of Taiwan is located in the sea near Dongshi Township of Chiayi County. It is the main oyster farming base and represents an important economy for local fishing communities. Owing to environmental changes, the Waisanding Sandbar is shifting and disappearing. This change is likely to generate an impact on the economy of local oyster and fishing communities and has reached a critical point, necessitating immediate action from aquafarmers and the government sector. The key to the sustainable development of the fishing community lies in finding ways to mitigate the effects of environmental changes, sustain the fishing sector, maintain employment opportunities, and assist fishing communities with industry transformation. Against this backdrop, this study integrated three aspects—environment and climate, industry and management, and adaptation strategies—into the framework for analyzing environmental changes and the sustainable development of fishing communities. First, in-depth interviews and focus group discussions were held with oyster aquafarmers, fisheries organizations, government representatives, and academic scholars. The objective of these interviews was to explore their environmental awareness, perceived economic uncertainties arising from environmental changes, and their views on the sustainable development and adaptation strategies of the oyster industry. Subsequently, the analytic hierarchy process (AHP) was used to assign weights and quantify the attitudes and opinions of different stakeholders regarding environmental change and adaptation strategies. Finally, the perspectives of different stakeholders were further analyzed and used as the basis for bridging the gap in risk communication to facilitate the formation of adaptation strategies and gain support from more local stakeholders.

2. Materials and Methods

2.1. Study Area

Oysters are one of the most economically important molluscs cultivated in the shallow sea of Taiwan. Taiwanese oyster aquafarmers generally cultivate Crassostrea gigas or Pacific oysters on the southwest coast of Taiwan [22]. According to statistical data published by the Fisheries Agency of Taiwan, the average production in Chiayi County reached 8900 metric tons between 2016 and 2020, accounting for 37–47% of oyster production nationwide. Chiayi County is considered the most suitable place for oyster farming because of its proximity to the Waisanding Sandbar, which acts as a natural barrier to the destruction of waves and the northeast monsoon. Furthermore, Chiayi County is free from industrial pollution, making it capable of producing high-quality oysters [9]. Oyster farms in Chiayi County are largely located in the sea area between the coastal zone of Chiayi County and the Waisanding Sandbar. Here, oysters are cultivated using cradles and floating racks. Cradle racks are used in shallow sea areas or intertidal zones, whereas floating racks are used in sea areas with deeper water.

Wind and rain disasters have been the cause of financial losses for aquafarmers. To protect the rights of aquafarmers, the Chiayi County Government began introducing demarcated fishing rights and licensing in 2006. The first demarcated fishing right in Taiwan was granted on 31 May 2006, setting a new milestone for oyster farms in shallow seas.

Managing a demarcated fishing right can provide a basis for offering assistance in the event of a natural disaster. It also enables the monitoring of oyster farming activities (e.g., current status, production, and sales), the reinforcement of fishery resource management and conservation works, and the sustainability of the oyster industry. In addition, the Chiayi County Government promulgated the "Self-Government Ordinances for the Management of Demarcated Fishing Rights for Oyster Farms in Chiayi County" on 20 August 2009. The purpose of this ordinance is to promote the reasonable and effective utilization of coastal zones, to establish a reasonable system for aquafarmers to operate aquaculture in state-owned sea areas and to protect the rights of aquafarmers. Areas for

oyster farming in Chiayi County were demarcated into 46 zones (Figure 2) for management. However, environmental changes have posed challenges to fisheries management. Due to the geomorphic evolution of the Waisanding Sandbar from 1985 to 2020 (Figure 2), some parts of the demarcated zones now overlap with the Waisanding Sandbar (e.g., Zones 3, 10, 16, 17, 18, 26, 28, and 33) and other neighboring sandbars (e.g., Zones 31, 36, 38, 39, 40, 41, and 43) and are now located on the left side of the Waisanding Sandbar (e.g., Zones 25, 26, 28, 32, 33, 34, and 35).

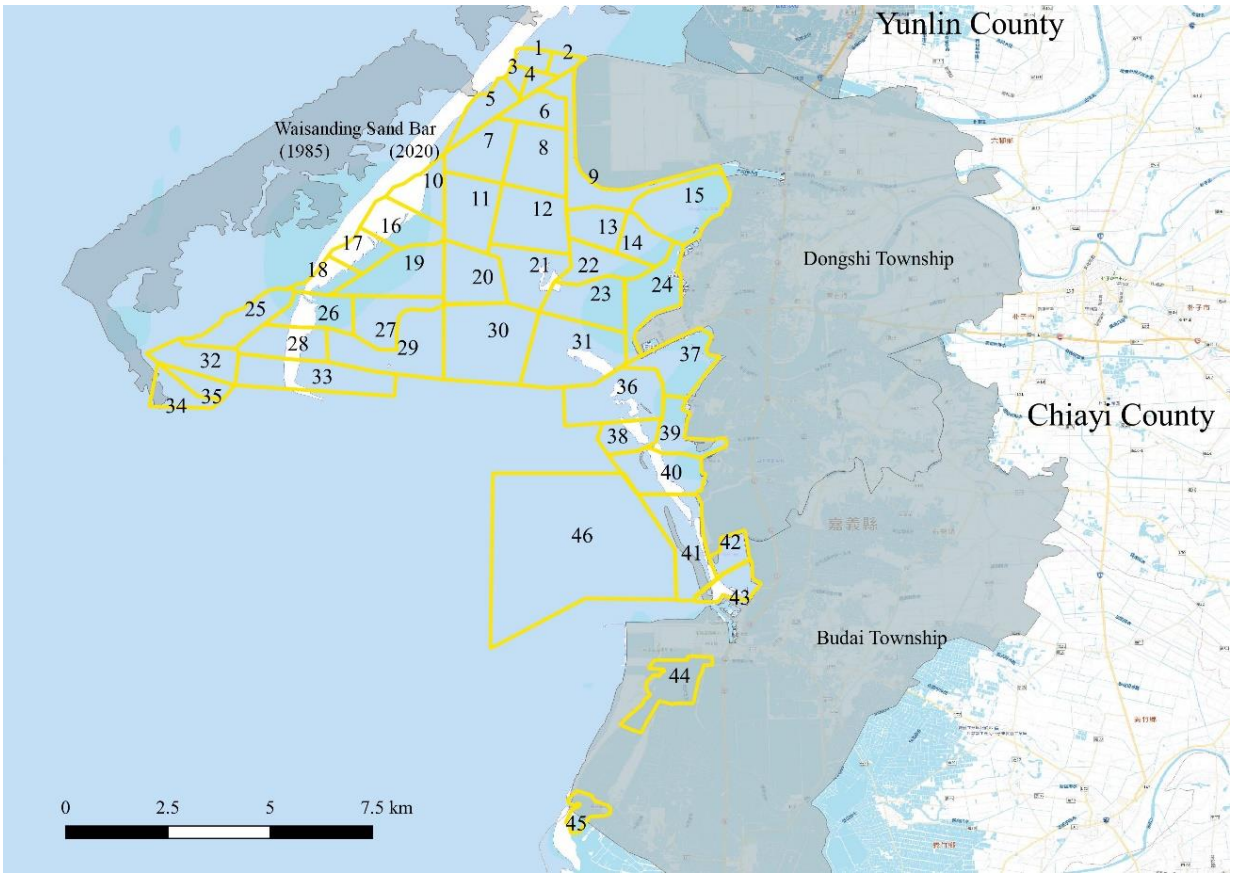


Figure 2. The evolution of the Waisanding Sandbar near Chiayi and an overview of the demarcated zones for oyster farming.

2.2. Estimation of LUCC

The constant loss and landward retreat of the Waisanding Sandbar in recent years have resulted in the gradual reduction in oyster farm areas. In 2010, the area of the shallow sea oyster farm was 4780 ha, and the area of the cradle rack setup was 751 ha. These areas dropped to 2862 ha and 648 ha, respectively, in 2020 (Figure 3). Between 2010 and 2020, the oyster farm area on the Waisanding Sandbar decreased from 5531 ha to 3510 ha. An analysis of LUCC [7] shows the land use and land cover changed ratio. This study uses its calculation method ((final year area deducting initial year area)/initial year area) to calculate the LUCC change ratio of Waisanding Sandbar between 2010 and 2020, which is 36.54%. In addition, oyster production in Chiayi decreased by 30.87%, from 12,483 metric tons in 2010 to 8630 metric tons in 2020. In other words, the movement and cover of the Waisanding Sandbar have gradually diminished the area of local oyster farms, thereby generating an impact on the economy of the oyster industry in Chiayi County.

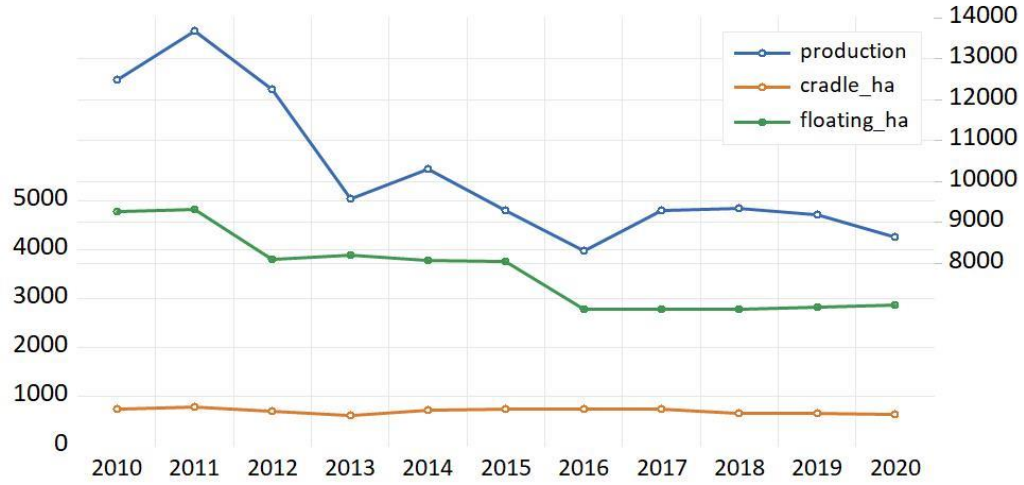


Figure 3. Oyster production in Chiayi County and areas of floating and cradle rack setups between 2010 and 2020. Source: Taiwan Fishery Agency and Chiayi County Government (2010–2020). Note: The left side is the floating and cradle racks aquaculture area (ha), and the right side is the oyster production (mt).

2.3. Qualitative Research Methods

This study adopted purposive sampling and a three-stage method to gain insight into the views of different stakeholders on the environmental change of the Waisanding Sandbar and the sustainable development of the oyster farming industry. In-depth interviews were used in the first stage. In the second stage, two-round focus group interviews were applied to organize views on the environment, climate, oyster industry, and management, and the adaptation strategies. In the final stage, the AHP method was adopted to analyze the opinions of different stakeholders. In Stage 1, in-depth interviews were conducted between September and December of 2021 with the following individuals: a manager and a staff member of a fisheries organization, two aquafarmers who use floating racks, two aquafarmers who use cradle racks, a recreational fishery operator, and two expert scholars. The objective of the in-depth interview was to shed light on the interviewees' subjective experience. An interview guide was developed before the interview and focused primarily on the environmental changes of the Waisanding Sandbar and the current status of oyster farming (Supplementary Table S1). During the interview, open-ended questions were asked and adjusted as needed depending on the interviewee's answer. The interview was carried out in no specific format (words or semantics) and was entirely focused on the interviewees. Interview responses, in-depth questions, and contents were completely recorded and encoded [23].

In Stage 2, two rounds of focus group interviews were held at the Dongshih office of the Chiayi Fishermen's Association on 17 and 27 December 2021. The interviews aimed to explore the participants' views and discuss the problems that some researchers had hoped the participants could discuss in a moderately structured group. The interviews were centered on three aspects: (a) factors influencing oyster farming, (b) challenges in oyster farming, and (c) strategies for adapting to the socioeconomic and sustainable development of the coast. 8 to 12 people participated in each round of interviews [24]. Representatives from each stakeholder group were invited, including oyster aquafarmers who use cradles and floating racks, recreational fishery operators, fisheries organizations, scholars and government representatives. The focus group interview was organized (see Supplementary Table S2) to determine the effects of the environmental changes of the Waisanding Sandbar on the oyster industry and the socioeconomic impact of the coastal fishing communities in Chiayi County. A focus group can provide an abundant and massive volume of complex data. To avoid omitting any crucial information during the selection process or generating

selective errors, the entire discussion was transcribed, and the views and discussions on each issue were further categorized and coded [25].

2.4. AHP Questionnaire Design

AHP is used in a multicriteria decision-making problem under uncertain situations. It provides a framework for analyzing multiattribute decision-making problems. A complex situation is structured within a hierarchy of attributes, and the relative importance of each attribute is assigned a subjectively judged value. Finally, these results are integrated to determine the overall ranking of the attributes [26]. A hierarchy helps decision-makers understand a situation or problem. In the selection of an appropriate solution, alternatives must be evaluated against certain criteria to determine the priority of these alternatives, thereby identifying the appropriate solution. A decision-making process often involves different measuring standards that have different weights [27]. Therefore, there are no absolute values, but values derived from pairwise comparison. The purpose of this approach is to have evaluations by different decision-makers to avoid generating weight differences due to personal and subjective opinions [28]. Although the AHP method, which simplifies complex problems, can be used in uncertain situations and for linear decision-making problems with multiple evaluation criteria, it does have many limitations, including that some factors may not be compared pairwise, or the correlation between factors is not considered. However, this study, with oyster farmers as its subjects, assessed their acceptance and overall willingness to complete the questionnaire and investigated the cognitive gaps among different stakeholders. As a result, this study looked to seek a consensus and feasibility of adaptation strategies in the face of environmental change through the AHP method.

AHP has been frequently used in the literature to analyze and explore LUCC [29–31]. This study was conducted to investigate the socioeconomic uncertainties that environmental changes have brought to the oyster industry and to understand how different stakeholders perceive environmental risks and industry operations and how their sector adapts to environmental changes. The dimensions and factors for the "Key Factors in the Environmental Changes of Waisanding Sandbar that Influence the Sustainable Development of Oyster Farming" questionnaire were developed based on the interview contents. The dimensions were environment and climate, industry and management, and adaptation strategies. Next, five scholars with relevant areas of expertise were invited to assist in reviewing the questionnaire dimensions and factors. An AHP questionnaire was considered complete once the scholars, through expert validity, exhibited consistency of >0.8 in the judgment on the appropriateness of the questionnaire items and the content breadth of the entire questionnaire. The questionnaires were distributed via purposive sampling between December 2021 and January 2022. The samples of aquafarmers were selected by conducting questionnaires on representative subjects recommended by Chiayi Fishermen's Associations. The stakeholders were aquafarmers, fisheries organizations, the government sector, and scholars. Fisheries organizations were included because they are the communication bridge between the government and fishing communities. Incorporating the views of fisheries organizations, as opposed to only the individual perspectives of aquafarmers or the government, provides a more comprehensive understanding of regional fisheries development and management. In total, 38 valid questionnaires were retrieved, including 19 from aquafarmers (who use cradles and floating racks), 10 from fisheries organizations, and 9 from government representatives and scholars (see Supplementary Table S3).

3. Results

3.1. Interviews Summary

3.1.1. Factors Influencing Oyster Farming

The aquafarmers explained that the accumulation of drifting sand and the speed and direction of water flow are the main factors causing the environmental changes in the Waisanding Sandbar and silting in oyster farming areas. These factors not only affected

the number of racks (floating or upright) that could be installed and the coverage of cradle racks in the farming area but also caused waterway silting. In addition, the southwest airflow or typhoon during spring to autumn every year affects oyster farming activities and the Waisanding Sandbar to an extent. Water quality influences the density and growth rate of oysters. Some oyster farming areas had poorer water quality (Zones 1–4), which was possibly because of the lower current speed in the area, thus resulting in lower oyster density. The fisheries organizations speculated that a prolonged period of silting affects oyster farming in the coastal zones of Chiayi. Every year, aquafarmers must also worry about the typhoon season, because this weather event might destroy and damage their oyster beds.

The academic scholars indicated that long-term studies on the environmental changes of the Waisanding Sandbar reported a 200-m decrease in length and a 40,000-m^2 reduction in area annually over a 10-year period. In addition, the sandbar is moving landward, with the southernmost tip moving faster than the northernmost tip, thus overlapping with the southern part of the oyster farm (Zone 33). This change is due to silting and water flow. The sandbar will eventually touch dry land if human intervention is not adopted. At this rate, Zones 1 to 31 of the demarcated fishing right zones will be affected. While the Waisanding Sandbar was previously considered a natural barrier for oyster farms in Chiayi, it would eventually lose its role as a natural barrier and become open land for oyster farming. In that case, cradle racks will no longer work, and only floating racks could be used to cultivate oysters, thus putting oyster aquafarmers at significantly greater risk. Scholars, however, maintained that the Waisanding Sandbar area is free from ocean debris and marine pollution and that by reducing oyster density and removing silts, oyster aquafarmers should be able to maintain or improve the quality of water in that area, thereby facilitating the sustainable development of the oyster industry.

3.1.2. Challenges in Oyster Farming

Recently, aquafarmers have seen a gradual decrease in oyster production as a result of the following phenomena: the Waisanding Sandbar is shrinking, sinking, and retreating landward annually. Because of this trend, the oyster farm area will eventually lose its natural barrier, floating rack facilities will be susceptible to the northeast monsoon, oysters will grow more slowly or will be vulnerable to the southwest airflow, and cradle racks will be covered by drifting sand, rendering them unusable. In addition, the diminishing farm area also affects aquafarmers' livelihood and employment opportunities. For example, a small farming area means less oyster growth. Reduced production then affects the number of oysters available for cleaning and shucking, both of which create job opportunities for women in fishing communities. Consequently, job opportunities for women are affected, thereby generating a massive socioeconomic impact on fishing communities. Moreover, reduced production means that there are not enough domestic supplies to meet domestic demands, which leads to increased oyster importation (Taiwan's oyster imports increased from 1414 tons in 2015 to 3457 tons in 2021, and its oyster self-sufficiency rate dropped to 88.1% in 2020 from 93.9% in 2015 [32]). However, imported oysters are cheaper than locally produced oysters, and their quality is indiscernible, which will severely impact domestic market prices (Supplementary Table S4). The aquafarmers also mentioned that with oysters cultivated on the east side of the Waisanding Sandbar (Zone 19), they were able to hang 10 oyster shells on a single string. Now, they can hang only nine oyster shells at most because of drifting sand, which affects the depth of the water. Furthermore, cradle racks are now covered by drifting sand, rendering them unusable. Silting in the waterway also forced aquafarmers to reroute their fishing vessels, which consumes time and increases fuel costs. The cost of shucking oysters has also increased recently because of rising labor costs.

The fisheries organizations indicated that approximately 70% to 80% of the oyster farms along the coast of Chiayi County are located within the perimeter of the Waisanding Sandbar. There are more than 1000 oyster aquafarmers, including approximately 250 culturing by floating racks, more than 800 using cradle racks, and some oyster aqua-

farmers employing both methods. Oyster production has dropped in recent years. Silting in the waterway has forced aquafarmers to take a different route, which incurs more operational costs for aquafarmers. The lack of nighttime navigation equipment puts aquafarmers at risk. Not all aquafarmers are managed under the demarcated fishing rights. The fisheries organizations encourage aquafarmers to apply for demarcated fishing rights to avoid losses from natural disasters. Because there is a fee for the demarcated fishing rights, aquafarmers tend to be optimistically biased. However, a typhoon or natural disaster event is usually followed by an increase in the number of aquafarmers applying for the demarcated fishing rights. Recreational fishery operators indicated that there are 18 recreational fishing vessels in Chiayi County, attracting an average of approximately 200,000 tourists annually before the COVID-19 pandemic. However, intense competition and an aging population (employed workers were mostly older adults) result in higher turnover, occasionally leading to labor shortage problems. If the Waisanding Sandbar completely disappears in the future, Chiayi County will have one fewer tourist attraction spot and attract fewer tourists, thus affecting the source of income of recreational fishery operators.

According to expert scholars and government representatives, Chiayi County has approximately 11,700 oyster beds cultivated using floating racks; 2399 oyster beds or approximately 21% have applied for demarcated fishing rights. Aquafarmers who are granted the demarcated fishing right must pay NT$500 annually to use the sea. Aquafarmers are entitled to a NT$300 reward if they assist the government in recovering oyster beds and a cash payment of NT$5000 per bed when they sustain losses from a natural disaster (provided that they declare the amount of oyster stocks they have and that they lost 20% or more of that stock). Oyster farms using cradle racks require an area of more than 700 ha; approximately 400 ha or 70% have applied for demarcated fishing rights. Aquafarmers may submit their applications to the Chiayi City Government for demarcated fishing rights, which will be approved by the Chiayi County Government and reported to the Chiayi Fishermen's Associations with one-year validity. For every hectare, aquafarmers must pay NT$1000 to use the sea, and they are entitled to a cash payment of NT$25,000 per hectare when they sustain losses from a natural disaster (provided that they declare the amount of oyster stocks they have and that they lost 20% or more of that stock). The cradle racks are now covered by drifting sand, rendering them unusable for oyster farming, yet the farmers still must pay a fee to use the sea. Considering that demarcated fishing right zones are affected by environmental changes and that natural disasters are not frequent events, some oyster aquafarmers who use floating racks do not find cash incentives appealing and are not motivated enough to apply for a demarcated fishing right. This makes the fishery sector difficult to manage.

3.1.3. Strategies for Adapting to the Socioeconomic and Sustainable Development of the Coast

The aquafarmers hoped that the oyster industry would be sustainable. When asked about ways to mitigate the topographic change of the Waisanding Sandbar, the aquafarmers suggested surrounding the sandbar with fixtures or a protective fence made of oyster shells to fix the sandbar in place and reduce landward siltation. By doing so, working individuals in the entire oyster chain can secure their jobs. Meanwhile, private companies should be allowed to conduct river dredging and then fill the Waisanding Sandbar with the dredged sand. Oyster farming has a low carbon footprint and facilitates carbon fixation; if a sustainability fund can be created through carbon trading, it can offer financial relief for the annual maintenance of the aquaculture environment. Recreational fishery operators advised the government to step up efforts to promote the recreational fishery sector, help aquafarmers transform their operations, and relax relevant laws and regulations, such as relaxing rules to allow fishing tourism. The fisheries organizations asserted that sand stabilization in the Waisanding Sandbar and waterway dredging are crucial to the sustainable development of oyster farming in Chiayi. However, these factors can lead to a short-term increase in oyster importation. The organizations therefore suggested imposing control or raising tariffs on

imported oysters (e.g., controlling import quantity and labeling of country of origin) to prevent the oyster sector from being hit by imported oysters.

Expert scholars highlighted the chain effect that environmental changes have on the oyster industry and the socioeconomic aspect of fishing communities. In the short and medium term, production will drop if the aquaculture farming area is limited, in which case improving the industry's value chain is particularly important to the economy of the fishing community. In the long term, assisting with local industry transformation requires the collective efforts of industrial practitioners, government officials, and academic scholars. The local government did recommend installing wind turbines on the Waisanding Sandbar, but further assessment is needed to determine whether this setup can facilitate sand stabilization and mitigate sediment pollution. Nevertheless, evaluation and long-term analyses are still required to ascertain the general benefits (e.g., avoid environmental changes or mitigate the landward retreat of the sandbar) and socioeconomic benefits of investing in ways to achieve sand stabilization and reduce siltation. The relevant government authorities have adopted the following six measures to prevent beach loss on the Waisanding Sandbar: subsidies for sources of sand; beach nourishment; an artificial reef for conservation and wave dissipation purposes; afforestation, windbreak, and sand stabilization; a survey and impact assessment on the resources of the entire industry; and monitoring and evaluation. The ultimate objective of these measures is to mitigate the environmental impact on fishing communities and the fishery sector.

Based on the above interview contents, 18 findings were obtained (Table 1), three interview topics/dimensions were identified (environment and climate, industry and management, and adaptation strategies), and dimensions and factors were developed for the "Key Factors in the Environmental Changes of Waisanding Sandbar that Influence the Sustainable Development of Oyster Farming" questionnaire.

Table 1. Interviews Summary.

Interview Topic/Dimension	Finding
Factors influencing oyster farming/Environment and Climate	1. Drifting sand affects siltation in the farming area or waterway, and the Waisanding Sandbar is shrinking and moving. 2. Water flow affects the rate at which the Waisanding Sandbar is shrinking and moving. 3. Seawater quality affects the growth rate and quality of oysters in oyster farms. 4. Typhoon or southwest airflow results in oyster bed loss or damage.
Challenges in oyster farming/Industry and Management	1. Environmental changes lead to an annual reduction in oyster production. 2. A decrease in fishery labor demand impacts the economies of fishing communities. 3. Reduced production results in market price fluctuation and increased oyster importation, which will ultimately impact domestic producers. 4. Environmental changes lead to increased direct cost, such as reduced oyster stock and higher fuel cost. 5. The overall cost of the oyster farming industry includes waterway dredging and navigation facilities. 6. Reduction in domestic production leads to increased importation. 7. Environmental changes affect the management of demarcated fishing rights.
Strategies for adapting to the socioeconomic and sustainable development of the coast/Adaptation Strategies	1. Stabilize the sand on the Waisanding Sandbar to mitigate the rate of loss. 2. Dredge the waterway to remove silts. 3. Impose control on the total quantity of oysters that can be imported or raise tariffs on imported oysters. 4. Develop the recreational fishery sector. 5. Install wind turbines on the Waisanding Sandbar to facilitate sand stabilization and increase sources of income for locals. 6. Increase the value chain of the oyster industry. 7. Guide oyster aquafarmers to transform their operations.

3.2. AHP

The completed questionnaires (Key Factors in the Environmental Changes of Waisanding Sandbar that Influence the Sustainable Development of Oyster Farming) were analyzed using the Expert Choice software. According to the results (Table 2), the aquafarmers considered drifting sand to have a more significant effect on the environmental and climate dimensions, whereas the fisheries organizations, government, and scholars believed that seawater quality was more important. In the industry and management dimension, aquaculture cost was the most important to aquafarmers, while the other stakeholders believed the value of the oyster market was most critical. For the dimension of adaptation strategies, the aquafarmers, government, and scholars agreed that stabilizing the sand on the Waisanding Sandbar warrants immediate attention; the fisheries organizations contended that oyster import control or taxation is key to the sustainable development of the oyster industry. The following sections describe the perspectives of the different stakeholder groups (Figure 4).

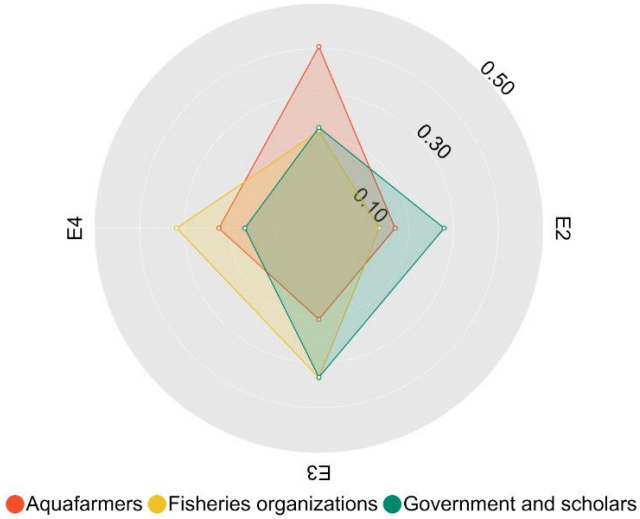
Table 2. Analysis of AHP questionnaire results.

	Aquafarmers (*n* = 19)		**Fisheries Organizations (*n* = 10)**		**Government and Scholars (*n* = 9)**	
Dimension/Factor	**Weight**	**Rank**	**Weight**	**Rank**	**Weight**	**Rank**
Environment and Climate						
E1. Drifting sand	0.404	1	0.216	3	0.224	3
E2. Water flow	0.170	4	0.135	4	0.279	2
E3. Seawater quality	0.203	3	0.333	1	0.332	1
E4. Typhoon or southwest airflow	0.223	2	0.317	2	0.165	4
Industry and Management						
I1. Fishery labor force	0.089	6	0.133	4	0.075	7
I2. Oyster production	0.203	2	0.165	3	0.137	4
I3. Oyster market price	0.159	3	0.217	1	0.285	1
I4. Cost of aquaculture activities	0.222	1	0.199	2	0.174	2
I5. Cost of aquaculture management	0.123	4	0.089	6	0.080	6
I6. Oyster importation	0.083	7	0.074	7	0.155	3
I7. Ocean and fisheries management	0.122	5	0.123	5	0.093	5
Adaptation Strategies						
A1. Sand stabilization of the Waisanding Sandbar	0.220	2	0.145	3	0.233	1
A2. Waterway dredging/silt removal	0.145	4	0.128	4	0.150	3
A3. Impose oyster import control or tariffs	0.254	1	0.295	1	0.108	6
A4. Develop recreational fishery sector	0.065	7	0.089	6	0.146	4
A5. Install wind turbines on the Waisanding Sandbar	0.072	6	0.053	7	0.058	7
A6. Increase the value of the oyster industry (by reusing oyster shells)	0.158	3	0.162	2	0.165	2
A7. Provide guidance on industry transformation	0.086	5	0.128	4	0.141	5

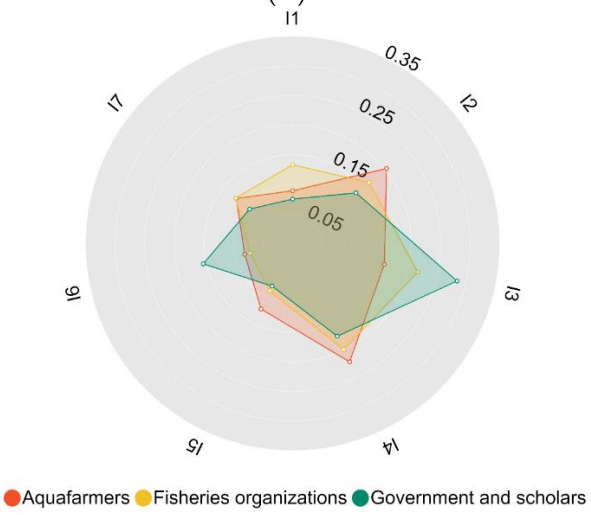
Note: C.I. value = 0.01. Data source: Organized by this study.

3.2.1. Aquafarmers

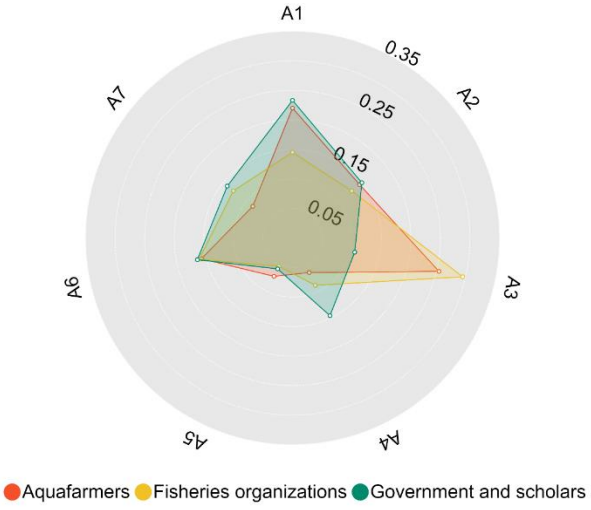
For the environmental and climate dimensions, the aquafarmers attached a higher level of importance to drifting sand (0.404) and then typhoons (southwest airflow; 0.223). In terms of industry and management, aquaculture cost (rising fuel and shucking costs; 0.222) was considered most critical to the sustainability of the oyster industry, which was followed by oyster production (0.203). Finally, imposing oyster import control or tariffs (0.254) was the preferred adaptation strategy, which was followed by the sand stabilization of the Waisanding Sandbar (0.220).



(**A**)



(**B**)



(**C**)

Figure 4. Weight of the key factors among the different perspectives of stakeholders. (**A**) Environment and Climate. (**B**) Industry and Management. (**C**) Adaptation Strategies.

3.2.2. Fisheries Organizations

For the environmental and climate dimensions, the fisheries organizations attached a higher level of importance to seawater quality (0.333) and then typhoons (southwest airflow; 0.317). The oyster market price (0.217) was deemed most critical to the oyster industry and management, which was followed by aquaculture cost (0.199). Finally, adaptation strategies should prioritize imposing oyster import control or tariffs (0. 295) and then increasing the value of the oyster industry (0.162).

3.2.3. Government and Scholars

For the environmental and climate dimensions, these stakeholders attached a higher level of importance to seawater quality (0.332) and then water flow (0.279). The oyster market price (0.285) was regarded as the most critical to the oyster industry and management, which was followed by aquaculture cost (0.174). Finally, the sand stabilization of the Waisanding Sandbar (0.233) should be the main focus of adaptation strategies, which was followed by increasing the value of the oyster industry (0.165).

4. Discussion

In the face of the major shock of Waisanding Sandbar environmental change on the social and ecological system of fishing communities, this study adopted two-stage interviews and the AHP analysis. The results showed the necessity to help different stakeholders confronted by the environmental change to promote risk communication and enhance risk governance capabilities. Additionally, how to improve the resilience of oyster farming in an increasingly uncertain culturing environment is another topic of concern. Finally, in response to the movement and reduction in Waisanding Sandbar, measures in the past primarily focused on environmental and ecological monitoring without investigating and monitoring the industrial economy and fishing communities' social system. This increases difficulties in designing industrial adaptation strategies. Based on this, the discussion is developed in three parts:

4.1. Risk Communication Is Facilitated by Increasing Social Capital and Adopting the Views of Different Stakeholders

The study results revealed a difference of opinion among different stakeholders on the following issues: the impact that the environmental changes of the Waisanding Sandbar have on the sustainable development of the oyster industry; environmental and climate risks; problems in oyster industry and management; and strategies for adapting to sustainability. The local knowledge that local aquafarmers have on long-term environmental changes, as well as challenges in industrial operations, should play a pivotal role in adaptation strategies. Considering the environmental changes, social capital can be viewed as a means of promoting information exchange, which in turn raises people's risk awareness, thereby honing their ability to adapt to risks [33–35]. Previously, the strategies for adapting to environmental changes were largely based on a top–down approach or expert opinions instead of public opinions. Complex issues such as the risk of environmental changes underline the importance of coastal communities as well as the roles and functions they play. This is particularly true when aquafarmers and community residents will likely be makers of disaster problems, post-disaster victims, and providers of solutions to risk mitigation. Therefore, it would be more meaningful if different role players are able to promote risk communication, bottom–up implementing and centralized planning and organization with regard to adaptation of stakeholders [36], take part in the process of managing environmental change risks, and effectively implement adaptation strategies [37–39]. Taking the changes in the environment of the Waisanding Sandbar in Chiayi County as an example, Taiwan is moving in this direction to communicate risks more effectively.

4.2. Strategic Planning for Variation and Uncertainty Is Required in Fisheries and Aquaculture Management

The migration of the Waisanding Sandbar and land cover has made it more challenging to manage aquaculture and fishery activities. Aquafarmers are well aware of the risks of long-term environmental changes [40]. These risks include a decrease in the land area of aquaculture farms, increased aquaculture risks, and an increase in oyster importation, all of which affect the development of the oyster industry. Coastal changes driven by the evolution of the environment will likely incur significant economic losses, but the utilization of coastal zones still carries an opportunity cost, which depends not only on the impact and economic factors of environmental changes (e.g., future changes in the value of coastal industries) but also on the return on investment in coastal zones. Under environmental changes, the oyster industry, fisheries management, and adaptation strategies require a delicate balance in the formulation of sustainability policies and strategies. Nevertheless, the sustainable development of fishery industries will be greatly facilitated by a quantitative coastal risk assessment of fisheries sustainability. It will also benefit from a fisheries management model and a risk valuation and protection mechanism that helps aquafarmers transfer risks or make early plans for industry transformation [41]. In addition, redesigning a method of governance entails strategic planning for variation and uncertainty that requires different data on socioecological systems and flexibility in data integration and application. The uncertainties of environmental changes impede the redesigning of governance. Uncertainty encourages the use of short-term plans and visions that focus on immediate problems and supports the illusion that adaptation can be a response to environmental change and industrial sustainability. For example, drifting sand, aquaculture cost, and oyster import control or tariffs are, in the opinion of aquafarmers, the most critical factors. However, silting remains a possibility after waterway dredging, cradle racks will be continuously covered by drifting sand, and maintaining production to meet market demands with a shrinking aquaculture farm is still a problem that must be considered. Based on government-collected data on the history of fisheries activities in Chiayi County, existing fisheries management systems as well as economic, social, and governance-driven factors are fundamental to governance adaptation. Basic information pertaining to aquafarmers, oyster industry practitioners, and communities, in addition to long-term environmental monitoring, is required to predict impacts and devise governance plans. The results of these actions can enhance the resilience of fishing communities and industries to environmental changes.

4.3. Adaptation Strategies Should Strike a Balance between Risk and Return

The Waisanding Sandbar significantly affects the economy of fishing communities, as it impacts not only land space for oyster farming but also the livelihood of aquafarmers, oyster production, and economic activities (e.g., oyster cleaning, soaking, shucking) in the industrial chain. Therefore, future environmental impact assessments on oyster industries must consider other economic activities in the oyster industry and recreational fishing operators who rely on the Waisanding Sandbar as a tourist destination. In addition, suitable support and assistance with adaptation should be provided. Oyster production, import quantity, and consumer market demands must be monitored and subjected to market analysis and management as needed. These actions all serve to avoid severe economic impacts on fishing communities and the outflow of fishing populations [42]. Effective coastal plans and management strategies should involve a reliable local-scale prediction of the evolution of the Waisanding Sandbar and coastal zones (that is caused by climate- or nature-induced changes in the average sea level, storm surge, wind wave, and river). Prediction at the local scale enables a holistic evaluation of the aquaculture risks at the optimal local scale. Subsequently, risk information, climate actions, and adaptation to environmental changes, among other measures, can be achieved to strike a balance between risk and return [3]. To mitigate the destruction of the Waisanding Sandbar, long-term cost investments in sand stabilization and waterway dredging, among other adaptation

strategies, are imperative. However, the socioeconomic benefits of these strategies and their effectiveness in mitigating the destruction or landward movement of the Waisanding Sandbar still require long-term analysis and evaluation [43].

5. Conclusions

Oysters are one of the main aquatic products produced in Taiwan. Chaiyi County sits adjacent to the Waisanding Sandbar, which is a natural barrier that benefits oyster farming. Ascribed to this geographic advantage, Chiayi County is considered the largest oyster producer in Taiwan. However, because of the gradual changes in the environment of the Waisanding Sandbar, the oyster farming environment along the coast of Chiayi is shrinking, leading to greater operational risk and uncertainty. Past studies have largely discussed issues concerning the sustainable development goals of the United Nations, such as climate actions [44], biodiversity [45], sustainable food production [46], and maintaining the socioeconomic status of fishing communities [47]. The issue of fisheries sustainability in light of environmental changes is equally important. For this reason, this study adopted the perspectives of different stakeholders and explored the environmental impact on coastal oyster farms, the challenges in the economy of fishing communities, and adaptation strategies. During the period of transition in response to environmental changes, disagreement regarding strategies for adapting to environmental changes is inevitable. Therefore, socioeconomic and ecology complexities and uncertainties should be considered for enhancing social capital and promoting risk communication, more diverse social–ecological system data to assist fishery governance, and oyster industry development and adaptation strategies. In addition, the perspectives of aquafarmers and fisheries organizations must be adopted during the development, variation and uncertainty strategic planning in fisheries and aquaculture management and implementation of adaptation strategies to achieve sustainable development goals. It is believed that experiences related to changes in the environment of the Waisanding Sandbar can provide a reference for other regions.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/fishes7050243/s1, Table S1. Interviewees in both rounds of focus group interviews. Table S2. AHP questionnaire: Aquafarmer interviewees. Table S3: AHP questionnaire: Aquafarmer interviewees. Table S4: Import volume and average price of major oyster importing countries in Taiwan's markets over the years.

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