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Developing payment for ecosystem service schemes for coastal aquaculture in southwestern Taiwan

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ABSTRACT: Taiwan's aquaculture farms are mostly established along intertidal zones and coastal land areas, and their presence may affect coastal ecosystems and their ecosystem services (ESs). Payments for ecosystem services (PES) represent a potential method of enhancing the provision of ESs for coastal aquaculture; thus, their feasibility should be discussed. In this study, we conducted focus group interviews to identify issues and collect information about coastal aquaculture in southwestern Taiwan, and we developed a PES framework for coastal aquaculture based on our findings. The identification of ESs and the inclusion of a market design (e.g. pricing, incentive, and conditionality) in a PES scheme might be key factors for successfully transforming aquaculture into an ES provider. PES schemes could be applied to coastal oyster farming in Taiwan, and coastal oyster farmers who adopt eco-friendly aquaculture should receive subsidies to secure revenues. The findings presented here will provide important reference information for policy makers and managers to design a feasible PES scheme for coastal resource management.

KEY WORDS: Payment for ecosystem service · PES · Aquaculture · Coastal resource management · Economic incentive · Oyster farming

1. INTRODUCTION

The United Nations indicated in the 2005 Millennium Ecosystem Assessment report (MEA 2005) that humans are using natural ecosystems at a greater scale and faster rate than previously reported. These changes have imposed considerable risks and stress on these ecosystems; currently, 60% of ecosystem services (ESs) are being degraded or used unsustainably, and ecosystems are being polluted and overdeveloped (MEA 2005). Launched by the United Nations Environment Programme (UNEP) in 2007, the Economics of Ecosystem and Biodiversity (TEEB) initiative aims to promote global awareness of the value of biodiversity and ecosystems and safeguard natural capital. The initiative also states that if remedial measures are not adopted, humans will face serious consequences by 2050 (TEEB 2010). Several studies have highlighted the importance of ESs to humans in recent years (Daily 1997, Costanza et al. 1998, Chan et al. 2006, Worm et al. 2006, Beaumont et al. 2007, O'Higgins et al. 2010, Barbier et al. 2011, de Groot et al. 2002, Martinez-Harms et al. 2015, Chen et al. 2018).

Martinez-Harms et al. (2015) pointed out that the ES concept is a critical issue in environmental decision making. Fujita et al. (2013) mentioned that ES degradation is a market failure that likely stems from the inflexibility of established markets to incorporate the full spectrum of ecosystem goods and services in

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coastal areas. Payment for ecosystems/environmental services (PES) is one type of market-based instrument for using ESs to address market failure issues and external costs (Engel et al. 2008, Froger et al. 2015). The failure of management of the west coast of Taiwan has led to substantial environmental impacts that affect coastal ESs, such as coastal pollution, erosion, subsidence, coastal development, improper use of coastal resources, conflicting use of coastal areas due to habitat destruction, and natural disasters (Chiau 1998, Fan 2001, Hsu et al. 2007, Jang et al. 2016). The high density and resource use of coastal aquaculture is one major pressure faced by the coastal ecosystems of western Taiwan. Taiwan's coastal aquaculture typically uses intertidal zones, lagoons, and coastal lands to culture aquatic plants and animals. Thus, high-density aquaculture inevitably impacts local ecosystems and environments, and the overuse of water and land resources is an inherent problem of coastal aquafarms. Currently, the overuse of land and water resources is a key challenge for coastal aquaculture on the west coast of Taiwan, which is exposed to considerable environmental impacts (Chiau 1998, Fan 2001, Hsu et al. 2007, Jang et al. 2016). The overexploitation of water and land resources has led to conflicts in the development of aquaculture, the economy of local communities, and the sustainability of the environment (Liao & Liu 2006, Hsieh et al. 2007).

Aquaculture farms can provide a diverse range of ESs (Mathé & Rey-Valette 2015, Popp et al. 2019), although these farms are more typically viewed as industries that require stringent regulation and active management as consumers of ESs rather than as providers (Alleway et al. 2019). Thus, implementing management practices and PES policies are expected to mitigate environmental problems caused by aquaculture, restore wetland ESs, and provide constructed ESs so that consumers of ESs become providers of ESs (e.g. environmental and climate regulation, flood control, and other services). Coastal aquaculture through well-designed PES scheme arrangements, with the government as the leader in planning and implementing PES policies, might reduce the negative externalities caused by aquaculture and provide ESs to improve the welfare of the public.

This study focused on developing PESs for coastal aquaculture in southwestern Taiwan. To this end, we assessed the feasibility of implementing PESs to change Taiwan's aquaculture practices in a way that enhances coastal ESs. A PES framework for Taiwan's coastal aquaculture is also provided in this study. We hope that our findings provide a feasible PES scheme for coastal resource management to formulate management-related recommendations and references for resource managers and policy makers.

2. PAYMENT FOR ECOSYSTEM SERVICES CONCEPT

The concept of ESs gained traction in the late 1990s, as evident in the increasing number of exploratory studies conducted around the world. An ES can be commonly defined as 'the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life' (Daily 1997, p. 3). ESs are commonly considered 'the benefits people obtain from ecosystems' (MEA 2005, p. 1). A PES is an environmental resource management tool that offers economic incentives to local participants in exchange for ESs (Engel et al. 2008). The definition of PES varies widely, although a common definition is the policy and market instruments that reward ecosystem managers based on the benefits that their managed ecosystems provide (Salzman et al. 2018). The loss of ESs due to degradation has been rephrased in terms of market failure, and market-based instruments for the provision of ESs, coupled with the suppression of perverse subsidies, are presented as solutions to deal with market failure issues and external costs (Engel et al. 2008, Froger et al. 2015). Previous studies have indicated that PESs are policy instruments tailored to address mismanagement and externality problems from the perspective of ecosystem managers (Engel et al. 2008, IUCN 2011, Bladon et al. 2016). According to an Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services report (IPBES 2019), PESs could offer compensation for the voluntary acceptance of restrictions to reduce degradation, such as shifts in resource uses or practices. PESs are conditional on beneficial actions and generate incentives for the voluntary provision of ESs by varied private actors. Therefore, a PES can offer opportunities for modifying and potentially reversing incentives for resource users to overexploit or convert them.

PESs are based on the Coase theorem and the 'beneficiary pays' principle. However, in practice, landholders or natural resource holders may be unwilling to act as ES providers because the incentives are insufficient. Therefore, PES programmes must be designed so that they consist of an ES buyer and seller. Generally, buyers in a PES programme are users of ESs, in which case the PES programme is

user-financed. Some PES programmes are designed to include the government as a buyer, with due consideration given to the overall welfare of society. Regarding PES design, ES buyers are asset holders, owners, or managers, such as farmers, private forest owners, or fish farm managers/owners, while buyers are beneficiaries if they are users of the resources and habitats. Conditionality is essential in any PES scheme; therefore, the ES provider should secure its delivery of the ES (Wunder 2005, Tacconi 2012, Bhatta et al. 2014), and PES payments are made only if the provision of the service is secured or the agreed-upon land-use caps are complied with on a quid pro quo basis (Robertson & Wunder 2005). In addition, some studies have indicated that PES can be considered an improvement over earlier approaches because it offers positive incentives for voluntary behavior, conditional on performance, with a direct linkage between the incentive and the desired outcome (Ferraro & Kiss 2002, Wunder 2005, Kerr et al. 2014). In practice, PESs have been successfully applied in resource management (Corbera et al. 2007, Kosoy et al. 2007, Asquith et al. 2008, Pagiola 2008, Wunder & Albán 2008, Wunder et al. 2008, Liang 2012, Smith et al. 2013). Previous studies have mostly focused on terrestrial ecosystems, while few research works and case studies have examined the application of PESs in coastal and marine management. The 2011 IUCN report discussed the use of PES programmes in ocean and coastal ecosystems and proposed a specific set of implementation and evaluation steps. When applying PES programmes in coastal ecosystems, the most crucial stage is completing the verification and evaluation of coastal ecosystems (Pagiola 2008).

Bladon et al. (2016) outlined the principles that theoretically set PESs apart from other fisheries management tools and described the extent to which they may be addressed in a fisheries context; they also indicated that PESs are most likely to be feasible and effective in commercially valuable fisheries. In terms of coastal management, few studies have focused on mangrove ESs and blue carbon (Lau 2013, Thompson et al. 2017). PESs contribute not only to the ecological environment but also to poverty reduction in rural areas by providing a possible source of additional income for landowners and land managers (Pagiola et al. 2005); however, good practice cases and management measures for aquaculture are lacking in Taiwan's coastal areas. Weitzman (2019) reviewed the application of the ES concept to aquaculture and indicated that the ES concept poorly covered aquaculture systems, ESs and values, and approaches. He also mentioned that consistent and comparable ES measures specifically related to aquaculture are needed. Hence, implementing PES schemes might be a potential measure for enhancing sustainability for coastal management and development in Taiwan.

3. RESEARCH AREA

In 2018, the value of Taiwan's aquaculture fishery reached 37.5 billion NTD, accounting for approximately 40% of the overall fishery sector. Aquaculture provides high-quality protein to supply the domestic market. Due to limited environmental resources, Taiwan's aquaculture development and management focus on the transition of the industry and the current management measures that particularly address environmental effects, ecolabels, and diversification into tourism and ornamental fish businesses (Chen & Qiu 2014). Therefore, numerous measures have been successively implemented, such as registration systems, subsidies, certification systems, and traceability of aquaculture products. Nevertheless, insufficiently effective environmental policies have been implemented to improve the environmental issues associated with Taiwan's aquaculture industry.

Aquaculture facilities are mainly distributed along the southwestern coasts of Taiwan. In this area, several unique coastal ecosystems exist, such as lagoons, sandbars, large-scale intertidal wetlands, and estuary wetlands. Coastal ecosystems can provide diverse ESs in these areas of Taiwan (Lew & Wu 2017, Kuo & Wang 2018, Hsu 2019). Additionally, these regions represent good habitats for rare migratory birds (e.g. black-faced spoonbills) (Ueng et al. 2006, Huang, 2021). Thus, these ecosystems and habitats are valuable for protection and conservation.

We conducted a feasibility survey on coastal aquaculture located between the northernmost area of Changhua County and the southernmost area of Pingtung County (Fig. 1). Statistical data indicate that the area of aquaculture totaled 2626.30 ha in Changhua County, 7814.21 in Yunlin County, 8147.08 ha in Chiayi County, 14 184.82 ha in Tainan city, 3937.75 ha in Kaohsiung city, and 3506.81 ha in Pingtung County. In summary, the largest areas of aquaculture among the 6 counties and cities in this study were found mainly in Tainan city, Chiayi County, and Yunlin County. In addition, oysters are a popular animal for farming in the coastal areas of these cities/counties in Taiwan. In 2019, production totaled 1738 t in Changhua County, 3600 t in Yunlin County, 9181 t in Chiayi County, and 3420 t in Tainan

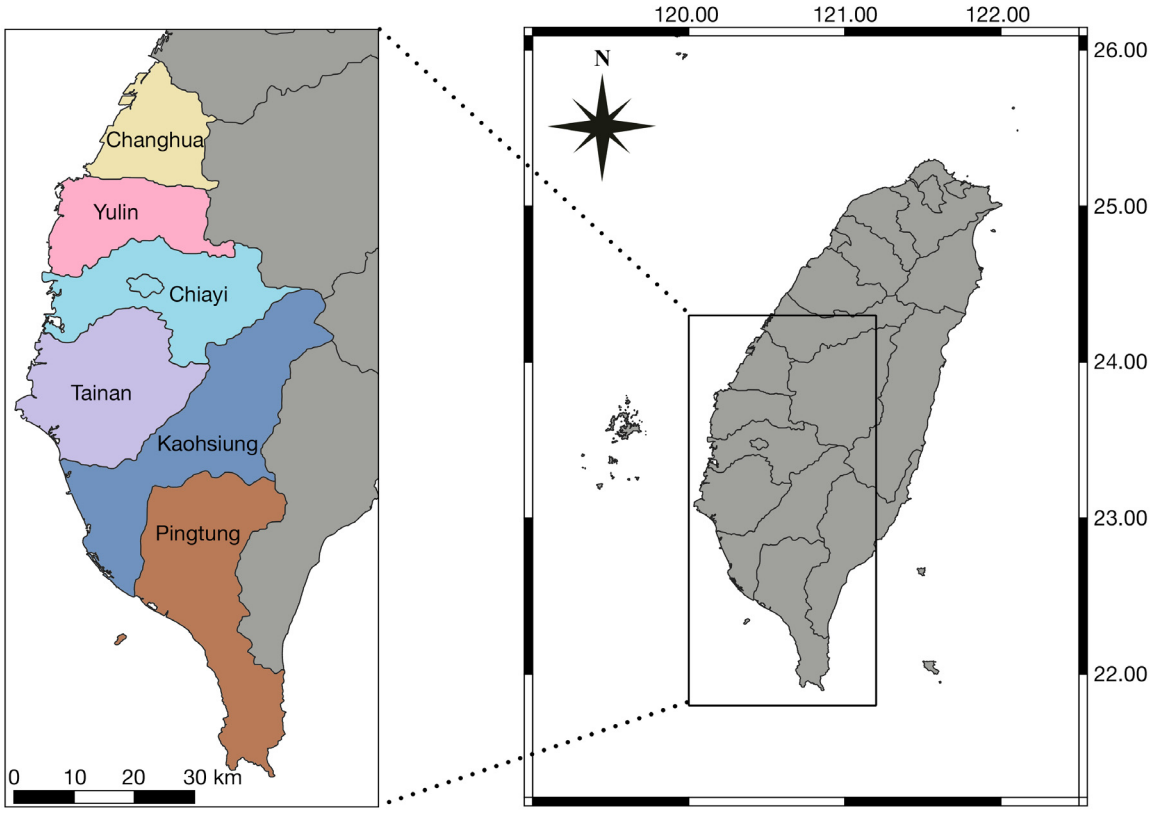

Fig. 1. Feasibility survey areas on coastal aquaculture in this research, located in southwestern Taiwan

city, which accounted for 17 939 t (out of 19 413 t in total in Taiwan). However, the interactions between aquaculture and rich coastal ecosystems are critical issues for sustainable development in this area; thus, developing effective management measures is an important task for aquaculture development in Taiwan.

4. FOCUS GROUP INTERVIEWS

We conducted focus group interviews to collect the opinions of various experts and scholars. Their opinions were used to define the ES targets that could be provided in this study for PES development as potential solutions to aquaculture environmental issues. In focus group interviews, groups of individuals who meet specific criteria are interviewed based on the objectives of a study. Focus group interviews involve applying interview techniques in group interactions and engaging in discussions on pre-established issues to acquire research data (Merton et al. 1990, Morgan 1997). This section describes the contents and processes of the focus group interviews we conducted in this study.

4.1. Interview design

We conducted 2 rounds of focus group interviews. The first round was held on 8 April 2015 at National Taiwan Ocean University, and the following 6 topics were discussed: (1) Coastal aquaculture is facing various environmental problems; what environmental problems might be faced by coastal aquafarmers? (2) What government measures should be taken to improve aquaculture environments? (3) Which laws serve as the legal basis for applying PES for aquaculture? (4) What are aquafarmers' views on the protection of coastal environments? (5) Which economic methods can transform farmers into ES providers? (6) What are feasible directions for the implementation of PESs in Taiwan?

The second round was held on 1 June 2015 at National Cheng Kung University, which is located near the aquaculture area. The outline for the second interview was adapted from the contents discussed in the first interview; thus, we focused on oyster farming according to the results of the first interview: (1) What are the major environmental challenges faced by oyster farming in Taiwan? (2) What environmental problems are associated with oyster farming

and potential solutions? (3) What are the potential problems in the implementation of PES schemes for oyster farming? (4) What are the effects and benefits of relevant legislation on the implementation of PES programmes in oyster farming?

4.2. Coding and analysis

The margin coding approach was adopted to obtain the most thorough information on which to base the analysis in this study because it can transcribe verbatim and analyse digital recordings collected by focus group interviews (Bertrand et al. 1992). Two researchers were involved in the data analysis, and all the coding and information were recorded in an Excel sheet for systematic analysis. The first researcher read and identified themes within the data and manually coded these themes into appropriate categories according to our research objectives, and the second researcher independently checked the first researcher's interpretations.

4.3. Focus group participants

Focus group interviews can involve full groups, mini groups, or telephone groups depending on the nature of the research. Considering the expertise and funding of this study, we invited 8 experts who had professional knowledge related to aquaculture and marine environments (4 scholars, 3 researchers, and 1 industrial expert) to participate in the first round of focus group interviews. The composition of experts is detailed in Table 1. The second round of focus group interviews placed equal emphasis on industry and academic research and involved 8 experts with professional knowledge related to aquaculture and marine environments (2 scholars, 4 staff members of the fisher associations, 2 researchers, and 1 industrial expert). The expert composition is detailed in Table 2. This study complies with research ethics, and consent to participate and permission to collect data by recording were obtained from all participants. All data are presented anonymously to avoid revealing the participants' personal information.

Table 1. Participants in the first round of focus group interviews

Code	Expertise	Occupation
A	Marine environment	Scholar
B	Fish farm environment	Scholar
C	Aquaculture	Scholar
D	Aquaculture	Researcher
E	Agriculture and resource economy	Scholar
F	Agriculture and resource economy	Researcher
G	Aquaculture	Manager
H	Fishery and resource economy	Researcher

Table 2. Participants in the second round of focus group interviews

Code	Expertise	Occupation
A	Fishery extension	Staff of fishers' association
B	Fishery extension	Staff of fishers' association
C	Fishery extension	Section chief of fishers' association
D	Fishery extension	Staff of fishers' association
E	Marine and coastal management	Scholar
F	Aquaculture	Scholar
G	Coastal ecological management	Researcher
H	Fishery and resource economy	Researcher
I	Aquaculture	Manager (aquaculture farmer)

4.4. Key messages collected from the interview results

4.4.1. First round

The interviewees' opinions are summarized in Table S1 in the Supplement at www.int-res.com/articles/suppl/q013p477_supp.pdf. In terms of environmental issues, 4 interviewees believed that water resources, subsidence, and freshwater salinization were major environmental problems facing aquaculture farming. One interviewee indicated that subsidence, water resources, and freshwater salinization were relatively more severe environmental problems affecting the coastal aquaculture industry. Another interviewee mentioned that freshwater resources could not be effectively allocated to farmers for use and that the most problematic area of aquaculture is the overexploitation of groundwater; however, because the government has yet to properly and effectively allocate water resources, aquaculture should not be held entirely accountable for this problem. An interviewee also questioned whether farmers were the main culprits behind the subsidence and water resource problems and stressed the need to establish a causal relationship. One of the interviewees indi-

cated that farmers rarely consider environmental problems and suggested that whether or not aquaculture is environmentally friendly is another problem that needs to be addressed. In summary, most interviewees indicated that water resource issues are major environmental challenges for Taiwan's coastal aquaculture.

In terms of governmental measures, respondents indicated that the government should adopt practices that ensure the efficient use of water resources. For example, the interviewees believed that freshwater could be fed into aquaculture farms and then redirected back into paddy fields, thereby increasing the efficiency of water resources. In addition, they suggested that water could be extracted from canals. Seawater is generally extracted from inshore waters near coastal embankments; however, there is no effective allocation and management for seawater extraction, thus causing coastal landscapes to be in disarray. Therefore, the government needs to formulate effective water supply and extraction measures. An expert mentioned that PES, administrative control, or environmental trusts are applicable methods; however, which of these solutions are better or feasible must be assessed. The purpose of PESs in aquaculture is to provide farmers with an alternative environmentally friendly culturing method on the premise that fish feeds can be sustainably supplied.

An interviewee suggested formulating policies for a specific area first to address the different problems facing aquaculture farms in counties and cities along the western and southern coasts of Taiwan. In fact, no specific agencies or entities (such as fisheries authorities, environmental authorities, or natural conservation authorities) are responsible for PES implementation in Taiwan. However, most of the interviewees suggested that the entity managing the implementation of a PES scheme must be established or identified and that the governing agencies with which the body communicates must be defined to resolve any problems derived thereafter. With the support of government policies, proposals, goals, and implementation methods for each stage should be established, and local farmers' support must be obtained simultaneously.

Economic means might transform aquafarmers into ES providers, and the experts in the interviews mentioned that ownership of aquaculture farms must be clearly defined before a PES policy can be implemented. In Taiwan, some aquaculture farmers are landowners (landlords) while others are tenants. Thus, establishing ownership can be achieved by employing administrative control, and the influence of existing production practices should be minimized. Interviewees also recommended that basic information be collected about the aforementioned problems before conducting a PES assessment. Aquaculture farmers were most concerned about the level of monetary compensation if they were to change their current practice. Thus, such policies should involve self-funding (i.e. obtaining required funds from management targets). Two interviewees suggested sourcing funds for PESs from corporate organizations because the government might not have the budget for PES schemes given its current financial difficulties. In general, screening for farmers who exert a greater environmental impact was identified as an important policy objective for developing a PES scheme.

In this meeting, the interviewees also discussed feasible directions for the implementation of PESs in Taiwan. Two interviewees suggested focusing on lagoon oyster farming to promote a new PES scheme because the oyster racks in this area could be suitable for a preliminary investigation of the ESs derived from the area. One interviewee mentioned aspects regarding ES valuation in aquaculture farms. The purpose of a payment is to change the behaviors of farmers. Hence, the vision and problems of PES implementation should be established to devise policy goals. Problems that should be considered include the negative environmental impact of existing aquaculture practices and how to encourage farmers to adopt environmentally friendly practices.

4.4.2. Second round

The second round of results provided additional useful information and findings regarding the research purpose (Table S2). The interviewees indicated that oyster farms in Tainan city mainly use floating racks to cultivate oysters. Because oyster larvae are difficult to cultivate, oyster farmers in Tainan city usually purchase juvenile oysters in Chiayi County, thereby reducing the risk of losses. A majority of interviewees maintained that natural disasters substantially influence oyster farming facilities. Complete facilities or methods to mitigate such impacts are not available, and government relief is limited. Thus, natural disasters are a risk that farmers must assume.

The interviewees indicated that oyster racks and polystyrenes are discarded every season after oyster harvesting, and these waste materials have severely polluted the coastal environment. Simi-

larly, waste (mostly polystyrene) generated from oyster farming activities is scattered along the coasts and in coastal waters, which negatively affects the coastal landscapes and recreational quality. City governments have attempted to address these problems by meeting with farmers to discuss and collect their opinions. Another major problem in oyster farming is the generation of marine litter in the form of polystyrene foam, which represents a further ecological impact on oyster farming. The interviewees also indicated that the Tainan city government is managing oyster farms in shallow seas by establishing rules and regulations for oyster farming management: (1) self-governance rules for the management of shallow sea oyster farming in Tainan city require oyster farmers to report and recycle culturing facilities and (2) regulations governing the management of floating raft oyster farming in Tainan city stipulate control over the total number of oyster racks allowed.

Currently, Taiwan does not have a comprehensive policy for marine debris management or a smooth communication channel for local government agencies to address marine debris problems. The government should focus on awareness campaigns, increase the duration of ocean education in schools, raise people's environmental awareness in daily activities, and integrate environmental awareness and cognition with community residents and business operators. The government should also reinforce its continuous management and monitoring of marine debris. Besides compulsory regulations, a payment scheme by ES users is recommended. The use of polystyrene floats should be reduced by coupling the aforementioned system with incentive programmes. Furthermore, polystyrene floats should be treated and managed as solid waste. In other words, the government should strengthen the enforcement of existing policies, laws, and regulations concerning polystyrene floats, establish complete management systems, and actively promote the use of subsidies or direct payment for the development of alternative materials.

Oysters are cultivated using different methods, such as floating racks and cradle racks (horizontally hanging strings of the fixed rack culture method) (Fig. 2). Hence, different types of oyster cultures around Taiwan can generate dissimilar problems. Two expert interviewees mentioned the need to first determine how the presence or absence of oyster farming affects the environment and then clarify the types of ESs oysters can offer. Only then can we explore how to formulate a PES framework that offers enough incentives to encourage business transformation. If only the perspectives of business owners who believe that growing oysters does not negatively impact the environment are considered, then negative effects on carbon fixation and other ESs, as mentioned above, may be generated. The interviewees referred to relevant studies that reported the carbon fixation effect of oyster farming, thus implying that growing oysters is beneficial to the environment and ecosystems. However, very few people in Taiwan are aware of this aspect. From an ES perspective, the cost of environmental resources should be borne by users, which means that farmers should be ES sellers, while other users (e.g. government and agriculture farmers around these areas) should be buyers.

Fig. 2. Examples of oyster aquaculture in Taiwan: (a) floating racks and (b) cradle racks

5. MANAGERIAL IMPLICATIONS

According to our findings, farmers have not yet fully realized that the sustainability of environmental resources is a key factor for the sustainable development of aquaculture; therefore, they occasionally make inappropriate decisions with respect to their aquaculture practices. Additionally, this study found that the foremost task of addressing aquaculture problems is improving resource use, and several studies have described the potential solution to aquaculture resource issues (Mao 2002, Frankic & Hershner 2003, Primavera 2006). In this section, we discuss PES development in terms of environmental issues based on our findings.

5.1. PES framework development

The PES framework varies according to the participants involved; we developed a PES framework for Taiwan's aquaculture according to Greiber's (2009) suggestions and our findings. The operational framework is shown in Fig. 3. In this framework, ES buyers are users of ESs, such as the government, public, stakeholders, community/local residents, and non-profit organizations, whereas ES sellers are providers of ESs, such as landlords, farmers, and farms/land managers. Moreover, 2 critical tasks in this framework need to be assessed. First, ESs provided by coastal aquaculture farms should be identified and evaluated as potential objects of transaction. Second, a PES market should be designed based on ES evaluations. Subsequently, effective incentive and conditionality designation represents the key factor for PES schemes. The entire framework should be supported by legal bases and institutional arrangements. The details are discussed in the following section.

5.1.1. ES identification

The ESs of coastal aquaculture mainly include water regulation, water purification, climate regulation, carbon fixation, habitats and biodiversity, landscapes, and aquatic product production. These services could be potential subject matters of the transaction in a PES scheme. According to the results of our focus group meeting and related research (Huang 1997, Chen & Qiu 2014), water management is the main problem encountered by Taiwan's coastal aquaculture. Therefore, the efficiency of water use and the improvement of water resources and quality are the first problems to be solved. As an example of a water resource issue, freshwater could be fed into fish farms and then redirected back into paddy fields, thereby increasing the efficiency of water resources. Pond water could be extracted from canals; however, there is currently no effective allocation and management for water extraction from canals, which causes coastal pipelines to be in disarray, resulting in environmental and landscape problems.

Southwestern Taiwan is an important region for migratory birds in winter; thus, ecological environments, habitats, and biodiversity are other important services. These migratory bird habitats can also provide opportunities for ecotourism (birdwatching) and environmental education. Therefore, for the surrounding leisure and tourism industries, coastal aquaculture can also provide cultural services, such as aesthetics, landscape, and sightseeing (Lew & Wu 2017, Huang 2021).

5.1.2. Scheme development based on market design

PES schemes must be designed to consist of an ES buyer and seller. Buyers in PES schemes are users of ESs, and in this case, the PES schemes are user-

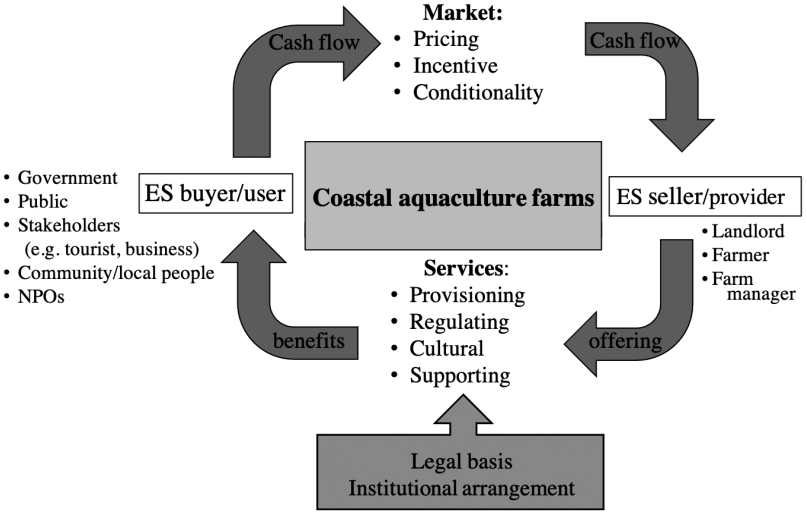

Fig. 3. Framework of the payment for ecosystem services scheme designed for Taiwan's aquaculture industry. ES: ecosystem service; NPOs: non-profit organizations

financed. Some PES schemes are designed with the government as buyers, and in this case, the PES schemes are government-financed (Engel et al. 2008). The PES framework varies according to the participants involved. When a PES scheme is managed by the government, it is called a public PES (or government-driven PES) in which the government intervenes in ES transactions, thereby ensuring that a specific ES is protected and supplied (Greiber 2009). According to the focus group interview results as well as those reported by Alston et al. (2013) and Swallow & Meinzen-Dick (2009), ownership must be defined first to serve as a basis for institutional design before implementing a PES scheme. When PES is implemented, farmers are most concerned about the amount of compensation that they can receive. That amount depends on the source of the funding and how self-funding is achieved. Therefore, pricing ESs is critical for implementing PES schemes in coastal aquaculture.

Several studies pointed out that when a PES scheme is designed, in addition to pricing based on the evaluation of ESs, economic incentives and conditionality are the key factors for a successful PES scheme (Kaczan et al. 2013, 2017, Kerr et al. 2014). Therefore, we need to consider payment methods, timing, monitoring, agreement, and service links in developing PES schemes for Taiwan's coastal aquaculture. The following suggestions may be useful: (1) the establishment of mandatory unified water intake stations that are subsidized or operated by the government can reduce random water use by farmers, reduce the pressure on water use, and improve the ESs of water purification, water conservation, and flood regulation in coastal aquaculture; (2) government subsidies can be used for ecologically friendly aquaculture that uses low environmental impact materials (e.g. natural materials or reusable material), circulating water systems, or probiotics to improve the aquaculture environments, thereby enhancing the benefits of ESs for coastal aquaculture; (3) for aquaculture farms located in important habitats and biological hotspots, the government should provide low-density and aquaculture fallowing subsidy measures to improve the quality of habitats and increase the effects of biodiversity and species conservation; (4) for the aforementioned items, the main beneficiaries include the public or the surrounding residents, and the government can be considered the main payer. However, a PES fund should be established for other industrial operators or users that are highly dependent on ESs, such as ecotourism operators, agriculture, animal husbandry, and coastal fisheries. The fund can be financed by donations from beneficiaries, environmental taxes, user fees, and investments from stakeholders to operate PES schemes.

5.1.3. Legal basis and institutional arrangement

The laws and regulations of aquaculture management in Taiwan are documented in the Fisheries Act and related sub-laws. Therefore, environmental improvement measures for aquaculture management are formulated and implemented by the Fisheries Agency. However, the Fisheries Agency is concerned about aquaculture development and production activities, so there is no urgency or demand for the formulation of PES schemes to improve environmental issues associated with aquaculture. After the Coastal Management Law and the Wetland Conservation Law were implemented, the legal foundation and basic structure began to be used as the basis for the implementation of PESs so that such schemes could be managed by the Land Management Department or the Environmental Conservation Department.

The Wetland Conservation Act and Coastal Management Law were effectuated in 2015; the law stipulates various types of compensation measures as the legal framework for the application of PESs. The Wetland Conservation Act and Coastal Zone Management Act again highlight how the process of drafting and negotiation can consider both the original agricultural and fishery purposes of coasts and wetlands from an anthropogenic standpoint and the problems concerning ecological conservation. Since the promulgation of the Wetland Conservation Act, several wetland types have been established by the Act. During the process of establishment, traditional farmers expressed concerns and conflicting emotions about the regulatory system, and this was reflected in the focus group interviews in this study. Conflict associated with the concept of PES involves considering how to economically incentivize traditional farmers to accept eco-friendly practices. According to Article 4 of the Wetland Conservation Act, no net loss to coastal wetlands can be achieved by 'adopting impact mitigation, off-site compensation or ecological compensation in the development and utilization acts, to ensure no loss to the wetland area and its ecological functions.' No net loss has occurred since the 1990s in the USA (Robertson 2000), and it is currently an important ecological conservation and restoration policy for global wetlands. Eco-compensation and mitigation policies have been adopted in several

countries, such as in Canada (Rubec & Hanson 2009), China (Xiong & Wang 2010), and the USA (Zedler 2004). Given this context, the use of a PES scheme can encourage coastal farmers to provide ESs by adjusting their aquaculture farms to restore or improve local wetland environments and motivate farmers to provide constructed wetland ESs. Consequently, this mechanism can serve as a potential pathway to achieving 'off-site compensation' and 'no net loss' in the utilization of wetland resources.

5.2. Feasible methods of oyster aquaculture

This subsection adopts coastal oyster farming as mentioned in the focus group results as an example to discuss the feasibility of promoting PES schemes, the status of relevant policies, and future development. Relevant research is limited in Taiwan, although one study offered a framework for ecosystem restoration by oyster farming and suggested that the government should invest 11 million NTD yr^{-1} to ensure oyster farming ESs for wetland restoration (Kung 2013).

Numerous studies have indicated the environmental benefits of oyster reefs (Grabowski et al. 2012), but ESs provided by oyster farming are seldom discussed in Taiwan. From the economic perspective of negative externalities, the greatest environmental problem caused by coastal oyster farming is the generation of polystyrene foam and waste, which are marine debris that impose environmental risk to coastlines, specifically under climate and environmental influences. These polystyrene foams and wastes have been verified as risk factors to marine organisms (Jang et al. 2016). Therefore, as a solution to environmental problems, PES schemes can be applied to coastal oyster farming by first calculating the costs of replacing polystyrenes with other low environmental impact materials. Coastal oyster farmers who adopt eco-friendly aquaculture practices should receive subsidies to secure revenues. In 2012, the Tainan City Government announced an autonomy regulation to manage oyster farming, and it required farmers to deliver applications for farming rights (free of charge) in the waters of Tainan city. In 2020, the Chiayi County Government announced a new autonomy regulation to regulate oyster farmers, who were required to obtain farming rights. This new regulation also sets a farming right fee for different styles of oyster farming. Suspended tray oyster farmers must pay 1000 NTD per hectare, while floating rafts are 500 NTD per shed; additionally, farmers must cooperate with the local government to recycle abandoned sheds and eliminate uncoated polystyrene buoys. In addition, the Fisheries Agency began to design incentives for traceable and environmentally friendly aquaculture farmers in 2020, although such work is still in the planning and demonstration stage and does not represent a comprehensive PES scheme for environmental issues. Thus, a comprehensive PES scheme for Taiwanese aquaculture remains to be developed.

6. CONCLUDING REMARKS

PES schemes can become key policy instruments if the governing agency can engage in proper institutional planning, provide economic incentives, and effectively communicate policy contents. Aquaculture farmers are concerned about whether their own economic benefits will be affected; therefore, the identification of ESs and implementation of a market design (e.g. pricing, incentives, conditionality) in a PES scheme might be important success factors for shifting aquaculture to an ES provider.

Several recent regulations have served as the legal basis for PES schemes or incentive-related policy instruments. Currently, Taiwan's government agencies have begun to develop payment schemes and have tried to improve the sustainability of coastal aquaculture; thus, we need to conduct more comprehensive assessments to provide useful information and references for policy makers and resource managers.

In conclusion, this study provides suggestions and directions for PES schemes in coastal aquaculture management. Additionally, more ES valuations and PES trade mechanisms for coastal aquaculture will provide important reference values for the design of PES schemes.

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