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Integrated Adaptation Strategies for Human–Leopard Cat Coexistence Management in Taiwan

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Abstract: In Taiwan, the leopard cat (*Prionailurus bengalensis chinensis*) remains the only extant native wild cat species. Previous studies have suggested anthropogenic factors as a cause of their decline, mainly due to conflicts with local farmers. Adaptation strategies that generate co-benefits are key to achieving human–wildlife coexistence. However, an understanding of the local views on such strategies is currently lacking. In this study, we performed the first regional assessment of 10 adaptation strategies for human–leopard cat coexistence and examined the impact of the socio-demographic factors affecting farmers' willingness to participate in these strategies based on quantitative interviews with 418 farmers in Miaoli County, employing an importance–performance analysis. We also present an integrated conceptual framework capturing five adaptation strategy domains and their resulting benefits, which lay the structural foundation for facilitating resilient coexistence. Our findings suggest that (1) respondents' perceived importance and performance of adaptation strategies were significantly different; (2) respondents most agreed with improvements in the incorporation of local knowledge/skills into science and policy and the establishment of adaptive co-management with local associations/non-governmental organisations; and (3) respondents aged below 49 years, supportive of coexistence, who did not own poultry, and preferred local farmer organisations to facilitate coexistence, were more likely to participate in the proposed adaptation strategies. Our findings provide guidelines for the future direction of the conservation and management of leopard cats that help achieve harmonious coexistence in shared landscapes.

Keywords: adaptive capacity; carnivore conservation; human dimensions; human–wildlife coexistence; importance–performance analysis

Citation: Nguyen, L.B.; Chen, H.-C.; Seekings, T.B.W.; Dhungana, N.; Chen, C.-C.; Lee, C.-H. Integrated Adaptation Strategies for Human–Leopard Cat Coexistence Management in Taiwan. *Sustainability* **2024**, *16*, 4031. https://doi.org/10.3390/su16104031

Academic Editors: Itai Beeri, Ofira Ayalon and Orit Hirsch-Matsioulas

Received: 12 April 2024
Revised: 6 May 2024
Accepted: 9 May 2024
Published: 11 May 2024

1. Introduction

Human–wildlife conflict (HWC) presents a global conservation and wildlife management challenge [1]. Although humans have coexisted with wildlife for millennia, growing competition over habitats and resources has increased steadily [2]. Conflicts arising from this competition have contributed to the extinction of numerous species [3], changes in ecosystem structure and function [4], and the loss of crops, livestock, property, and human life [5,6]. Worldwide, substantial declines in the geographic ranges and population sizes of carnivore species have been reported [7,8], adding pressure to an existing vulnerability to extinction due to their biological traits [7,9]. Presently, the ranges of numerous carnivore species such as tigers [10], lions [11], jaguars [12], and leopard cats [13] are located increasingly within human-dominated and human-modified landscapes (e.g., agricultural areas), in part because their respective prey species (e.g., poultry, cattle, rodents) inhabit those areas. The frequency and economic cost of conflicts between humans and carnivores have widely increased [14,15] and sustainable human–wildlife coexistence remains severely impeded because of inadequate adaptation strategies.

In Taiwan, which is generally characterised by a low predator density, the leopard cat (*Prionailurus bengalensis chinensis*) remains the only living native species of wild cat (*Feloidea*) after the Formosan clouded leopard (*Neofelis nebulosa*) was declared extinct in 2013 [16]. Despite being classified as an 'endangered' species and fully protected by national laws since 2008 [17], their number has drastically decreased to less than 500 individuals, which are distributed among three isolated populations on the West coast of Taiwan in Miaoli, Nantou, and Taichung counties [18]. The species often suffer from anthropogenic factors, including habitat fragmentation and degradation [19], road kills associated with increased infrastructural development, pesticide contamination through their prey [18], and illegal trapping and poisoning due to retaliatory reactions from farmers, for whom leopard cats are poultry pests [19,20].

The obvious vulnerability of leopard cats and the importance of their protection are widely recognised by conservationists. However, to date, their overall conservation effort is characterised as being inconsistent and heterogeneous, with insufficient communication and collaboration among diverse stakeholders who have different and sometimes conflicting interests. Common conservation efforts involve mitigation measures such as the promotion of leopard-cat-proof chicken coops. Yet, this concept has not gained much traction as few smallholder farmers want to invest in costly coops. Other popular measures include erecting simple and cheap fences. However, these are usually insufficient for deterring unwanted animals. In addition, according to locals, feral dogs have exacerbated human–leopard cat conflicts by attacking poultry and, while doing so, creating holes in fences that then enable leopard cats to enter, too. Furthermore, regardless of any particular mitigation measure, even when wild animals like leopard cats are not directly involved in harming people or their property, disputes over the risks and values associated with conserving such species give rise to underlying social conflict [21,22], especially when conservation interests conflict with livelihoods and economic development and when stakeholders have deeply entrenched and irreconcilable beliefs or priorities [23]. This is no different in the rural counties of Taiwan, including our research sites.

Leopard cats enjoy a largely positive reputation in Taiwan and the importance of their conservation is widely recognised. However, this is rarely reflected at the local level, where impacted communities suffer substantial and diverse costs due to their presence. Due to the continuing and increasing number of incidences of HWCs involving leopard cats, conservation efforts have become more concerted in recent years, especially with the "Payments for Ecosystem Services (PES) for Endangered Species and Critical Habitat Promotion Programme", launched in 2021 by the Forest Bureau of the Council of Agriculture (COA), which seeks to balance the need for species conservation and local economic development. This programme incorporates an incentive system that pays "ecosystem wages" [24] for favourable initiatives, including eco-friendly farming, community patrol teams, and conservation promotion. It also offers compensation to farmers who experience poultry depredation. However, while this programme constitutes the most comprehensive approach to date, to our knowledge, local people in the target areas were not involved in any stage of the design of the programme. As a result, the extent to which the programme actually reflects the values and needs of local communities, as well as their participation in and support for its respective efforts and initiatives, remains unclear. Up to now, no assessment of the effectiveness of the current efforts in leopard cat conservation in Taiwan, including this PES scheme, has been conducted. While a previous study indicated that local attitudes towards leopard cats improved on the basis of a hypothetical PES scenario, the underlying reasons behind those attitudes remained opaque [25]. A few individuals merely refer to PES as motivation for increasing their tolerance for wildlife disturbance or for supporting wildlife conservation [25]. By contrast, local people raised some concerns about the programme, including unsustainable long-term funding, insufficient compensation to offset costs, the occurrence of cheating by increasing the presence of wildlife on private land to maximise payments, adverse effects resulting from increased incidences of illegal hunting [25], and the exacerbation in local inequality through participation filters (i.e., compensation is paid to landowners rather than to tenant farmers).

Human–leopard cat coexistence and the necessary adaptation strategies for achieving favourable outcomes of this coexistence necessarily involve the consideration of complex social relations and the underlying interests and values of individuals and communities. While conservation is a public interest, the majority of leopard cat hotspots are located on private land [18]. Therefore, the values and attitudes of local people are of crucial importance. Generally, negative attitudes towards wildlife and their protection can lead to illegal killings and opposition to management policies, thereby hindering conservation efforts [26]. Similarly, exclusion from decision-making processes often leads to resentment and feelings of alienation in locals [27,28]. Debates over how and whether to coexist with other animals are drivers of social, economic, and political conflict within and among human communities [5,22]. Thus, understanding, mitigating, and resolving the social conflicts surrounding conservation are central to achieving favourable outcomes, including the protection and restoration of species.

Regarding leopard cats in Taiwan, conservation efforts to date remain characterised by an insufficient appreciation of the human dimension of the implicated conflicts; in other words, conflicts of interest among the different stakeholders. Among these, the values and attitudes of local people are the least understood and the least integrated. In addition, current adaptation strategies involve disparate efforts pursuing separate objectives. To ensure mutual adaptation and coexistence in shared landscapes, an integrated approach is necessary, in which sufficient consideration is given to the perspectives, attitudes, and needs of locals, who constitute the first line of contact with wildlife. Yet, in Taiwan, research on local perceptions of adaptation strategies for human–wildlife coexistence is scant, and local, specific interdisciplinary research on the more effective incorporation of these strategies is currently lacking. This limits the opportunities to promote collaboration among stakeholders to ultimately address HWCs. Such research is urgently needed to guide effective interventions and facilitate contextualisation within international conservation discourse. Only through a comprehensive assessment of adaptation strategies co-benefiting local people and wildlife can possibilities for achieving advanced and sustainable coexistence in a changing world be identified.

In this study, we conducted the first regional assessment of adaptation strategies for the management of conflicts with wildlife from the viewpoint of farmers, focusing on the 'endangered' Formosan leopard cat and using an importance–performance analysis approach. We also constructed an integrated adaptation framework for human–wildlife coexistence that bolsters the locals' capacity to adapt to HWCs. The outcomes of this study provide insights and practical benefits for improving the conservation of leopard cats and their management in Taiwan and thereby aid in facilitating sustainable coexistence. Our findings can help in understanding and fostering positive behaviours in local communities to reduce the threat to leopard cats, strengthen stakeholder relationships, and enable the designing of effective wildlife policies and incentives. The scope of this research is the integration of adaptation strategies under a guiding framework centring solely on leopard cats in the context of Taiwan. However, our conceptual framework, methods, and emerging themes are pertinent to wildlife conservation worldwide, particularly in cases characterised by a lack of integration between adaptation strategies and community inclusion.

2. Materials and Methods

2.1. Study Areas

This research was conducted in three townships in Miaoli County: Yuanli, Tongxiao, and Sanyi, which are situated in western Taiwan (Figure 1). There are 15,530 households in

Yuanli, 11,520 in Tongxiao, and 5561 in Sanyi, with 4179, 3884, and 1047 farming households in each township, respectively [29,30]. These townships were chosen because they are leopard cat hotspots [13,18] and because they are beneficiaries of the "Leopard Cat-Friendly Ecological Service Payment" programme offered by the Taiwanese government.

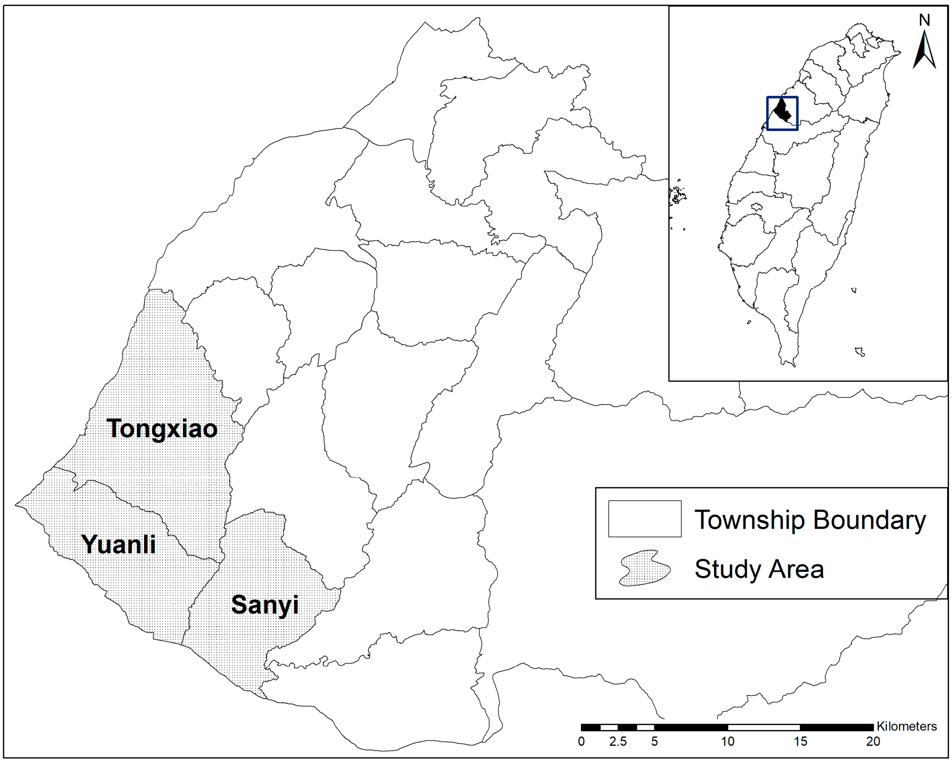

Figure 1. Map of Tongxiao, Yuanli and Sanyi Townships, Miaoli County, Taiwan.

2.2. Integration of Adaptive Capacity Framework into Human–Wildlife Coexistence

Adaptive capacity refers to the coping mechanisms and mitigation strategies [31] that enable people to anticipate and respond to change, minimise its consequences, recover, and take advantage of new opportunities [32]. Cinner, et al. [33] synthesised research across a range of disciplines to highlight how adaptive capacity could be built across five critical domains in (but not limited to) the field of climate change [34,35]. These are (1) the assets that people can draw upon in times of need; (2) the flexibility to change adaptation strategies; (3) social organisation, as in the relationship between individuals, communities, and organisations; (4) learning to recognise and respond to changes; and (5) the agency that provides people with the ability to manage changes in the future. When applied to the field of HWCs, access to these five domains enables local people to reduce the impact of conflict by implementing protection measures, substituting foregone income with other income sources, minimising economic loss by changing practices, and, most importantly, working collectively with different stakeholders to achieve co-adaptation.

Here we present an integrated adaptation framework for human–wildlife coexistence (Figure 2) that aids in building people's adaptive capacity at the local level to support local communities in adapting to the impacts of HWCs. This conceptual framework comprises three interrelated layers with beneficial interactions. The outer layer, the adaptation strategies domain, uses the five core elements of the adaptive capacity framework, which entails recognising the importance of adaptive capacity: assets, flexibility, social organisation, learning, and agency. The middle layer depicts the resulting benefits, with the underlying assumption that successfully implementing adaptation strategies would enhance locals' adaptive capacity to manage conflicts with wildlife. A safe environment enabling both local people and wildlife to thrive is crucial for maintaining healthy biodiversity and achieving conservation outcomes while safeguarding human well-being and economic benefits. Resilient communities that can navigate the complexity of HWCs possess the capacity to withstand, adapt to, and recover from the challenges posed by interactions with wildlife, while maintaining their social, economic, and ecological integrity. A strong collaboration among stakeholders, fostered by effective communication and shared adaptive co-management, is the product of building trust and consensus, learning through sharing, and incorporating local knowledge and expertise in decision-making processes. This adaptation process ultimately improves the effectiveness and legitimacy of policies and regulations related to HWC management to ensure that management interventions are contextually appropriate, socially acceptable, and environmentally sustainable. At the heart of the framework is the goal of achieving coexistence between humans and wildlife through the intangible process of integrating adaptation strategies into everyday life. The following subsections detail the characteristics of each adaptation domain and provide examples of existing adaptation strategies.

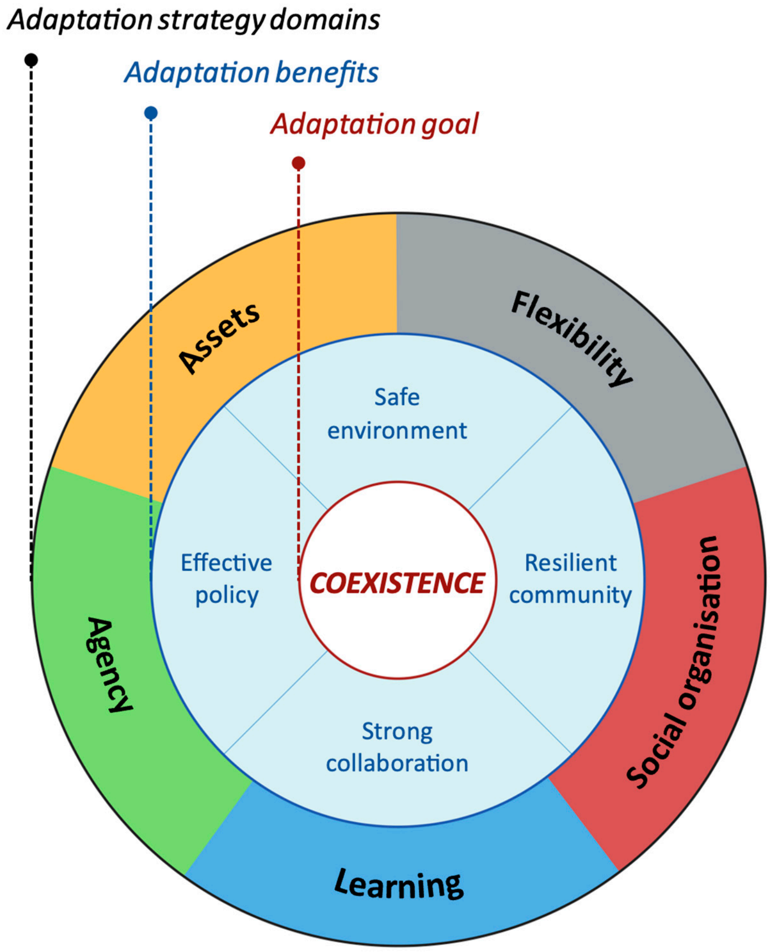

Figure 2. Adaptation framework for human–wildlife coexistence, illustrating the three interrelated layers, with the outer ring capturing core adaptation strategy domains, the middle ring featuring the resulting adaptation benefits, and the centre representing the ultimate adaptation goal—coexistence between humans and wildlife.

2.2.1. Assets

The accessible assets that people have to adapt to wildlife conflicts could be financial, technological, or service resources [33], often found in the form of prevention and mitigation measures [1,36,37]. Preventative measures refer to actions that help prevent HWCs or minimise their impact [15]. This is the core tenet of effective HWC management. These techniques include lethal and non-lethal approaches. Lethal control, such as legal hunting and selective harvesting, has been widely applied to non-protected species [5,6,38]. Nonlethal measures are primarily used in preventing conflicts with protected species; these include fencing, livestock enclosures, early warning systems, guard animals, and repellents [39]. Mitigative measures aiming to minimise the negative impacts caused by HWCs include systems that provide compensation, insurance, or incentives [5,40,41]. When equipped with the necessary assets, people are generally better able to adapt during times of conflicts.

2.2.2. Flexibility

The flexibility domain refers to the ability of people, in switching to the adaptation strategies available [33], to reduce ecological impacts while maintaining economic development. In communities prone to HWCs, this could be modifying current practices such as converting intensive conventional agriculture into wildlife-friendly farming [42], diversifying crops to reduce crop raiding [43], sharing and sparing land for habitat conservation [44,45], and adopting alternative non-invasive methods for controlling pests to avoid secondary poisoning to wildlife [46–48]. Flexibility also entails the possibility of shifting to different occupations either temporarily/seasonally or permanently in response to reoccurring HWCs by developing alternative livelihoods [49–51]. However, diversifying subsistence activities can inadvertently create ecological consequences if not performed properly [33]. In many cases, target communities often lack the necessary knowledge and skills to maintain the new practice and eventually fail to maintain their interest. In addition, abandoning a particular practice and replacing it with something new is associated with a considerable number of risks and costs. Thus, the promoted alternative must meet the needs and aspirations of the concerned groups and the functions of their initial livelihood [52]. Establishing the flexibility element of a person's adaptive capacity would require reliable access to capital and proper training.

2.2.3. Social Organisation

The social connections among stakeholders capture how they are organised to enable trust, dialogue, collaboration, and knowledge exchange [33]. Human–wildlife conflict management often involves multiple parties, including local communities, government agencies, conservation organisations, local associations, and academic researchers. Multi-level cooperation paves the way for an integrated approach by bringing together diverse perspectives and expertise to develop comprehensive solutions that address the root causes of conflicts and promote sustainable coexistence while ensuring shared responsibility among all actors. Building the social organisation component requires effort, resources, opportunities for open and safe discussions between the stakeholders involved, and a willingness to share power in during knowledge and decision-making [53]. Trust and social cohesion within this network often determine whether people support each other and act collectively when HWCs occur [33,54]. Increased trust through inclusive and fair participatory processes is thus more likely to lead to the resolution of conflicts between humans and wildlife, as well as underlying conflicts among stakeholders [53]. In cases where interpersonal or institutional distrust exists, a third party can play an essential role in between affected communities and other stakeholders by creating space and providing a means for mutual communication and sustainable cohesion [55]. An ideal facilitator, however, should act on behalf of local people to avoid being seen as an ally of other powerful parties, especially those that generate distrust in the first place.

2.2.4. Learning

The domain of learning describes the local capacity for generating, absorbing, and processing new information and adaptation options and applying them in real-life situations to manage changes and uncertainty [33]. In response to HWCs, local people need to learn a variety of skills and gather knowledge to play a proactive role in managing HWCs in ways that are both effective and sustainable. For example, understanding wildlife's behaviour and ecological roles aids in comprehending the movement patterns of different species, allowing for an anticipation of where and when conflicts might occur [56,57]. Likewise, conflict resolution techniques and their implementations are key elements that enable humans and wildlife to coexist [1,36,37], which can be provided through both formal education and informal learning forums where people are encouraged to bond through sharing their experiences and knowledge across different systems (e.g., stakeholders from different backgrounds such as indigenous communities, wildlife experts, and governmental authorities). Furthermore, regular updates on novel sustainable practices and adaptation strategies [58–60], as well as legal and policy frameworks [61], help foster community resilience in the face of unprecedented conflicts. However, learning may only lead to adaptation once other the domains of adaptive capacity are sufficiently present [33].

2.2.5. Agency

The agency domain refers to the local ability to manage prospective environmental changes [33]. Effective adaptation to HWCs requires people to have not only assets, flexibility, social organisation, and learning, but also the autonomy to respond to events that directly affect their lives. Integrating local ecological knowledge, experiences, and skills into science and policy can build local adaptive capacity and ownership [62–64], resulting in decisions that are more socially appropriate and politically acceptable [65,66]. When local communities are empowered, they become more invested in their success and conservation outcomes, and then become more sustainable. Considering the complexity of HWCs, adaptive co-management would help strengthen local adaptability and resilience through its dynamic, inductive, and self-organised process, centred on collaboration and social learning [67]. Unlike traditional top-down governance, this holistic management approach allows for the development of context-specific solutions that are tailored to the needs and priorities of affected communities [53,68,69]. At the same time, it facilitates communication and cooperation and nurtures trust, respect, and transparency among stakeholders [68,70,71]. Most importantly, an assessment of the adaptive co-management process needs to be implemented, and its findings should be communicated to local people and other stakeholders to facilitate ongoing research, develop practical strategies, and support partnerships [72].

2.3. Application of the Importance–Performance Analysis

The importance–performance analysis (IPA) is a diagnostic tool first developed by Martilla and James [73] which aims to identify areas in which improvements and priorities are most needed to effectively meet users' expectations and preferences. It is based on the perceived importance and corresponding performance obtained from surveyed respondents for various attributes or characteristics of a service, product, or organisation. Performance refers to one's satisfaction with an attribute, while importance refers to the impact this attribute has on one's overall experience. The attributes are often directly measured using a Likert scale and typically displayed in a two-dimensional plot, with importance represented by the vertical axis and performance constituting the horizontal axis. These two axes divide the IPA grid into four quadrants (Figure 3), where all evaluated attributes are presented on the basis of their mean ratings on the importance and performance scales, providing a visual display of the results and potential management strategies.

Since the interpretation of the IPA grid is relatively simple, it allows stakeholders from different backgrounds to understand the results more easily, making it a versatile decision-guiding tool. Specifically, attributes belonging to Quadrant (I), with high importance and low performance, indicate the elements requiring immediate management attention and maximum prioritisation to satisfy the needs of the target audience. Quadrant (II) represents attributes with high ratings in both importance and performance, meaning that resources are being effectively allocated and efforts should be maintained. These first two quadrants, labelled as the prioritisation zone, are considered the most critical areas where performance needs to be enhanced to meet users' satisfaction. Quadrant (III) harbours attributes that are both low in importance and performance; thus, no additional effort is required because they are of low priority. Finally, attributes belonging to Quadrant (IV), with low importance yet high performance, suggest over-performance, signifying an inappropriate allocation of resources and the lowest priority for investment. The last two quadrants are referred to as the deprioritisation zone.

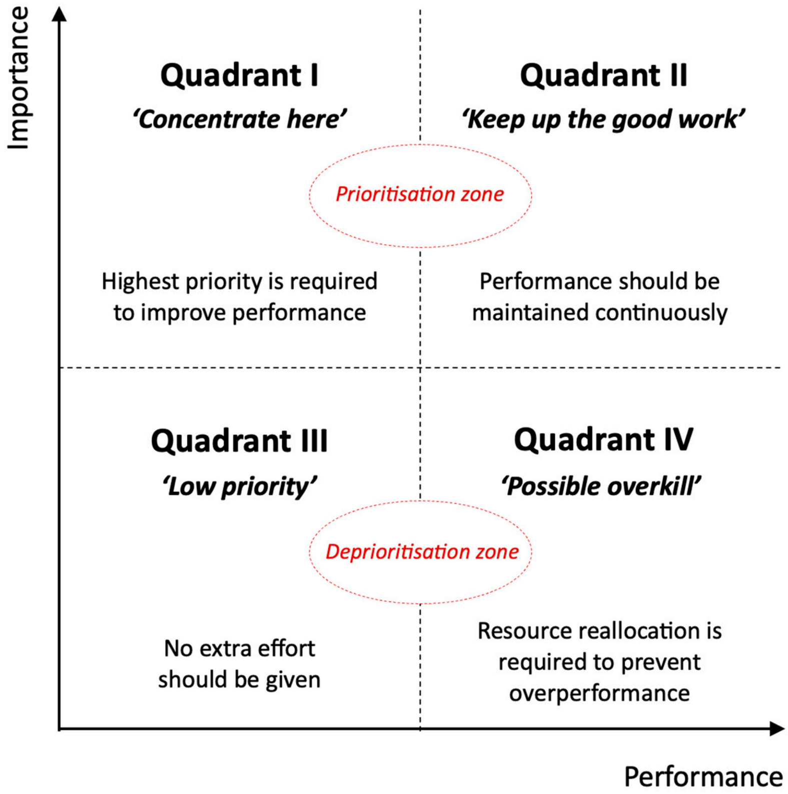

Figure 3. Importance–performance grid (adapted from Martilla and James [73]).

The IPA technique has been widely adopted in various fields and contexts because of its simplicity and user-centric approach [74]. In terms of natural resource management, studies using the IPA matrix have been documented in protected areas' governance [75–79], ecosystem services [80,81], and wildlife conservation [82,83]. The application of an IPA in HWCs grants a distinctive opportunity for the integration of the perspectives of impacted communities into wildlife management and policies. This study employed an IPA to evaluate the relationships between farmers' perceived importance of the adaptation strategies for human–leopard cat conflicts and their perspectives regarding the performance of these measures. This evaluation process facilitated the identification of the adaptation strategies that are considered most important to the local farmers and how well they are performing. Furthermore, we pinpointed the factors that influence farmers' willingness to participate in leopard cat conservation. Drawing from these findings, we discuss our recommendations for future interventions that support coexistence.

2.4. Questionnaire Design

A total of nine in-depth stakeholder interviews were first conducted with individuals who were chosen on the basis of the following inclusion criteria: (1) being involved in the conservation/management/research of leopard cats, (2) having experience with the study sites, (3) representing different groups of stakeholders (i.e., the government, conservation NGOs, academic institutes, local associations), and (4) being potential gatekeepers who could help introduce local farmers to the research. Two of these belonged to the governmental sector, two were non-governmental organisation (NGO) personnel, three were academic scholars, one worked for a local farmer association, and one was from a research institute. We used snowball sampling to select respondents [84]. This involved asking key informants, personal contacts, and respondents to suggest individuals from various backgrounds who would be willing to participate. Most interviews were completed in Chinese, some in English, and they were recorded with permission granted. All interviews were conducted online using the Google Meet platform and lasted one to two hours. Essentially, all interview recordings were transcribed into electronic format via Microsoft Word by a research assistant before being translated into English by the lead author. Following this, all the data were migrated to a Microsoft Excel worksheet. While five attributes were identified prior to the interviews, based on the adaptive capacity framework, the levels of these attributes were thematically processed as they emerged from the results of the stakeholder interviews. These themes were then subsequently refined on the basis of the literature on adaptation strategies for human–wildlife coexistence, resulting in 10 corresponding indicators (Table 1). The identified attributes and indicators were then used for the design of the pilot questionnaire and the formal questionnaire for farmers.

Table 1. Adaptation strategy domains for managing conflicts with leopard cats, and their indicators.

Domain	Indicator	Code	Literature
Assets	1. Installation of proper fencing system	AS1	[85,86]
	2. Effective population control of stray dogs that disturb humans and wildlife	AS2	[87,88]
Flexibility	1. Alternative non-invasive methods to control rodents to reduce secondary poisoning of wildlife	FL1	[46–48]
	2. Wildlife-friendly farming practices	FL2	[58–60]
Social organisation	1. Community meetings to promote social cohesion, information exchange, and cooperation among stakeholders	SO1	[89–91]
	2. Establishment of a local group to facilitate communication among stakeholders	SO2	[55]
Learning	1. Educational guides on the ecological functions of leopard cats and their management methods	LE1	[56,57]
	2. Training and workshops on wildlife-friendly farming	LE2	[58–60]
Agency	1. Incorporation of local knowledge, skills, and management into both science and policy	AG1	[62–64]
	2. Establishment of adaptive co-management with local farmer associations/NGOs	AG2	[53,68,69]

Note: NGOs: non-governmental organisations.

The formal questionnaire was designed on the basis of our literature review, insights gained from stakeholder interviews, and results from the pilot test. It was first developed in English, and then translated to Chinese and back-translated to English to verify the translation. We first piloted it on five colleagues and 35 volunteer farmers in Miaoli, clarifying the wording where required, before beginning actual data collection with farmers. The final questionnaire consisted of three sections. In the first section, respondents were asked a series of questions about their support of coexistence between humans and leopard cats, their preference for a specific party to facilitate human–leopard cat coexistence (i.e., the government, conservation NGOs, and local farmer associations), and their willingness to participate in adaptation strategies for coexistence. The second section employed an IPA to evaluate the relationships between locals' perceived importance of the adaptation strategies for human–leopard cat conflicts and their perspective towards the performance of these strategies. Respondents were asked to rate 10 adaptation strategies on a five-point Likert scale from "1–very unimportant" to "5–very important" for the importance element and from "1–very unsatisfied" to "5–very satisfied" for the performance element. Finally, the third section collected respondents' socio-demographic characteristics, including their gender, age, marital status, educational level, and monthly household income. We also asked an additional question about poultry ownership. The aim was to determine whether having poultry would affect farmers' views on the conservation of leopard cats, since the species is considered a poultry pest.

2.5. Data Collection

A power analysis employing G*Power 3.1.9.6 software [92] was first conducted to determine the appropriate sample size, which was at least 53 farmers for each study area to achieve 95% power, using a one-way ANOVA test with $\alpha = 0.05$.

Interviews were conducted between August and December 2023 at Sanyi, Tongxiao, and Yuanli (Figure 1). Because this study focused solely on farmers, and not the general public, it was relatively challenging and time-consuming to find farmers using traditional sampling methods; the most convenient strategy was to interview respondents at events where they gathered in greater numbers, meaning our research team participated in a series of farmer activities and conducted all interviews on site. A list of farmer activities in the three study sites was provided by the key stakeholders who had previously attended our stakeholder interviews. Interviews were conducted variously in Chinese, Taiwanese, or Hakka, which were spoken fluently by all respondents and research assistants. Well-trained research assistants helped build a rapport with local people and conduct and interpret the interviews. Verbal consent was obtained prior to the interview; participation was voluntary; and respondents were informed that they could stop the interview at any time. Each interview lasted between 45 and 60 min; all respondents were over 19 years of age; and their identities were kept anonymous. We took due care to remain neutral and avoid leading questions and biasing the interviews.

2.6. Data Analysis

We used IBM SPSS Statistics 29 to process all the data collected for this study. Descriptive statistics was used to summarise the socio-demographic backgrounds of the surveyed respondents, as well as their perceptions and attitudes towards leopard cats and their conservation. A matrix of the importance–performance levels was employed to assess the respondents' ratings of the perceived importance and performance of the 10 given adaptation strategies. The arithmetic averages of their importance and performance scores were calculated, and a performance gap analysis was performed to quantify the difference between respondents' satisfaction with the strategies and their perceived importance. The gap was determined by subtracting the mean importance score of a strategy from its respective mean performance score. A negative gap value indicates dissatisfaction with an important indicator, while a positive gap value suggests the opposite. Paired t-tests were used to determine whether there were any significant differences between the means [93]; significance was set at 0.05.

A logistic regression model (LRM), under the theory of binary choice, was used to examine the impact of respondents' characteristics (independent variables) on their willingness to participate (WTP) in the adaptation strategies for human–leopard cat coexistence (dependent variable). Two models were constructed, and both consisted of the same dependent variable and independent variables; however, only the mean importance was included in the first model as the quantitative independent variable, while only the mean performance was included in the second model. Other variables that served as dummy variables were farmers' socio-demographic characteristics (e.g., gender, age, marital status, educational level, monthly household income), their preference for local farmer associations to facilitate coexistence with leopard cats, support for human–leopard cat coexistence, and poultry ownership. The models' goodness-of-fit (GOF) was determined using the Akaike information criterion (AIC) and log-likelihood ratio (LLR).

The formula for the AIC in the LRM is as follows:

$$\mathrm{AIC} = 2\mathrm{k} - 2\log(\mathrm{L}), \quad (1)$$

where k is the number of parameters in the model and log(L) is the maximised value of the log-likelihood function for the model.

The LLR can be estimated using the following equation:

$$\mathrm{LLC} = -2\log(\mathrm{L}_{\mathrm{null}} - \mathrm{L}_{\mathrm{full}}) \quad (2)$$

where log(L_{null}) is the log-likelihood of the constant-only model and log(L_{full}) is the log-likelihood of the final iteration of the model, with all predictors included.

3. Results

3.1. Respondents' Characteristics

A total of 418 valid questionnaires were obtained and analysed (Yuanli N = 189, 45.2%; Tongxiao N = 175, 41.9%; Sanyi N = 54, 12.9%) (Table 2), which met the computed sample size for G*Power. There were slightly more male (N = 238, 56.9%) than female respondents (N = 180, 43.1%), with most being married (N = 322, 77.0%) and over the age of 49 (N = 260, 62.2%). The majority of surveyed farmers were educated at the undergraduate level and below (N = 381, 91.2%), with fewer reaching the post-graduate level and above (N = 37, 8.9%). Their monthly household income varied, with 67.7% of respondents' (N = 283) families earning up to 60,000 New Taiwan Dollars (NTD) per month, 25.1% (N = 105) gaining between NTD 60,001 and NTD 100,000 per month, and only a small proportion, 7.2% (N = 30), having an income above NTD 100,000 monthly.

Table 2. Summary of respondents' socio-demographic characteristics.

Variable	N (%)		
	Supporters	**Non-Supporters**	**Total**
Gender			
Male	226 (57.2)	12 (52.2)	238 (56.9)
Female	169 (42.8)	11 (47.8)	180 (43.1)
Age			
20–29	39 (9.9)	0	39 (9.3)
30–39	41 (10.4)	0	41 (9.8)
40–49	75 (19.0)	3 (13.0)	78 (18.7)
50–59	120 (30.4)	12 (52.2)	132 (31.6)
Over 59	120 (30.4)	8 (34.8)	128 (30.6)
Marital status			
Married	301 (76.2)	21 (91.3)	322 (77.0)
Single	94 (23.8)	2 (8.7)	96 (23.0)
Educational level			
Junior high or below	115 (29.1)	12 (52.2)	127 (30.4)
Senior high	133 (33.7)	5 (21.7)	138 (33.0)
Undergraduate	111 (28.1)	5 (21.7)	116 (27.8)
Post-graduate or above	36 (9.1)	1 (4.3)	37 (8.9)
Monthly household income			
Up to NTD 40,000	134 (33.9)	5 (21.7)	139 (33.3)
NTD 40,001–60,000	132 (33.4)	12 (52.2)	144 (34.4)
NTD 60,001–80,000	52 (13.2)	2 (8.7)	54 (12.9)
NTD 80,001–100,000	47 (11.9)	4 (17.4)	51 (12.2)
NTD 100,001–150,000	18 (4.6)	0	18 (4.3)
Above NTD 150,000	12 (3.0)	0	12 (2.9)
Total			418 (100)

Note: NTD: New Taiwan Dollar; NTD 1 = USD 0.033.

We separated the sample into two groups: respondents who supported the adaptation strategies for human–leopard cat coexistence and those who did not support such measures. The number of supporters (N = 395, 94.5%) was much larger than that of those who were non-supportive (N = 23, 5.5%). Table 2 details a summary of the respondent socio-demographic characteristics of each group.

3.2. Perceived Importance and Performance of Adaptation Strategies

Table 3 outlines the means of the importance and performance of each of the indicators. Both the groups of supporters and non-supporters uniformly assigned a high level of importance to the 10 adaptation strategies, with mean scores of 4.34 and 4.28, respectively.

A gap analysis reveals significantly negative gaps for all indicators, with the perceived importance scores substantially higher than performance scores.

Table 3. Importance–performance means and gap analysis of adaptation strategy indicators.

Code	Indicator	Mean (Rank)		Gap P-I	t-Value	*p*-Value
		I	P			
Supporters (N = 395)						
AS1	Assets 1	4.44 (2)	3.14 (5)	−1.30	17.27	<0.001
AS2	Assets 2	4.37 (4)	2.26 (9)	−2.11	20.73	<0.001
FL1	Flexibility 1	4.07 (9)	2.82 (7)	−1.25	15.03	<0.001
FL2	Flexibility 2	4.32 (6)	3.20 (3)	−1.12	16.40	<0.001
SO1	Social organisation 1	4.30 (8)	3.21 (2)	−1.09	15.64	<0.001
SO2	Social organisation 2	4.31 (7)	2.92 (6)	−1.39	19.99	<0.001
LE1	Learning 1	4.45 (1)	3.58 (1)	−0.87	13.31	<0.001
LE2	Learning 2	4.38 (3)	3.15 (4)	−1.23	17.58	<0.001
AG1	Agency 1	4.36 (5)	2.56 (8)	−1.80	24.18	<0.001
AG2	Agency 2	4.38 (3)	2.10 (10)	−2.28	27.74	<0.001
	Overall mean	4.34	2.89	−1.45		
Non-supporters (N = 23)						
AS1	Assets 1	4.49 (1)	3.39 (2)	−1.10	13.91	<0.001
AS2	Assets 2	4.31 (5)	2.37 (8)	−1.94	18.24	<0.001
FL1	Flexibility 1	4.03 (7)	3.06 (7)	−0.97	9.61	<0.001
FL2	Flexibility 2	4.32 (4)	3.34 (3)	−0.98	12.31	<0.001
SO1	Social organisation 1	4.32 (4)	3.30 (4)	−1.02	14.85	<0.001
SO2	Social organisation 2	4.31 (5)	3.15 (5)	−1.16	16.29	<0.001
LE1	Learning 1	4.33 (3)	3.69 (1)	−0.64	9.96	<0.001
LE2	Learning 2	4.32 (4)	3.13 (6)	−1.19	15.74	<0.001
AG1	Agency 1	4.34 (2)	2.53 (7)	−1.81	21.47	<0.001
AG2	Agency 2	4.07 (6)	2.14 (9)	−1.93	25.93	<0.001
	Overall mean	4.28	3.01	−1.27		

Notes: I: importance; P: performance; paired *t*-tests significant at 0.05.

For the group of supporters, educational guides on the ecological functions of leopard cats and their management methods (LE1; mean I = 4.45) were perceived to be the most important measure, followed by the installation of a proper fencing system (AS1; mean I = 4.44) and training and workshops on wildlife-friendly farming (LE2; mean I = 4.38). They were also most satisfied with the performance of leopard cat-related educational sessions (LE1; mean P = 3.58), as well as community meetings to promote social cohesion, information exchange, and cooperation among stakeholders (SO1; mean P = 3.21) and wildlife-friendly farming practices (FL2; mean P = 3.20). Furthermore, they reported the largest performance gap in the establishment of adaptive co-management with local farmer associations/NGOs (AG2), with a mean difference of −2.28, and the smallest gap in educational guides on the species (LE1), with a mean difference of −0.87.

Meanwhile, the non-supporters believed that building good fences (AS1; mean I = 4.49) was the most important strategy, along with the incorporation of local knowledge, skills, and management into both science and policy (AG1; mean I = 4.34) and educational guides on leopard cats (LE1; mean I = 4.33). In terms of performance, similar to the supporting group, they were most satisfied with the education indicator (LE1; mean P = 3.69), followed by proper fencing (AS1; mean P = 3.39) and wildlife-friendly farming (FL2; mean P = 3.34). Finally, the most significant performance gap was ascribed to the effective population control of stray dogs that disturb humans and wildlife (AS2), with a mean difference of −1.94, while the smallest gap was also assigned to educational guides on the species (LE1), with a mean difference of −0.64.

3.3. Importance–Performance Matrix of Adaptation Strategies

The IPA grid (Figure 4) reveals numerous similarities between the supporters and non-supporters of adaptation strategies for human–leopard cat coexistence. Eight out of ten measures were placed in the same quadrants. Specifically, Quadrant I (concentrate here) consists of two agency indicators: the incorporation of local knowledge, skills, and management into both science and policy (AG1) and the establishment of adaptive co-management with local farmer associations/NGOs (AG2). Quadrant II (keep up the good work) includes the installation of a proper fencing system (AS1) and educational guides on the ecological functions of leopard cats and their management methods (LE1). There is only one indicator that is situated in Quadrant III (low priority)—alternative non-invasive methods to control rodents to reduce the secondary poisoning of wildlife (FL1). The most similarities exist in Quadrant IV (possible overkill), which harbours three measures: wildlife-friendly farming practices (FL2), community meetings to promote social cohesion, information exchange, and cooperation among stakeholders (SO1), and the establishment of a local group to facilitate communication among stakeholders (SO3).

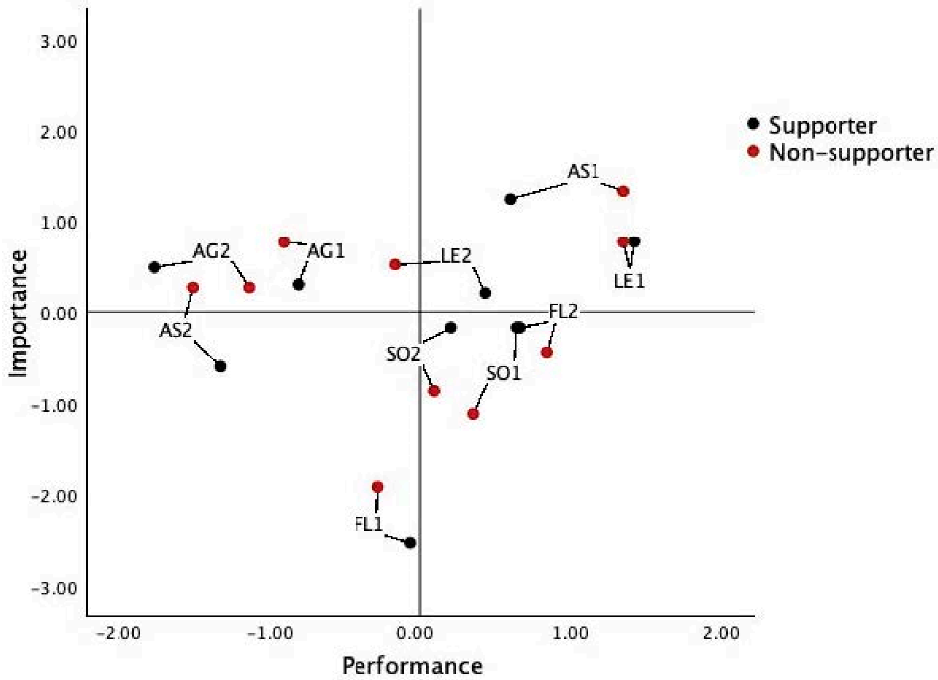

Figure 4. Importance–performance analysis grid of adaptation strategies by supporters and non-supporters.

There were only two differences in quadrant placement between the supporting and non-supporting groups. The first one concerned the training and workshops on wildlife-friendly farming (LE2) strategy, which was positioned in Quadrant II (keep up the good work) by the supporters while being placed in Quadrant I (concentrate here) by the non-supporters. The other difference was observed in the effective population control of stray dogs that disturb humans and wildlife (AS2). According to the supporters, it belonged to Quadrant I (concentrate here); however, it was not a priority for those who refused to support adaptation strategies (Quadrant III).

3.4. Factors Affecting Respondents' Willingness to Participate in Adaptation Strategies

Five socio-demographic factors (i.e., gender, age, marital status, educational level, and monthly household income) were specified as independent variables, but only 'age' was identified in the final models because it exhibited the strongest connection with the dependent variable—a WTP in adaptation strategies for human–leopard cat coexistence. After further testing, the sample was divided into two groups: '49 years and above' and 'under 49 years', to satisfy the binary nature of the LRM while showing a significant difference in the WTP in adaptation strategies between these groups.

The process of fitting the LRM was carried out to identify the models with the lowest AIC values that provide the most favourable trade-off between GOF and model complexity. As a result, three other variables (i.e., preference for local farmer association, support for coexistence, and poultry ownership), along with 'age', were included in the final LRM models (Table 4). The LLR values of both Model I and Model II (49.690 and 52.670) were greater than the chi-square value (15.09), indicating that the fitted models provided a significantly better fit to the data than null models.

Table 4. Estimated results of factors affecting farmers' willingness to participate in adaptation strategies.

Variable	**Importance of Adaptation Strategies (Model I)**		**Performance of Adaptation Strategies (Model II)**	
	Coeff.	**Std. Error**	**Coeff.**	**Std. Error**
Constant	−0.472	0.683	−1.250 *	0.667
Age [1]	−0.486 *	0.288	−0.464 *	0.289
Preference for local farmer association [2]	0.580 **	0.148	0.608 **	0.149
Support for coexistence [3]	1.125 **	0.379	0.699 *	0.402
Poultry ownership [4]	−0.450 *	0.245	−0.409 *	0.249
Mean importance	−0.199	0.705	-	-
Mean performance	-	-	1.337 *	0.767
AIC [5]	140.4		137.4	
AIC/N	0.336		0.397	
LLR [6]	49.690		52.670	
Chi-square value	χ^2 (5, 0.01) = 15.09			

Notes: ** p-value < 0.001, * p-value < 0.05. [1] Age: 1 = over 49 years, 0 = otherwise. [2] Respondents' preference for local farmer associations, instead of the government and non-governmental organisations, to facilitate human–leopard cat coexistence: 1 = yes, 0 = no. [3] Support for coexistence between humans and leopard cats: 1 = yes, 0 = no. [4] Poultry ownership: 1 = own poultry, 0 = do not own any poultry. [5] AIC: Akaike information criterion. [6] LLR: log-likelihood ratio.

In Model I, a preference for local farmer associations and support for coexistence with leopard cats positively corresponded to respondents' participatory behaviours, while age and poultry ownership were negatively correlated. The results show that those who preferred local farmer organisations to facilitate coexistence and those who were supportive of this cause were highly likely to participate in the proposed adaptation strategies ($p < 0.001$). In addition, it is also suggested that farmers over 49 years old and those who owned poultry would be significantly less interested in joining in with adaptation measures ($p < 0.05$). The results from Model II suggest similar traits in people who were more likely to have an active engagement in adaptation strategies for human–leopard cat coexistence, as well as in those who were less inclined to support such a cause, except that the variable 'support for coexistence' signified a less strong correlation than that of Model I ($p < 0.05$).

4. Discussion

4.1. Prioritised Areas of Adaptation Strategies for Coexistence

The findings of this study indicate participants' priority of a proper fencing system that effectively protects poultry from wildlife and feral animals, as well as good education on the ecological roles of leopard cats and their management strategies. Participants were also satisfied with the performance of these measures. In the last decade, Taiwan has been proactive in providing its citizens with environmental literacy following the implementation of its Environmental Education (EE) Act in 2011 [94,95]. Specifically, a conservation NGO has worked for years in Miaoli County to build trust and organise EE sessions with a focus on leopard cats. The organisation and its volunteers have also supported farmers in building better fences. However, many impacted households have not been approached due to a lack of financial and human resources and collaboration with other stakeholders. Fencing is one of the most common methods used to mitigate HWCs and has proven to be an effective tool [57,96] if properly designed, well built, and regularly maintained with timely and efficient repair [97,98].

Training and workshops in wildlife-friendly farming were also considered important, although, compared to the supporters, the non-supporters were more unsatisfied with their performance. However, both groups indicated that wildlife-friendly farming practices themselves are already overperforming. This could suggest that farmers might consider their farmlands to qualify as wildlife-friendly because this measure is attached directly to their performance, unlike most strategies that refer to the performance of other stakeholders. Training for unconventional practices such as wildlife-friendly farming or land sparing/sharing is often offered by the government and other organisations, which are more likely to be criticised, depending on their actual performance and their relationship with local communities. Further evaluation of the performance of these indicators is thus required.

Both strategies from the agency domain were perceived as essential yet dissatisfying regarding their performance level and were placed in Quadrant I (concentrate here). Taiwan's approach to wildlife conservation combines both top-down policies and regulations with bottom-up grassroots efforts. However, the former is more prevalent in most cases, including in our study areas. While scant, existing studies on natural resource governance in Taiwan reveal fragmented policymaking, limited coordination, and poor communication between stakeholders [99–101]. This corroborates our results, as surveyed farmers were discontent with the current state of adaptive co-management and the incorporation of local knowledge/skills into science and policy. All respondents from our stakeholder interviews also stated that local people have been excluded from most, if not all, decision-making processes. A command-and-control mentality can hinder conservation objectives [102] while producing ineffective bureaucracies, impeding communication, absorbing resources, and causing delays [103]. Furthermore, public policy deliberations are often dominated by scientific discourse powered by the government, which then impedes locals' participation and restricts the contribution of local knowledge to decision-making processes [104].

4.2. Participatory Behaviours in Adaptation Strategies for Coexistence

We identified the characteristics that affect participatory behaviours in adaptation strategies. Our results show that those who favoured local farmer associations to facilitate human–leopard cat coexistence and supported coexistence were expected to participate more actively in the proposed measures. The fact is that local communities are mostly commissioned by the central government to follow wildlife-related policies and regulations. This could explain why respondents chose local farmer organisations over other more powerful parties, since they are considered farmers' allies. Farmers often have closer relationships and greater trust with local organisations and conservation NGOs than they have with government agencies because these bodies may have an established rapport with local communities through ongoing engagement, consultation, and collaboration, leading to stronger partnerships and greater confidence in their efforts [105]. Local residents also tend to perceive more direct benefits and tangible incentives from working with these organisations. Although the central government could offer monetary incentives (e.g., compensation, performance payment), its bureaucratic structures and regulatory frameworks can be cumbersome and time-consuming for participants, especially those with lower levels of education, such as farmers [106].

Our research also indicates that older farmers were significantly less likely to participate in adaptation strategies for coexistence. This aligns with other studies that reported age to be negatively associated with attitudes towards carnivores [107,108]. Older farmers may have had a longer history of predation events. Such experiences can lead to negative attitudes and perceptions and a low level of tolerance, as they may have witnessed first-hand the loss of livestock or economic hardship caused by wildlife. There may be a generational divide in farmers, since the younger generations have been exposed for longer to evolving attitudes and conservation initiatives. Older people are often less receptive to new ideas or changes in agricultural practices, preferring traditional methods of predator control [109]. In addition, we found a strong correlation between poultry ownership and a willingness to participate in adaptation strategies, which is similar to the findings of Best and Pei [108] at these study sites. As leopard cats are often blamed for the attacking and killing of poultry, this group of people are more likely to have negative experiences with leopard cats, creating hostility towards the species and its conservation.

4.3. Implications for Adaptation Strategies and Policies

Over the past few decades, while Taiwan has invested substantial resources into protecting its last wild felid species, concrete conservation outcomes have yet to be assessed. Despite being fully protected by national law, anecdotal evidence from Miaoli County suggests that leopard cats are still trapped and poisoned for commercial purposes, by professional hunters, and for revenge, by farmers who have lost their poultry to the species [20]. Their low density in fragmented habitats renders them even more vulnerable when conflict with humans is added. To maintain the ecological carrying capacity of leopard cats, improving their natural environment is crucial. Active participation and the better training of farmers in wildlife-friendly farming and land sharing and sparing are thus critical to the creation of more space for suitable habitats for leopard cats, as well as other species [110,111], which may even increase crop yields with no extra monetary value or nutritional energy required [42]. Overall, it is crucial that all stakeholders collaborate to maximise the quality and scale of the prioritised adaptation strategies to meet the needs of those who suffer damage from leopard cats and those who might have underlying conflicts with other stakeholders.

The unwillingness or inability of local people to adapt to the presence of leopard cats in a shared environment could create major barriers to their coexistence. Influencing human attitudes and behaviours towards the species involved in HWCs, especially the older generations with a more extended history of HWCs and potential underlying disagreement with other stakeholders, is challenging, time-consuming, and requires a deep understanding of the ecological, cultural, social, historical, economic, and political drivers at play [55,112–114]. Overcoming these obstacles might be possible with help from local community leaders or farmer-based organisations that endorse behavioural adaptations [115]. The decentralisation and devolution of state power and authority could promote social equity and justice that ensure the interests, rights, and perspectives of affected groups, leading to a more equitable distribution of the benefits and resources from conservation initiatives [67]. Community-based organisations or local conservation NGOs could play a crucial role in facilitating coexistence by implementing initiatives with more streamlined and efficient processes, reducing administrative burdens and the barriers to participation. A more democratic co-management approach could allow local communities to act and sustain wildlife conservation. By valuing and integrating traditional knowledge and practices, this approach enables experts and local people to co-produce the skills and information required to enhance our understanding of local ecosystems and species dynamics, leading to more effective strategies. Furthermore, it allows conservation initiatives to be continuously adjusted based on new insights, changing environmental conditions, and feedback from different stakeholders, resulting in sustainable and lasting outcomes [31,67,116].

5. Conclusions

Transforming HWCs into coexistence is challenging but possible. However, sustainable conservation outcomes rely on a collaborative community-based approach with policies guided by scientific evidence and local knowledge [117]. Our study presents the first regional assessment of adaptation strategies for human–leopard cat coexistence in Taiwan based on local perspectives. We identified prioritised adaptation strategies for the effective management of leopard cats in Taiwan, as well as the characteristics of farmers who were more likely to support or resist these initiatives. Our findings help inform impactful conservation actions and policies that allow for adaptation to meet the needs of target groups and address their concerns. More importantly, we developed an integrated framework that can be adapted to local contexts and coordinated among stakeholders, enabling an enhanced understanding of how human–wildlife coexistence can be improved. While this study focuses on leopard cats in Taiwan, its methods can also be applied to other species elsewhere.

It is notable that, similar to other approaches, the template presented here is not a panacea and will not serve as a one-size-fits-all solution to guarantee sustainable co-existence in all intricate social–ecological systems [118]. The primary limitation of our study is its quantitative nature, which constrains its ability to capture the nuanced and qualitative aspects of the relationships between multiple stakeholders. Thus, the cultural, social, political, and psychological factors that influence human–wildlife interactions may not have been accounted for, limiting our complete understanding of the dynamics at play. Given the complexity and variability of the perspectives on HWCs and coexistence, future research should apply triangulation to merge qualitative findings with quantitative data to enhance the validity and reliability of research outcomes. Techniques such as in-depth interviews are useful to provide a rich and contextualised understanding of the experiences of various stakeholders on a personal level. In addition, it is crucial to conduct further investigations into the underlying conflict between the parties involved in species management to adequately inform effective interventions and address distrust.

Our study provides a starting point for conservation practitioners and other stakeholders to construct a more holistic understanding of HWCs and coexistence. The further use and development of our adaptation framework will hopefully help cultivate local preferences for co-adaptation and enable people and wildlife to thrive in shared landscapes.

Author Contributions: Conceptualization, L.B.N., C.-H.L. and H.-C.C.; methodology, L.B.N. and C.-H.L.; software, L.B.N.; validation, L.B.N. and C.-H.L.; formal analysis, L.B.N., C.-H.L., H.-C.C. and N.D.; investigation, L.B.N., H.-C.C. and C.-C.C.; resources, L.B.N. and C.-H.L.; data curation, L.B.N.; writing—original draft preparation, L.B.N. and T.B.W.S.; writing—review and editing, L.B.N., H.-C.C., T.B.W.S., N.D., C.-C.C., and C.-H.L.; visualisation, L.B.N. and T.B.W.S.; supervision, C.-H.L.; project administration, C.-H.L.; funding acquisition, C.-H.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Science and Technology Council, Taiwan: 109-2628-M-259-001-MY3; 112-2621-M-259-012.

Institutional Review Board Statement: Not applicable. However, the research protocol conformed to the British Sociological Association's Statement of Ethical Practice guidelines. Informed consent and approval to report the collected data from the interviews were obtained from all respondents. All respondents remain anonymous to protect confidentiality.

Informed Consent Statement: Informed consent was obtained from all respondents involved in the study.

Data Availability Statement: The data presented in this study are available on request from the first author.

Acknowledgments: We acknowledge the Taiwan Scholarship Program of the Ministry of Education of Taiwan for sponsoring the main author's PhD, as this project was a part of her dissertation. We thank Su-Jein Chang for her guidance and collaboration, our interviewers Wei-Yuan She, Cih-Rong Wang, Yi-Hwa Chin, Yun-Ching Tang, Chun-Yi Lin, and Hsianh-Hsu Fu for their fieldwork assistance, Blessings-Isaac Kanyangale for his academic support, and lastly the interviewees and other stakeholders for their contribution to this project.

Conflicts of Interest: The authors declare no conflicts of interest.

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