Butterfly farming for promoting sustainability and ecotourism: a case study of feasibility in Western Ecuador

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Abstract: Butterfly-farming projects have been economically successful, increasing livelihood opportunities for local people and promoting women's empowerment, governance, and conservation behavior. Moreover, local butterfly exhibitions can diversify the attractions of natural reserves and promote ecotourism. Butterfly farming involves rearing butterflies in captivity and marketing them to local or international exhibitions. We researched the feasibility of a butterfly farming project in Western Ecuador during summer 2013 as part of a longer-term applied research program involving capacity-building for local people. A preliminary strategic plan was developed, including a SWOT analysis and an analysis of market demand for a butterfly exhibition. In addition, biological research was carried out, and local people were trained to address two main weaknesses to implement an exhibition. Results showed that a butterfly farming project is feasible in the area due to the availability of biological information about butterfly species, a market niche for a butterfly exhibition at the reserve, and increased technical capacity and willingness of local stakeholders to participate. This study contributes to understanding how applied biological research can act synergistically to promote conservation and ecotourism in collaboration with local people.

Keywords: biodiversity conservation; butterfly farming; capacity-building; dry forests; ecotourism.

INTRODUCTION

Natural resources significantly contribute to national economies, although their contribution is rarely included in economic statistics, resulting in the so-called economic invisibility of nature (Bishop, 2015; TEEB, 2012); they represent strategic elements to achieve development in emerging countries (Blicharska *et al.*, 2019; UNDP, 2020). In addition, according to the UN, a development pathway encompassing biodiversity conservation has far-reaching consequences in people's capabilities, "going beyond incomes and livelihoods to include impacts on health, education and other dimensions of well-being" (UNDP, 2011). Achieving sustainability is nevertheless not an easy task because, among other factors, areas containing the greatest concentration of natural resources also face development challenges. The tropical regions in South America and Africa, for instance, include the highest concentration of biodiversity and wilderness areas (Myers *et al.*, 2000) but also have alarming levels of poverty (Wilshusen *et al.*, 2003; Chigonda, 2017). A challenge thus exists of balancing and even combining biological conservation with sustainable economic benefits for local populations near reserves, where natural resources concentrate (Boppre & VaneWright, 2012).

Sustainability refers to economic activities that "meet the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Several initiatives, including ecotourism projects to promote sustainability, have emerged to protect natural resources while enabling local people living in highly diverse and emerging countries to prosper (Roosa, 2020). One type of these successful initiatives is the development of projects involving the domestication and commercialization of natural resources, which are one of the few potentially 'win-win' effective solutions to preserve natural forests and reduce poverty (see Mpand *et al.*, 2014). An example of domestication is butterfly farming, linked to ecotourism. Unlike many other Integrated Conservation and Development Projects (ICDPs), butterfly farming has been economically successful and promoted sustainability (see Morgan-Brown *et al.*, 2010). Successful butterfly farming projects have been implemented in several developing countries, such as Tanzania (e.g., Amani Butterfly Project, Morgan-Brown *et al.*, 2010), Cambodia (van der Heyden, 2011), Kenya (e.g., KEEP project, Omenge, 2002; Kipepeo, 2006), Malaysia (e.g., Penang Butterfly Farm, Le Roux, 2012), Papua New Guinea (Parsons, 1992), Costa Rica (Brinckerhoff, 1999; Ickis, 2006) and Guyana (e.g., Kawe Amazonia butterfly Farm, Sambhu & van der Heyden, 2010).

Butterfly farming involves rearing butterflies in captivity and marketing them mainly to local or international exhibitions

(predominantly in the USA and Europe). Costa Rica, El Salvador, Colombia and Ecuador breeders mostly sell live butterflies for exhibits, and Peru farmers mostly sell dried butterflies to supply the collection and decoration market. Peruvian breeders have been also successful with rare species such as *Prepona* (previously belonging to the genus *Agrias)*, and have even produced hybrids of different species of *Prepona* and former *Agrias*. The exhibition industry has reached a global turnover of up to US$ 100 million (Mpand *et al.*, 2014); close to 40 million tourists visit butterfly exhibitions per year, and numbers are increasing (Boppre & Vane-Wright, 2012). In 2023, the two major butterfly pupae producers in Ecuador have exported over US$ 500,000 of pupae. A close link exists between this activity and forest conservation, since farmers rely on natural forests to obtain butterfly species and seedlings/seeds of host plants (i.e., plant species that provide food to larval stages of butterflies) to develop their captive populations (Morgan-Brown *et al.*, 2010).

Butterfly farming can promote local economies through ecotourism, because reared butterflies can be part of a local butterfly exhibition. These exhibitions can complement and enhance tourism to reserves (Gordon & Ayiemba, 2003), particularly in areas receiving large numbers of tourists (Rafi *et al.*, 2003). Revenue comes from entrance fees, mainly from other customer services facilities such as restaurants and souvenir shops (Ansari *et al.*, 2019), but also from sales of live pupae and dried butterflies. It is necessary to sell pupae very quickly, as most butterflies hatch in 8 to 15 days, whereas dried specimens might be sold months or years later. Local communities can participate directly as farmers, diversifying their livelihoods (Boppre & Vane-Wright, 2012), but also through other economic activities, such as the elaboration of handicrafts with butterfly wings (*e.g.*, frames, jewelry, etc.) (Rios, 2002). Local exhibitions can also contribute to address the demand constraints of international exhibits by creating an additional market within the country the butterflies are farmed.

Ecuador has a great potential to develop butterfly-farming initiatives, as it is one of the most butterfly-diverse countries worldwide, along with Peru and Colombia, with an estimated diversity of 4,000 species (Checa, 2013), almost twice the species richness found in Costa Rica, a widely recognized 'butterfly farming country' (see Checa, 2008). However, such projects are limited in Ecuador, which have been primarily focused on production for local exhibitions mainly found in lodges in the Amazon and northwest (Checa, 2008), with current activities mostly focused on pupae exports.

The initial economic investment required to develop butterflies farming initiatives is relatively small, demanding low costs from producers and requiring less land and effort than other crops (Rafi *et al.*, 2003; Gordon & Ayiemba, 2003). However, an essential constraint to developing butterfly farming projects in Ecuador and elsewhere is the lack of biological knowledge about butterfly species and technical capacity for butterfly farming (butterfly collection, rearing species in captivity, among others) (see Checa, 2008). Indeed, the latter is a significant problem, as local communities or farmers usually lack the resources, technical knowledge, or alliances with researchers to cover this gap (Carbó *et al.*, 2008; Baca, 2006). Although breeders might have the knowledge and skills for butterfly farming, active partnerships of actors in the butterfly house industry with scientists are seen as a key aspect to success, as scientists are able to generate baseline information for rearing butterflies and for developing educational material (Boppre & Vane-Wright, 2012). In addition, academic institutions could be involved in sustainability initiatives such as butterfly farming through participation in planning, management, and research, but also through capacity-building of local people (Shiel *et al.*, 2016; Schmitz *et al.*, 2010).

Therefore, two important objectives of this research were: 1) to apply ongoing butterfly research to generate baseline information for a butterfly farming and ecotourism initiative, and 2) to build the capacity of local people for this initiative in terms of butterfly research. Butterfly farming, like any other business, requires developing a strategic plan for its implementation and success. Hence, the third objective of this study was to create the preliminary steps of strategic planning for implementing a butterfly farming initiative at Lalo Loor Dry Forest Reserve (LLDFR), which might serve as a baseline for future planning efforts. It was a preliminary scheme since, to succeed, strategic planning must be a participatory process in which all stakeholders discuss and provide comments to construct it and further implement the project. The preliminary strategic planning carried out included an analysis of the feasibility of butterfly farming at LLDFR in terms of economics (*e.g.*, market demand), environment (*e.g.*, diversity and natural history of butterflies), and social perspectives (*e.g.*, the buy-in of local people). The strategic plan developed identified two challenges to implement the project, which were addressed through linkages to an ongoing biological research program to: 1) build the capacity of local people for butterfly farming research, including collection and rearing techniques, and 2) generate prior biological knowledge required for setting up a butterfly exhibition (*i.e.*, the natural history of butterfly species).

METHODS

Study site

Ecuador is a small South American country (256,370 km^2) located between Peru and Colombia. Ecuador is a megadiverse country containing two significant hotspots of diversity and endemism and one of the major wilderness areas, the Amazon (Myers *et al.*, 2000). Development following principles of sustainability is urgently required, particularly in Western Ecuador, where 70% of people are poor, and less than 5% of forests remain (Checa, 2008). Climate change and agricultural expansion are the major threats for conservation because of the positive feedback between forest fragmentation and drought (Laurance & Williamson, 2001). This feedback also poses risks for agricultural productivity, the primary economic income source of local communities.

Ecuador is an important ecotourism destination in Latin America due to its natural and cultural richness, receiving, for example, approximately 2.5 million tourists in 2018 alone; indeed, tourism, in general, represents the third contributing sector in terms of economic income (not considering the oil sector) for the national economy (Diaz-Christiansen, 2019). The Galapagos Islands have been a worldwide recognized

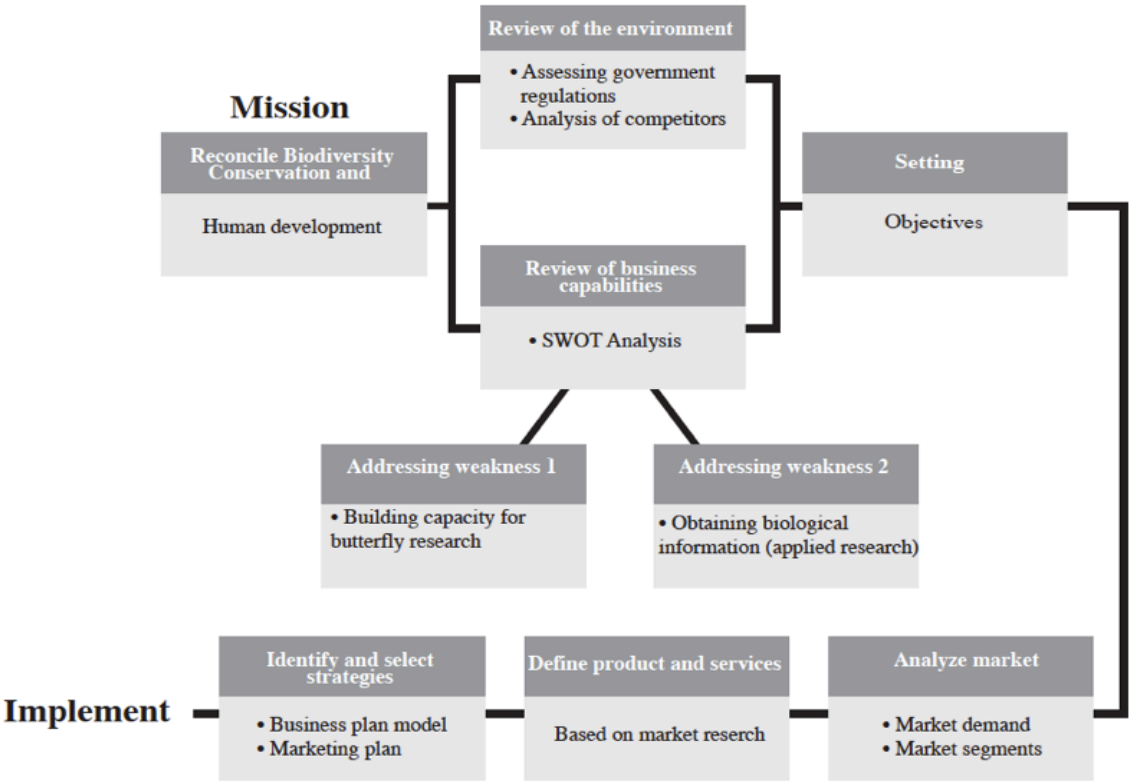

Figure 1. The strategic planning process to establish a butterfly exhibition at Lalo Loor Dry Forest Reserve (LLDFR) from mission to implementation. Through research, two main weaknesses were partially addressed: lack of technical capacity and biological knowledge about butterflies. Based on Patterson (2007).

	Strengths	Weaknesses
Internal origin	1. Access and proximity to markets 2. Extensive biodiversity/natural beauty 3. Ongoing scientific research 4. Expertise on conservation projects 5. A butterfly exhibition fits the management plan of the reserve. 6. Well-established relationship with stakeholders 7. Strengths of NGO administration 8. Well-established volunteering programme at the reserve.	1. Lack of biological information 2. Lack of technical capacity for butterfly farming
	Opportunities	**Threats**
External origin	1. Emerging domestic and international markets for tourism. 2. Extensive littoral and marine resources. 3. Low competition for natural-based touristic activities in the region.	1. Natural Disasters (flooding, earthquakes). 2. National/International recession 3. Covid Pandemic

Figure 2. SWOT analysis for a butterfly exhibition at LLDFR in Manabí Province, Ecuador.

ecotourism destination and are the most visited site in Ecuador; numbers of tourists have continuously increased from 41,000 in 1990 to 180,000 in 2008, which has also posed challenges for biodiversity conservation (Self *et al.*, 2010). This research was carried out in the Lalo Loor Dry Forest Reserve (LLDFR), located in the coastal region of Ecuador in Manabí province. The LLDFR is a private reserve and cover 180 hectares of tropical dry forest, a highly threatened ecosystem that is nearly extinct in Ecuador. Ceiba Foundation, which previously administered the reserve, is leading a conservation easement initiative to guarantee long-term protection of the reserve.

A butterfly monitoring scheme started in June 2009 and

continued through July 2014, with some results published (Checa *et al.*, 2014). This monitoring scheme provided information about effects of climatic variability and habitat change on butterfly communities, and butterflies were chosen because they represent one of the insect groups most widely used as biological indicators (Syaripuddin *et al.*, 2015). This monitoring scheme was based on inter-institutional collaboration at the national and international level: McGuire Center for Lepidoptera and Biodiversity (Florida Museum of Natural History, University of Florida, USA), Program of Sustainable Development Practice and Tropical Conservation and Development Program (University of Florida, USA), QCAZ Museum of Invertebrates (Pontifical Catholic University of Ecuador, Ecuador), Ministry of Environment (Ecuador, who provided research permits) and Ceiba Organization (USA, who administered the reserve and supported our research). The reserve is located just across the main highway connecting beaches and towns along the coastal region in Ecuador; indeed, it is part of a major touristic route called the *Spondylus Route*, analogous to the *Ruta del Sol* or Sun Route in Colombia. A butterfly exhibition at the reserve could thus attract incoming tourists who visit adjacent well-recognized beaches. The reserve has different attractions, including trails, birding, and wildlife viewing (e.g., howler monkeys, jaguarundi, parakeets, birds); it also offers lodging for scientific researchers, volunteers, and others (Ceiba Organization). These complement other attractions in the province, such as beaches, whale watching, and gastronomy.

Applied business research: Strategic planning

As a first step to assess the conditions for a successful butterfly farming ecotourism initiative in the LLDFR, applied research focused on business conditions was carried out using a strategic planning framework, focused on the proposed mission: *reconciling biodiversity conservation and human development in communities adjacent to the LLDFR*, *through a butterfly farming initiative*. To accomplish this, several steps of a strategic planning scheme were developed, following Patterson (2007), including a review of the environment for the business, review of business capabilities (using SWOT analysis), market analysis, and product/service definition (Fig. 1). In addition, biological research and capacity-building strategies (discussed below) were used to address potential weaknesses defined by the SWOT analysis, building on the long-term research program in the reserve.

The review of business environment included an analysis of competitors and the identification of competitive advantages in the tourism marketplace, and an assessment of government regulations for developing a butterfly exhibition at the reserve. These analyses and assessments were based on a literature review; a list of competitors was also created using information gathered in the field through exploration of similar businesses in the surroundings of the reserve. The review of business capabilities consisted in defining strengths and weaknesses, but also opportunities and threats through a SWOT Analysis (Fig. 2); this analysis can better inform the planning process to achieve the mission. To complete this analysis, information was gathered from fieldwork, from the literature review, and a semi-structured interview with the director of the Ceiba Organization. The following steps, analyzing the market and product definition, will be explained below.

Analyzing the tourism market and product definition were additional components of the business assessment. The market analysis focuses on determining market demand and market segments (Patterson, 2007). Market demand means people's interest in visiting a butterfly exhibition; meanwhile, the market segment refers to characteristics of potential customers (age, gender, geographic origins, interests). The market analysis for a butterfly exhibition and other ecotourism-related activities (*e.g.*, lodging and meals in the reserve, trekking trips, and others) was done using data gathered from surveys carried out with tourists, during the peak tourism season in Manabí province (July 2013). In total, 401 surveys were carried out with tourists at four different beaches located close to the reserve: Pedernales, Canoa, Bahía de Caráquez, and San Vicente. We requested oral informed consent from each person surveyed, as requested in the permit for human research issued by the Institutional Review Board at the University of Florida. A literature review was also performed to complement information gathered through surveys. Surveys were conducted on the beaches surrounding the reserve because, rather than creating 'new' tourism at its initial stages, the butterfly exhibition can take advantage of the 'well established' tourism in surrounding beaches and further complement it. To directly measure market demand, respondents were asked twice in the surveys to validate whether they were interested in visiting a butterfly farm at the reserve. Possible answers were YES, NOT SURE, and NO. Participants were also asked about their interest in other activities such as visiting a souvenir shop, walking in the forest, and lodging/eating at the reserve. Comments given when these questions were posed were recorded to get additional insight for product definition. Surveys also provided relevant information for future marketing activities (*i.e.*, where to promote products). Tourist survey data were valuable to define the business products, and services tourists were potentially interested in getting at the reserve, related to a butterfly exhibition and natural forests; product description also involved the price tourists were willing to pay to get a product or service (see Patterson, 2007).

The Contingent Valuation Method (CVM) was used to gather information about fees potential tourists were willing to pay; the method allows participants to state their willingness to pay through responses to open-ended or dichotomous choice questions in surveys (see Hejazi *et al.*, 2014). We used choice questions to determine the preferred fee; each participant was asked if they would be interested in visiting a butterfly exhibition if the cost were a fee from US$2 to US$10. The first choice given was a randomized number; if participants disagreed with the randomized value, they were asked to provide the preferred choice ranging from US$2 to US$10. Linear Regression Models in the form of Generalized Linear Models (GLM) were used to analyze which entrance fee groups of potential customers, depending on age and citizenship, were willing to pay to visit a butterfly exhibition at LLDFR. These models tested whether a significant relationship existed between a dependent variable (willingness to visit the reserve) and predictor variables (*e.g.*, age). All analyses were performed using R software.

Respondents were also asked whether they had heard about the LLDFR prior to the surveys and information source. These data were used to recommend marketing activities such as mass distribution and sales promotion.

Applied biological research: filling gaps identified in the business assessment

Results of the SWOT analysis (described below) showed two main challenges to implementing a butterfly farming project at LLDFR: lack of technical capacity and lack of biological knowledge. Therefore, biological research was carried out about butterfly species, and training programs were developed for local people to monitor, collect, and rear butterflies.

In terms of biological research, we took advantage of the monitoring program at LLDFR that started in June 2009. The biological monitoring consisted of sampling butterflies using traps with baits during seven days, every two months. This monitoring provided information about the abundance and distribution of butterfly species (where and when they occur) attracted to baits, many of which could be included in a butterfly farming project, considering their abundance and distribution.

Local people were trained about butterfly research within the monitoring scheme; training was provided during five field trips from March to November 2014. We requested oral informed consent from each person trained, as requested in the permit for human research issued by the Institutional Review Board at the University of Florida. Trainees learned about the experimental design in the reserve consisting of two transects with eight sample points each and two traps set up at each point, one in the understory and the one in the canopy (15-20 m). During the field trips, trainees accompanied a biologist to check 32 traps daily, during which they collected or marked trapped butterflies and changed the baits. The marking consisted of writing a number on the butterfly wing; the butterfly was then released after determining the species name and taking note of the collection place and date. During the inspections, trainees learned how to collect, identify, and gather collection information about butterflies (*i.e.*, site collection, date). Trainees learned how to identify butterflies in the field using a photographic guide.

Trainees also received training about butterfly-rearing techniques in May and July 2014. They learned how to collect eggs and caterpillars in the field and how to clean and feed butterflies in the rearing station. Trainees also gained knowledge on nursery production and helped establish the hostplant nursery in the station. This training was conducted during the following research phase. There are two mechanisms to find butterfly hostplants: the first consists in observing a female looking for a host plant. The second is to find plants with characteristic feeding damage left by caterpillars, such as leaving the major vein if a leaf intact as a resting perch. A second research component focused on gathering biological information about several butterfly species, including details about hostplants (*i.e.*, food for the immature stage or caterpillar), life cycle times, the survival rate of caterpillars, and other factors. The selected butterfly species were potentially useful for a butterfly exhibition.

This study was carried out from June through August 2012. Butterfly eggs or caterpillars were collected in the forest and reared in the reserve station. Immature stages were found by observing ovipositing females or searching potential hostplants. After collection, immature stages were transported to the station and kept in plastic containers until adult emergence. Containers were washed daily with soap and water to prevent viral and bacterial infections, and caterpillars were fed daily with foliage from their specific host plants. During this stage, we collected information about the development time and morphology of life stages and took photographs of different life stages. Moreover, to ensure the availability of appropriate food, a nursery of hostplants was also established in the reserve station. The nursery was developed with seedlings collected in the forests, transplanted using plastic bags and maintained in a small plot close to the rearing station. When a butterfly farming project starts, one of the main challenges for sustained butterfly production is to grow enough food plants to breed species in large quantities. As a sustainable project, collecting plants (cut branches) from the wild should be avoided, and new methods to obtain seedlings should be implemented.

RESULTS

Review of the environment (assessing government regulations and competitors)

In terms of external regulations, setting up a butterfly-exhibition ecotourism business in Ecuador requires obtaining three permits to operate, one from the Ministry of Environment (*Patente anual de funcionamiento*) to breed local fauna, another permit from the Ministry of Tourism (*Licencia anual de funcionamiento* or annual permit for operation) and a permit from the Municipality, to offer ecotourism activities. The last is indispensable if the butterfly farm is legally defined as an ecotourism venture. The Ministry of Tourism considers ecotourism as touristic activities that occur in natural areas without affecting the integrity of natural ecosystems and local culture; moreover, these activities are also expected to provide economic opportunities to promote conservation of natural resources and development for local communities (Presidencia de la República, 2008).

There are no competing butterfly exhibitions in the coastal area of Ecuador; a butterfly exhibition at LLDFR would therefore be one-of-a-kind in the region. Butterfly exhibitions are still scarce all over Ecuador, with some concentrated in the northwest and Amazonia at lodges, mainly targeting foreign visitors (Checa 2008). The most well-known exhibition, '*Mariposas de Mindo*' (Mariposas de Mindo, 2012) is located in northwestern Ecuador in Mindo (96 km from Quito), and which has been operational for several years and receives thousands of visitors every year. This exhibition is 240 km away from LLDFR.

Except for whale-watching activities in June-July, there is limited availability of natural attractions in the LLDFR area due to a very low number of natural habitat fragments and/or limited availability of infrastructure/services. Nevertheless, there are increasing local efforts to attract more visitors to adjacent natural reserves, improve awareness for environmental protection, and promote community outreach, agroecology, and other topics

(see Rio Muchacho [no date]; Third Millenium Alliance, 2021). Two main reserves are located in the surrounding area of LLDFR: the Jama Coaque Ecological Reserve, 3 km from the LLDFR and 7 km from the Pacific Ocean (Third Millenium Alliance, 2021), and Cerro Pata de Pájaro, which contains a mixture of primary and secondary forests, and agricultural lands (Birdlife International, 2014). Both reserves offer limited services for tourism and low accessibility. A clear comparative advantage for the LLDFR is its easy access for tourists, as it is located next to the main highway, and visitors are not required to do long walks to visit the natural habitats. Indeed, this proximity has allowed an increasing number of tourist visits to LLDFR over the past years.

Review of business capabilities: SWOT Analysis

Strengths and opportunities were analyzed to assess the business's capacity to establish a butterfly house at LLDFR. Figure 2 summarizes the main strengths, weaknesses, opportunities, and threats of implementing a butterfly exhibition at LLDFR. The SWOT analyses showed numerous strengths and opportunities to set up butterfly farming at LLDFR, and only two weaknesses and threats, which were partially addressed by the applied biological research described below, establishing a baseline of biological information needed and starting up the training of local people to collect and rear butterflies. During the preparation of this manuscript, a 7.8 magnitude earthquake struck Ecuador in 2016, with significant effects in Manabí, where LLDFR is located, which impeded the implementation of this project. Conditions greatly improved in the subsequent years, pointing to the feasibility of a butterfly farming project. However, during the later stages of preparation of this manuscript, another threat had to be included, the Covid pandemic, which posed major limitations to the tourism business and associated projects worldwide.

Applied Biological Research. Activities were developed to address two weaknesses identified by the SWOT analysis: lack of technical capacity and biological information. Previous experiences in other countries revealed that the initial stages of setting up a successful butterfly farming project required research about the natural history of butterfly species, implementation of rearing facilities, including a nursery, and capacity-building for butterfly research (Morgan-Brown, 2003; Sambhu & van der Heyden, 2010). These examples thus emphasize the importance of capacity-building and biological research as initial steps for butterfly farming. One of the unique aspects of this project was the opportunity to link ongoing biological research to the strategy to assess and address weaknesses identified in the butterflies farming proposal.

Biological Information. Approximately 150 caterpillars and eggs of 12 species were reared at the LLDFR Reserve from June through August 2012. From this sample, 8-9 species could be used for a butterfly exhibition due to their coloration, size, and relative ease of rearing. These species are *Heliconius erato*, *Dryas iulia*, *Itaballia marana*, *Scada zemira*, *Opsiphanes* '*cassina*', *Memphis artacaena*, *Heraclides anchisiades*, and *Consul fabius* (Appendix 1). For these species, photographs of life stages, hostplant species, development time, and collection area were recorded. A general recommendation is to implement a butterfly house with species that are relatively more accessible for managing and rearing, and about which more experience and published information are available; this is the case with species from the families Papilionidae, Pieridae, and Nymphalidae (see Mulanovich, 2007), such as: *Morpho helenor*, *Caligo atreus*, *Siproeta stelenes*, *Perrhybris pamela*, *Myscelia cyaniris*, *Hamadryas glauconome*, *H. amphinome*, *Elzunia pavonii*, *Parides eurimedes*, *Euptoieta hegesia*, *Biblis hyperia*, *Danaus plexippus* and *Eumaeus godartii*. All these species are known to survive very well in captivity. Information about the taxonomy and natural history of the other butterfly groups, Lycaenidae, Riodinidae, and Hesperiidae, are relatively scarce for the Neotropics. Apart from *Eumaeus godartii*, a lycaenid present at LLDFR and not too difficult to breed, very few species from these three families have been bred. Hostplant production is an important challenge, but even if it is solved, it could be difficult to obtain a second generation of these species due to the difficulties of successfully pairing males and females. For example, in our experience, in captivity males of the genus *Astraptes* (Hesperiidae) lack chemicals that are needed for pheromone production and mating, and females therefore only lay unfertilized eggs. These species thus require more research for farming and management and should not be included in a butterfly farming initiative during the initial stages.

Some characteristics make some butterfly species more attractive for a butterfly exhibition, such as larger size, bright coloration, slow-flying behavior (Checa, 2008), ease of capture, and abundance (Mulanovich, 2007). Based on these attributes, many of the butterfly species recorded at LLDFR (Appendix 2) during the monitoring scheme (2009-2014) have the potential to be farmed and to be included in a butterfly exhibition. The appendix also contains information about their relative abundance, collection site (microhabitat and strata), and a collection time (dry and wet season) to guide future collection efforts to set up captive populations. Other butterfly species not included in Appendix 1 or 2 can be included in a butterfly exhibition; this is just a preliminary list. Butterfly diversity, abundance, and the relative ease to rear some butterfly species and hostplants at LLDFR showed it is feasible to set up a butterfly house at the reserve in terms of the biological resources present.

Building capacity and empowering local people. Four people (three women and one man) from the surrounding communities of LLDFR received training on how to study and rear butterflies. Trainees practiced how to collect and identify butterflies in the field for five months and record and organize biological data.

Local people also learned to find and collect eggs and caterpillars, and to rear them in captivity. Women were more enthusiastic and participated in the project more than men. An important constraint for men's involvement was the fickle nature of work. For example, trainees were only required to work every two months for one week, and each received a payment of US$ 100 per week during the monitoring scheme. Men were looking for more stable jobs providing regular monthly income. This finding might indicate that women would be more willing

and able to participate in a butterfly farming project at LLDFR, depending on the nature of available jobs and opportunities in the project. Two women continued to work, received training in the butterflies monitoring project, and were very enthusiastic about being involved in the project in the long term. This continuous collaboration of local people in the butterfly project, involving the collection and handling of butterfly species, showed that setting up a butterfly exhibition at the reserve is socially feasible. Further evidence for social feasibility came from solid support provided by the Ceiba Organization and the willingness to participate of young biologists who assisted in the project, who could serve as trainers for additional local people. It is, however, important for a successful long term breeding program to receive technical assistance of an experienced professional who can help rear butterflies.

Analysis of the market

Most of the 401 tourists surveyed at beaches adjacent to LLDFR were Ecuadorians (361, 90%), females (55%), and aged 15-34 years (54%). To directly measure market demand for a butterfly exhibition at LLDFR, people were asked twice about their interest to visit the exhibition: 29 (7%) respondents changed their answers when asked the second time; most of them (86%) switched from 'no' or 'not sure' to 'yes.' In the following sections, we analyze responses given the first time the question was posed, to get more conservative results. The majority of respondents (354 or 88%) were interested in visiting a butterfly exhibition at LLDFR; 6% were unsure, and 6% were not interested.

When asked about their willingness to visit a butterfly exhibition, some respondents shared additional comments. Several (n=15) believed having a butterfly exhibition in the area was a fascinating and fun idea; other respondents were also interested in observing more animals and visiting the forest (n=15) and expected to have additional attractions for children and a place to buy drinks and food (n=7). Five respondents believed a butterfly exhibition was an additional attraction to visit the region. Some respondents (n=3) believed an exhibition might promote conservation and more contact with nature.

Potential visitors also showed different interest levels in other activities at LLDFR, such as visiting a souvenir shop, walking in the forest, staying overnight, and dining. Most potential customers (220, 57%) were 'very interested' or 'interested' in visiting a souvenir shop, although some (39%) respondents initially doubted, to later provide a 'yes' as an answer ('doubtful yes'). Some respondents were 'very interested'/ 'interested' to walk in the forest (33%), stay overnight, and eat dinner (25%) at the reserve. Still, a significant group of potential customers doubted their willingness, mainly to stay overnight and have meals (67%).

These results showed evidence of market demand for a butterfly exhibition and a souvenir shop at LLDFR. There is less clear evidence of market demand for the other activities: lodging/eating and walking in the forests. More detailed surveys are required to detect why respondents are dubious about having these services at the reserve and/or how the reserve could increase their interests if these services are implemented.

Definition of products and services based on market research

Defining what customers will buy is not an easy task, and a 'handful of surveys isn't likely to uncover the answer' (Mullins and Komisar 2009). Thus, people may not visit a butterfly exhibition even though survey data suggested a market demand existed. A plan is therefore required that focuses on limited investment at the initial stages. Through continuous monitoring, new approaches or expansions can be implemented to improve the butterfly exhibition business. It is important to "rigorously stress-test that plan, as quickly and inexpensively as you can, at its most critical points of vulnerability." If evidence suggests the need to change the plan, it should be done while monitoring the process again (Mullins & Komisar, 2009).

Hence, a small butterfly exhibition could be initially set up at LLDFR to test the market demand suggested by tourist survey data. The exhibition might be small built with basic infrastructure to exhibit 8-10 species and 150-200 butterflies flying at any one time. Rearing could focus on butterflies with relatively fast development times (less than 2 months) and feeding habits requiring fast-growing hostplants. However, the exhibit should be large enough so that visitors perceive it is worth the entrance fee. If it is not possible at the initial stages, guided tours should be implemented.

The initial investment to implement a butterfly rearing facility is around US$ 20,000, to cover the following facilities: a 500 m^2 greenhouse, 42 cubes with anti-mosquito nettings and 6 metallic tables to support these cubes, an automatic irrigation system (nebulization and drip systems) with a clean and permanent water supply from the ground, a workshop to store materials, and a clean area with good lighting to prepare shipments (for pupae exports).

The exhibition could be complemented at the initial stages with a coffee shop and a souvenir shop. The shop might sell t-shirts and shopping bags with local flora and fauna prints. It could also distribute handicrafts made by adjacent communities (*e.g.*, lamps made with bamboo and colorful textiles made in Tabuga, a nearby town) and other souvenirs. Survey data suggested that potential customers were interested in authentic souvenirs representing local flora and fauna and low-priced products. They recommended different items such as bracelets, necklaces, t-shirts, postcards, key chains, magnets for fridge doors, and photo services available against backdrops representing butterflies, wildlife, or natural habitats.

A coffee and souvenir shop could increase revenues since these customer facilities can be more profitable than entrance fees (Rafi *et al.*, 2003). Increased revenues from additional facilities are especially important for reserves receiving low/ medium numbers of visitors (Spergel, 2007; Eagles, 2002). A restaurant could also be implemented at later stages, and the butterfly exhibition expanded. There must also be space for innovative funding with other private ventures on special-purpose merchandise (Eagles, 2002), or linking tours with other regional attractions to increase revenues. Exporting pupae for international exhibitions is another option to increase the economic income, especially to ensure the long-term sustainability of the project.

The initial butterfly exhibition would demand at least 2-3 people from adjacent communities for the breeding program

and exhibition management. Nonetheless, the possibility of a future expansion of the souvenir shop offers additional economic opportunities for more local people to get engaged in the project. Other butterfly farming ecotourism projects have successfully implemented this component (e.g., Tanzania and Kenya), which provided economic income for local women by elaborating handicrafts such as jewelry and frames using butterfly wings (Rios, 2002; Morgan-Brown, 2003; Kipepeo, 2006).

The involvement of local communities in the butterfly farming business would make the project socially fairer and more viable in the long term as a real ecotourism venture, by providing financial benefits and empowerment for local people (Honey, 2008). The business should also be aware of the other ecotourism requirements: minimize impact, build environmental awareness, provide direct benefits for conservation, respect local culture, and support human rights and democratic movements (Honey, 2008).

Survey results suggested that Ecuadorians were willing to pay a higher average entrance fee (US$ 4.9) in comparison with foreigners (US$ 4.6) to visit a butterfly exhibition at LLDFR. However, it is possible that the reduced sample size of foreigners (n=41), compared to nationals (n=361), biased the results. Furthermore, the oldest and youngest age groups were willing to pay higher fees (people aged >55 and 15-24) compared to the other age classes. However, the results of GLM showed that age and nationality were not significant predictors of willingness to pay entrance fee (age: Chi-Square 59,3 p=61; nationality Chi-Square 0.8 p=0.7).

The reserve currently charges an entrance fee of US$ 5 to visit the forest (for national and international visitors, Reserva Lalo Loor (2023)), a price very similar to that which tourists are willing to pay. However, A butterfly exhibition at LLDFR should consider offering a reduced fee for Ecuadorians, children, and the elderly, but pricing policy must reflect production costs (Eagles, 2002). It is a common strategy for reserves, including protected areas, to offer a reduced fee for national visitors. However, foreign visitors are still charged far less than they are willing to pay in many parks (Spergel, 2007). The difference between a foreign visitor and a national visitor's fee can be up to US$ 94 in areas such as the Galapagos National Park (Foreign visitors pay US$ 100, Ecuadorians US$ 6). Although foreign visitors may be willing to pay more, they also expect 'value for their expenditures' in service excellence and experience-enhancing features (Wight, 2001). The reduced fee is intended to make the visits more affordable for local people, promoting local awareness and appreciation for conservation and biodiversity.

Advertising and promotional strategies

Only 62 (15%) of respondents had heard about the LLDFR prior to the tourist surveys, and from this sample, only eight people had visited the reserve. Respondents knew about the LLDFR through different sources, mainly through the road sign that signals the entrance to the reserve (29%), radio/television (26%), and comments from other people (16%). This information can be helpful to define how to diffuse ecotourism promotional materials.

Survey data revealed that the LLDFR needs to develop marketing and advertising strategies to increase the number of tourists and hence revenues. Marketing is one of the most critical components of the travel industry in general (Honey, 2008) but is often overlooked. The lack of adequate leisure marketing and tourism management capabilities has been a key challenge common to many protected areas worldwide (Eagles, 2002). Moreover, research analyzing which major themes ecotourism operators wished they had known about before entering the business highlighted marketing and business planning (McKercher & Robbins, 1998; Page & Dowling, 2002). During an interview, Ceiba Organization mentioned that limited investment had taken place for marketing efforts. Nevertheless, marketing strategies must be implemented carefully to make the butterfly exhibition economically successful.

Not only is a marketing plan needed, but a complete business plan also is required to make the business successful. Business plans for ecotourism projects can prevent several problems by detecting vulnerable business areas in advance and effectively guiding business strategies (Patterson, 2007). The business plan involves a business description, products and services, sales and marketing, operating requirements, and financial management (Patterson, 2007).

DISCUSSION

An important contribution of this study was the opportunity to link ongoing biological research to the strategy to partially assess and address weaknesses identified in the butterfly farming ecotourism proposal (lack of biological information and technical capacity of local people). This study thus demonstrated how applied research and direct community involvement could address weaknesses and provide a solid basis for conservation and sustainable projects by creating a new attraction for ecotourism. In this way, scientists accomplished their responsibility to support butterfly farming through the generation of relevant knowledge (Boppre & Vane-Wright, 2012) and capacity-building of local people to promote sustainability (Shiel *et al.*, 2016; Schmitz *et al.*, 2010).

This research at the LLDFR remains at the initial phase mainly because of the 2016 earthquake and subsequent onset of the Covid-19 pandemic. However, a butterfly farming initiative was recently implemented in Tabuga, a town close to LLDFR, but is now facing challenges due increasing insecurity in the coastal region of Ecuador, and due to the limited funding, considering that no income is expected during the first year.

Sustainable livelihoods

Sustainable livelihoods are enhanced when butterfly farms are set up near natural reserves, decreasing the pressure for unsustainable use of forests by creating jobs and additional sources of income (van der Heyden, 2011; Sambhu & van der Heyden, 2010). Indeed, the World Tourism Organization created the Sustainable Tourism-Eliminating Poverty (ST-EP) program, recognizing tourism as an important strategy to improve socio-economic conditions of rural communities (Diaz-Christiansen, 2019), including the creation of new sources of jobs, especially for women and young people (Casas *et al.*, 2012).

Butterfly farming can promote local livelihoods and diversify household economies (Parsons, 1992), even in marginal mountain lands (Rafi *et al.*, 2003). In Kenya, the annual per capita income doubled after a butterfly farming project was implemented, and butterfly sales can contribute up to 80% of recorded revenues (Gordon & Ayiemba, 2003). In Tanzania, the Amani Butterfly Project increased local income by at least 15-20%, and butterfly farming became an additional livelihood component, complementing other farm and off-farm activities (Mpand *et al.*, 2014).

In Latin America, butterfly farming represents a significant source of income for breeders compared to other countries worldwide. In Africa and Asia, butterfly farming is often a side part of the income and activity of the farmers, and pupae are usually sold at low prices (less than $ 1 each). In America most breeders have made butterflies their main source of income; they also benefit from a much higher sales price.

At LLDFR, a local butterfly exhibition can provide additional livelihoods as local people can get involved as farmers, services providers, or participants in additional economic activities such as the elaboration of handicrafts using butterfly wings in later stages of the project. Moreover, this initiative can also facilitate the distribution of handicrafts made by other communities to incoming tourists.

Community Development

Involvement of local communities in the butterfly business might produce far-reaching consequences, enhancing social capital through improved governance, organization, and leadership skills of local communities, and women's empowerment (Morgan-Brown, 2003; Kipepeo, 2006; van der Heyden, 2011).

Women's empowerment is promoted due to new sources of income and jobs. In Tanzania and Kenya, most butterfly farmers are women (Morgan-Brown, 2003; Le Roux, 2012). Moreover, women farmers can earn up to US$ 950 per month, much more compared to other traditional businesses such as charcoal production or farming chickens (Le Roux, 2012). It is also interesting to note that butterfly farming groups formed mainly by women (or having at least 50% women) progressed faster because women tended to provide more consistent efforts and attention to daily butterfly farming activities (Morgan-Brown, 2003). Butterfly farming can also be more suitable for women, as farmers can rear butterflies or elaborate handicrafts in their own home, combining them with domestic chores (van der Heyden, 2011), and activities are compatible with other women's activities such as chicken raising (Mpand *et al.*, 2014)

Enhanced human capital can also encourage 'grassroots' initiatives towards conservation, as has occurred with butterfly farmers from African countries. These initiatives included higher participation in environmental committee activities, planting trees, preserving natural forests in household land, community-led expansion of existing protected areas, and discouraging illegal cutting in protected areas (Morgan-Brown, 2007). Butterfly farming can thus enable local people to create bottom-up solutions, being the actors and leaders to promote sustainability.

Finally, butterfly farming projects can be a model by which key stakeholders such as local and national governments, NGOs, and local communities can collaborate and promote sustainability (Morgan-Brown, 2003). This occurs because each stakeholder has specific responsibilities and strengths, and the performance of each member is thus essential for the project's success (Sambhu & van der, Heyden 2010). Strong partnerships with local people provide political legitimacy that often is lacking, and conservation and management efforts become more efficient (Painter & Kretser, 2012).

Biodiversity and ecosystem conservation

It has been shown that butterfly farming does not have negative effects on wild populations of species reared in long-term projects (Moyle and Small 2016). Moreover, butterfly farming can directly promote conservation by creating additional sources of income for rural communities and indirectly through education (Parsons, 1992). In the case of environmental education, the butterfly exhibitions or related activities (*e.g.*, workshops for school teachers and students) can be a helpful tool, indeed changing people's attitudes towards conservation (Gordon & Ayiemba, 2003). Butterflies are ideal organisms for environmental education due to their charismatic appearance for the general public, aesthetic value, and ease to 'get in touch' through exhibitions. Consequently, the exhibition offers visitors a hands-on experience and makes the 'abstract' concept of biodiversity more real.

Moreover, the butterfly house could expand and diversify in the future to include additional species such as orchids, fishes, and frogs. Potential customers were also interested in carrying out different activities in the reserve, such as trekking and staying overnight. These activities, along with an expanded exhibition, can deepen the natural experience for visitors and increase awareness and interest in forest conservation (Le Roux, 2012; Boender, 1995) and environmental sustainability, particularly for local communities involved in the initiative (Le Roux, 2012). In addition, reared butterflies can also be exported to international exhibitions, creating an additional source of income for the reserve and people involved. It is reasonable to forecast an income of US$ 25,000 a year from export sales, an amount resulting from selling 400 pupae per week during 10 months in a year at an average price of US$ 1.5. This income will definitely contribute towards payments of infrastructure and 2-3 permanent workers. It is important to note a potential constraint to year-round butterfly production in seasonal forests as LLDFR, since several butterfly species are not present as adults during drought months. Butterfly breeding must take into account this important natural variation in wild populations, to produce a sustainable income.

Applied research closely associated with a sustainability initiative

The butterfly monitoring scheme set up at the LLDFR to detect impacts of climate and habitat change offered the opportunity to train local people and obtain biological information about which species to include in a butterfly farming project. The butterfly exhibition will closely link ongoing scientific research with a socioeconomic initiative with broader impacts. This is so because local-based biodiversity

monitoring projects that integrate ecological research, capacity-building, and income generation are practical tools to achieve conservation and poverty reduction (Sekercioglu, 2012).

Furthermore, a monitoring scheme associated with a butterfly farming project at LLDFR can offer additional advantages. According to Parsons (1992), "the research and monitoring part of a butterfly farming system can ensure the implementation and promotion of educational aspects that a purely economic enterprise might not have time to do" (Parsons, 1992). For example, wildlife clubs for local children in Guyana have traditionally performed bird surveys but became interested in researching butterflies after butterfly farms were set up in their communities (Sambhu & van der Heyden, 2010).

Capacity-building for local communities

Capacity-building and technical support of local people is key for long term success in butterfly farming. It is especially important to increase the diversity of butterfly species reared in order to better compete with other breeders in Latin America. Some butterfly species are difficult to breed due to their life history traits or challenges to grow their hostplants. For example, *Cithaerias pireta* is a highly desired species for all markets but is difficult to rear in large and sustainable quantities over time; this species requires the characteristics of its natural habitat to reproduce, it is thus necessary to recreate its habitat of shaded forest in captivity to obtain fertilized eggs, information only people with technical experience can provide to local farmers.

Moreover, 'unless the people of biodiversity-rich countries in the developing world can take the lead in the conservation of their regions, long-term, sustainable solutions are unlikely to be found, and the limited funds for conservation are likely to be misspent' (Rodríguez *et al.*, 2006). In addition, capacity-building can establish strong partnerships among stakeholders, including conservationists, local people, government, and international organizations. It can also promote cooperation between national universities in the capital city and rural people, thereby helping to decentralize knowledge and research. These institutional linkages should improve the multiplier effect of capacity-building (Clubbe, 2013).

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