Land Crab Management for Conservation and Tourism Development in UNESCO Cu Lao Cham – Hoi An Biosphere Reserve, Vietnam

Thao Ngoc Le - Management Board of Cu Lao Cham – Hoi An Biosphere Reserve, Vietnam.

Bieke Abelshausen - Vrije Universiteit Brussel, Belgium

Tri Hoang Nguyen - Hanoi National University of Education, President and Secretary General – Vietnam MAB National Committee

ABSTRACT: Land crabs, *Gecarcoidea lalandii*, native to forest and tidal areas, are considered a tropic factor sustaining the food chain and food web in marine-mountain ecosystem/ecotone, and a valuable source of nutrition for tourism and livelihood development. Land crab populations are used as indicators for forest and marine ecosystems health and are considered a contributing factor to the sustainable development of Island communities. Cham Island, located in Quang Nam province in central coastal Vietnam is explored as a case study to examine the influence that socio-economic development and natural disasters can have on land crab populations and associated benefits for sustainable development. Attempt for solutions have been offered and implemented by governments, managers, the scientific and grassroots communities to aid in the conservation and sustainable development of this valuable resource.

Introduction

Cham archipelago is known as a collection of beautiful, untouched islands with wild values and outstanding biodiversity, both in the forest and under the sea. With an area of 5.175 ha water surface surrounding 8 islands, it is the place for more than 311 hectares of coral reefs, 50 hectares of sea grass, seaweed, and more than 10 beaches [10] with fine white sand, and the soft tidal cliffs surrounding the islands. These are important habitats, home to numerous marine species and human development.

Not only outstanding in landscaping marine biodiversity, Cham Islands also owns primeval green forests covering the whole island. In addition to providing forest products, Cham Islands is a place of rare genetic conservation; specifically, the reservoir of fresh water which supplies residents on the island. These situations are the decisive factors for land crab life.

The outstanding value of biodiversity and cultural history of Cham Islands have made it a special attraction for tourists. The process of formation and preservation of these values have been intimately connected with the history of Hoi An ancient town: this connection served as the basis for the United Nations Educational, Scientific and Cultural Organization (UNESCO) to recognize Cham Islands as the core area of the Cu Lao Cham – Hoi An Biosphere Reserve [19].

KINGDOM	**ANIMALIA**
PHYLUM	Arthropoda
SUBPHYLUM	Crustacea
CLASS	Malacostraca
ORDER	Decapoda
INFRAORDER	Brachyuran
FAMILY	Gecarcinidae
GENUS	*Gecarcoidea*
SPECIES	***Gecarcoidea lalandii*** ***(***H. Milne Edwards, 1837***)***

Table 1: Land crab identification [21]

The land crab population in Cham Islands.

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Figure 1: Land crab *Gecarcoidea lalandii* (Thao, N. L)

The distribution of *G. lalandii* on the Cham Islands knows the highest species occurrence on Hon Lao Island. Hon Lao is the largest and only inhabited island of the archipelago. *G. lalandii* is a nocturnal species that inhabits caves. Their habitat perimeter extends between 1 to 12 meters around their cave [8]. Based on local ecological knowledge from the Cu Lao Cham residents a population density of several hundred crabs per cave is observed, which is perceived as a high population density with the highest intensity on Hon Lao island, one of the eight island of the Cham archipelago. Land crab population size on Cham islands varies between 30,000 and 35,000 individuals [1], [6], [8], [15], [17]. Their main food sources consist of vegetables, forest leaves, worms, and dead animals. The size of female land crabs varies according to their habitat. Female size varies between 50-60 mm on Hon La, Hon Tai and Hon Dai and 70-80mm on Hon Lao [8]. This variation in size depending on their habitat is possibly due to the difference in forest cover.

Reproductive characteristics of G. Lalandii on Cham Islands.

The reproductive season is initiated in the transition period between the rainy and dry season (end of March, beginning of April). The occurrence of thunderstorms appears to trigger the breeding pattern of land crabs, as sexually mature crabs leave their caves after storms and migrate to nearby streams for breeding. The breeding season of *G. lalandii* occurs between June and September [1] [15] [17]. Measurement data gathered by community science volunteers, local fishermen, shows that land crabs carrying eggs have a size varying between 40 to 78 mm, with the highest frequency around 60mm [12], [14]. The largest size, 80mm, was found on Hon Lao Island [8]. The breeding process entails the nocturnal migration of female crabs from their caves to tidal areas. Female crabs use their pincers to remove the eggs and release them in the ocean. This process is very fast, varying from 5 to 10 minutes, after which they quickly return to their forest caves [8].

Figure 2.1: The *G. lalandii* male in Cham Islands [15]

Figure 2.2: The *G. lalandii* female in Cham Islands [15]

After being released into the sea water, land crab larvae spend an average of 7 to 10 days developing into juvenile crab during which they change their shell several times. Juveniles crawl to the shore and live near the water's edge until they have relatively grown up and migrate into the forest where they live until maturity and only return to sea for spawning by which they complete their lifecycle.

According to Liu and Jeng, 2007, a female crab *(G. lalandii)* can spread from 70,000 to 210,000 larvae [8]. However, according to Damholdt (2006) female crabs

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at Cham Island carry 35,992 to 248,528 eggs as the number of eggs depends on the size of the female crab [6]. Various factors have been suggested as possible reasons: predation animals, habitat limitation, inadequate food supply, shrinkage of living space and barriers in their migrant path.

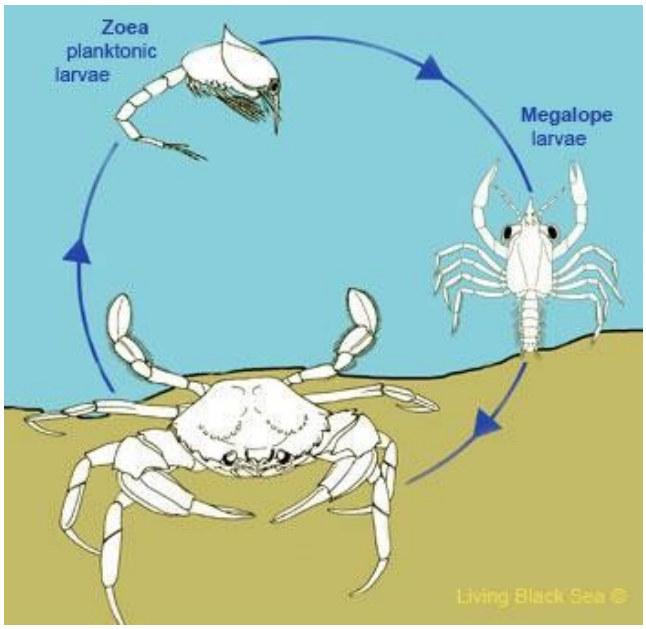

Figure 3. The *G. lalandii* lifecycle [20].

Ecological significance of land crab population on Cham Islands.

Land crabs are extremely important for the ecosystem in general and in particular for forest ecosystems. They help transfer the energy flow from land into the sea and back, promote the biogeochemical cycle by consuming falling objects in the forest litter, reduce erosion, activate the soil structure and improve groundwater resources. In addition, land crabs have a positive role in seed dispersal and enhancing flora biodiversity of the rainforest [8] Thus, the evolution of land crab population will reflect the situation and health of forest ecosystems on Cham Islands.

Community understanding of biological and ecological characteristics of the land crab.

From different thinking and understanding of land crab life, research on Cham Islands have added scientific information for local people for understanding on: where land crabs live, what their ecological environment is, what their food source is, what its life cycle is, how to protect the land crab population in the wild. These issues are used as a basis to attract local people to become involved in land crab conservation and sustainable development processes focusing on their sustainable livelihoods.

Methodology

In order to answer the question whether land crab management can contribute to conservation and sustainable tourism development in the core zone of a World Biosphere Reserve, various analysis steps were conducted: secondary data is collected using literature review and primary data is collected via Participatory Rural Appraisal.

Literature review

Land crab biological information was collected from secondary data including national and international scientific publications and reports from the MPA Management Board and local governments. Variables subtracted from these articles and reports include topography, geomorphology, vegetation index, humidity, land use patterns and population characteristics to calculate the distribution, yield and population size of land crabs.

Study Area

Cham archipelago located on the East of Quang Nam province, 18 km far from Hoi An city and 15 km far from Cua Dai river mouth. Cham Island constitutes 8 islands: Hon Lao, Hon Tai, Hon Dai, Hon Mo, Hon La, Hon Kho, Hon Cu and Hon Ong. Hon Lao is the largest island and the only island with human habitation: the Cham Islands population of about 3.000 people, constituting 600 households, reside in Tan Hiep commune on Hon Lao. 80% of these households exploit fishery resources as primary source of income [5]. Cham islands marine protected area (MPA) was established for ecological balance, sea environment protection, biodiversity conservation, conservation and development of fishery resources, ecosystem and habitat conservation, and preservation of the long standing cultural and historical value of Cham Island, and protection against negative natural and human impact. The establishment and subsequent actions of Cham Island MPA impacts and impulses socio-economic development and sustainable eco-tourism.

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Currently, the Tan Hiep commune and Hoi An City government implement a strict strategic plan.

Biological diversity of the archipelago is linked to beach, river mouth, nypa palm forest, estuary and the down stream of the Thu Bon river basin for creating a large ecosystem linking corridor. The integration between Hoi An ancient town, a UNESCO world heritage site, and natural resources has shown the special value of the World Biosphere Reserve; the harmonisation of man and nature.

Participatory Rural Appraisal (PRA)

Empirical research for this article was conducted using Participatory Rural Appraisal (PRA). Participatory Rural Appraisal entails methodologies that allow for direct learning from local people in which information is owned and shared by these local people [3]. PRA is a "bottom-up" approach that allows for the collection of data from groups of people that not only incorporates local needs and knowledge but which also allows for decision-making [18].

The methodology used for this PRA includes the DPSIR framework [7] and SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis.

Data was gathered in a workshop during which stakeholder surveys were used for analysis of the current situation and the identification of indicators. Additionally, scenarios were created to present possible solutions and develop an orientation for activities on land crab conservation. The organization of scientific conferences with the participation of national and international experts and the application of local ecological knowledge (LEK) resulted in the creating of indicators for land crab catch monitoring. These indicators include exploitation area, catch time, crab size, eggs carrying status, land crab quota, eco-labeling. The combination of both scientific and local knowledge is used to strengthen the scientific merit of the data as local knowledge in Vietnam is often questioned for its ecological accuracy and trustworthiness [11]. The cost-benefit analysis recipe by Boardman [13] is used to compare and evaluate the effectiveness between traditional management models and the four forces combination model (Government, Scientists, Entrepreneurs and Farmers) in the land crab conservation strategy. An interdisciplinary inspection team including police, executive, farmers union member of Tan Hiep People's committee, MPA staff and communities was established to oversee the catch criteria implementation process and trade activities, and land crab use on Cham Islands.

The present value and investment benefit was calculated by:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$

And profit ratio was calculated by:

$$BCR = \frac{\sum_{t=0}^{n} \left(\frac{B_t}{(1+r)^t} \right)}{\sum_{t=0}^{n} \left(\frac{C_t}{(1+r)^t} \right)}$$

NPV: Net Present Value; BCR: Benefit Cost Ratio; B_t: Benefit at time t; C_t: Cost at time t.

Results

Land crab resources situation, management, exploitation and conservation.

Analysis shows that in 2000 land crabs were caught on the islands only accidently and were limitedly used for consumption or as gifts for relationships on the mainland. In 2006, the MPA was established and visitors began to come to the islands. As a result, land crab consumption and associated land crab cultivation jobs were created. In 2009, Cham Island became the core zone of the Cu Lao Cham - Hoi An Biosphere Reserve. The number of tourists increased quickly thereby increasing the land crab use demand. Subsequently, the amount of people exploiting land crabs, mining time, frequency, crab size decreased, and exploitation area increased, crab size decreased. Development on Cham Island resulted in the construction of a road circling Hon Lao Island. Both the construction process and the road itself are perceived to impact the ecosystems health in general and in specific the habitat of land crabs; limiting the availability of food for the land crab population on Cham Island.

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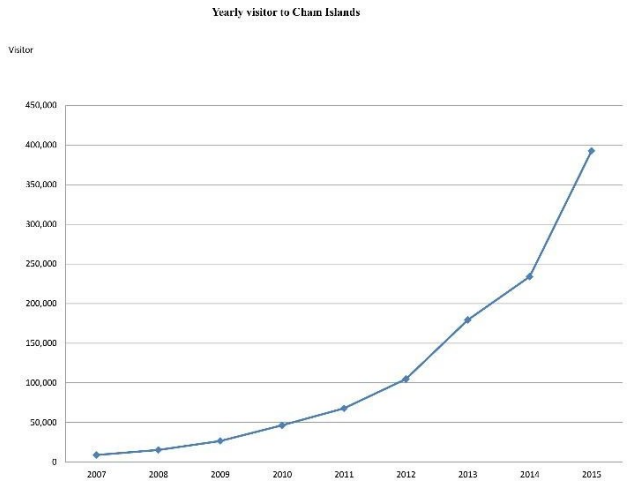
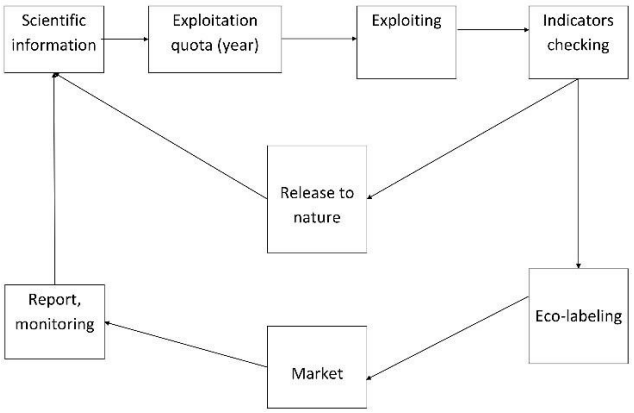


Graph 1: Yearly visitors to the Cham Islands [4]

Figure 4: Visitors on the boat to Cham Islands (Thao. L.N)

Exploitation and consumption activities of land crabs on Cham Island were limited in 2009 by Directive No. 04/2009-CT on September 20 by the Hoi An People's Committee. Analysis shows that this prohibition was not a perfect solution to protect the land crab. As tourism demands continued to rise, people continued to illegally exploit land crabs. Enforcement of this Directive was problematic and ineffective. This resulted in conflicts between community members, tourists, the government and continued until a harmonious balance between exploitation and conservation was suggested by the project "Community participation in natural recovery and conservation of land crab on Cham Islands" by Global Environment Facility (GEF). This project received agreement from the Government and has been implemented as a pilot since 2011.



Graph 2: Land crab exploitation management process in Cham Islands [12].

The management process based on size, time, status, eggs carrying, eco-labeling does not only allow exploitation and local livelihood development; it also supports a natural conservation mission.

DPSIR analysis for conservation and development of land crab populations.

The main results of DPSIR analysis show that urgency is needed for locals and governments to find balance between development and conservation in the implementation of plans.

Driven	The Islands knows a high infrastructural development; Local people increased their forest leaves mining activities.
Pressure	Natural living space has been narrowing and is becoming increasingly fragmented; Nutritional resources are declining; Migration paths are increasingly interrupted by barriers; wildlife decreases.
State	Natural exploitation yields are declining; the average size is decreasing.

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Impact	The ability of natural land crab populations to maintain their population size and income per yield will reduce.
Response	To apply exploitation indicators; to manage people who are exploiting land crabs; to establish the combination of the four forces in land crab management and exploitation.

Table 2: DPSIR analysis results of land crab management process on Cham islands.

SWOT analysis results on land crab population conservation

Strengths	Stakeholder participation for land crab preservationist achieved (*Government, Scientist, Entrepreneur and Community*). Land crab was managed by indicators (*Catching time, crab size, egg carrying status, eco-labelling and Who is allowed to exploit*). Income from land crabs catching is higher than in other sources of income. Subsequently, it has attracted local people to join in land crab conservation implementation.
Weaknesses	Over-exploitation of land crabs in the forest and exploitation in the tidal area when they are carrying eggs is a significant thread. Furthermore, as livelihoods on the island are not diverse - many people are pushed to join the exploitation of the land crab. Conflicts continue to occur with land crab exploitation and tourism growth. Limited attention is given to this issue by the government, conservation agencies and societal actors. Currently the preservation of land crabs for future generations is considered extremely limited.
Opportunities	Cham Islands is one of the few archipelagoes in Vietnam that can keep freshwater and maintain biodiversity for land crab's lives. Land crabs are an indicatory organism, if land crabs are conserved well then all ecosystems, habitats and biodiversity of the islands will also be protected. In addition to defense and security strategies, Cham islands has a very high significance in ensuring social security for about 3,000 people who are living on the islands and for receiving nearly 500,000 tourists each year. There are many research institutes concerned with land crab resources on Cham Islands. They provide supporting scientific information for the local community in land crab conservation strategy.
Threats	Cham Islands has built a lot of infrastructure in recent years such as a road circling the island, electricity cables, sea ports, sea walls and many future projects will be invested in on the islands. This has resulted in a reduction and fragmentation of the natural living space of the land crabs, has affected surface water and groundwater on the islands, and resulted in a decline of the quality and distribution of vegetation surface, cutting off the spawn migration path, and impacted other activities in the land crab lifecycle. Evolution of climate change and harsh living conditions are

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	increasing the negative impact to land crab life's cycle and population.

Table 3: SWOT analysis results of land crab management process on Cham islands.

Establishment and implementation of the land crab exploitation and protection team

The exploitation and protection land crab team was established in 2012 and consisted of 18 members who are professional exploiters. The membership was expanded to 33 members in 2016. The team installed regulations, monthly-yearly quota and the price of land crab. Indicators for land crabs are developed and include size, male/female rate, carrying eggs status, and eco-labeling.

These indicators and the enforcement are the result of cooperation between the farmers union, the Hoi An city government and local people. Furthermore, members also coordinate with the relevant authorities concerning the protection and development of the land crab population in nature.

Creating the land crab catch management indicators

The criteria developed and applied for land crab exploitation on Cham islands are:

(i) Catch, sale, use time allowed: 01st of March to 31st of July.
(ii) The land crab catch quota: based on the current situation of land crab population from scientific information, local people and government agencies discuss and set the land crab catch monthly and yearly quota. The quota is around 10,000 crabs per year since 2012.
(iii) Land crab catch size allowed: Larger than 7 cm of carapace.
(iv) Carrying eggs status: it is not allowed to catch female crabs carrying eggs.
(v) Price: Fixed price is valid for one year.
(vi) Eco-labeling: All legally exploited land crabs are eco-labelled before sale.

Figure 5: Eco-labeling to land crab product (Thao. L.N)

Graph 3: Land crab catching and population rehabilitation phases.

Promoting the four forces combination in land crab catching management process

Although land crab exploitation management processes have been applied, many difficulties and conflicts remain. Enforcement of regulations and controlling exploiters has been shown very difficult to manage. People who are not members of the land crab exploitation team continue to illegally exploit.

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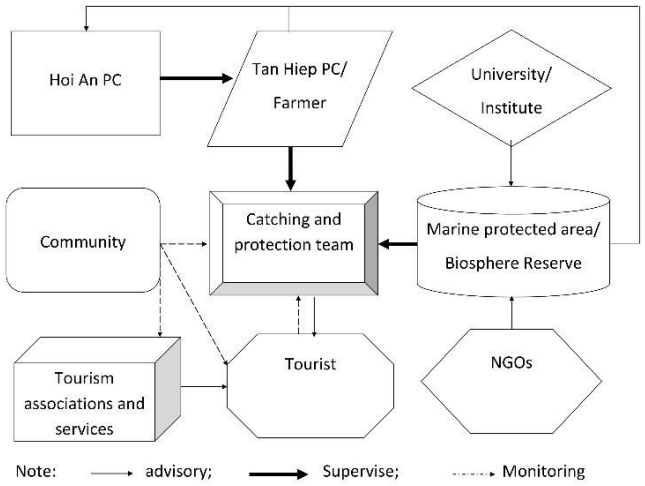
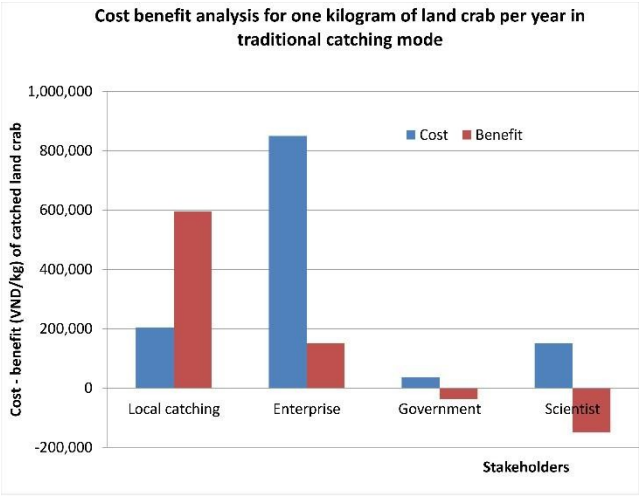


Graph 4: The operational diagrams of four forces cooperation mechanism in land crab management and conservation on Cham Islands [14].



Graph 5: Cost benefit analysis for one kilogram of land crab per year in traditional model [13].

Additionally, members have been reported to transfer eco-labels without the authorities' approval. The activities of the interdisciplinary inspection team are difficult and have been considered inefficient [14]. To resolve these issues the four forces cooperation mechanism for land crab exploitation management processes is proposed. This mechanism comprises the following targets; stakeholder participation, creating coherence and close coordination between stakeholders, creating mutual control between parties, reducing management burdens for authorities, promoting internal resources and strengths of the parties and creating mechanisms to divide responsibilities in managing and reducing risks for resource conservation.

Figure 6: The four forces representatives to participate in land crab co-management program.

The cost of funding to conserve the land crab on the islands amounts to around 1.367 billion Vietnam Dong (VND). This amount is used as a baseline to compare the cost benefit and profit ratio between the traditional model and the 4 forces combination model in land crab management and development process [13].

	Cost	**Benefit**	**CBR[20]**
Traditional mode	1,241,750.00	558,250.00	0.45
4 forces combination	363,700.00	960,000.00	2.64

[20] CBR: Cost Benefit Ratio

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Differences	-878,050.00	401,750.00	2.19

Table 4: Cost – benefit – and CBR comparison [13] Unit: VND

The application of the 4 forces combination in land crab management and development has showed a higher significance in CBR for the whole Cham Island society.

Discussion

Land crabs play a very important role in people's lives on Cham Islands. They are stimulating for tourism development and as biological indicators to monitor the forest ecosystems health. Population size and distribution of land crabs depend on coverage and forest vegetation quality. In the life cycle, land crabs need forests for habitat and food, and tidal areas to spawn. Increasing construction on the islands is impacting the life cycle; making the living space segmented, reducing water resources, decreasing food sources, increasing barriers on the spawning migration path. Currently, the exploitation, sale and use of land crab management at Cham Islands has come into shape. The management is based on scientific information and participation, and ownership is given to the societal partners. However some challenges still persist. To ensure economic development and national security the migration path, eco-region and food resources should be maintained and protected. These issues require the participation of stakeholders to discuss and solve issues in scientific and local practical conditions to improve the land crab population viability. The analysis yielded results on 5 levels: awareness raising, habitat and nutrition preservation, migration path protection, spawning ground protection, human-nature conflict reduction, and the four forces combination effectiveness enhancement.

How to raise stakeholders' awareness on land crab conservation

Understanding on land crabs is a basic necessity for conservation and sustainable development of this resource. The awareness of stakeholders must be raised and exploitation should be linked inextricably to the land crab resource conservation. Analysis reveals that an appropriate program should be designed for each different occupation group.

How to maintain the natural habitat and nutrition resources of land crabs

More and more construction on the island scatters and fragments the eco-region and depletes surface water resources. Additionally, the local forest leave collection for commercial purposes is affecting the distribution and quantity of the vegetation surface - a habitat and food resource for land crabs. The Biosphere Reserve and its stakeholders should reflect on the negative impact from infrastructure construction and increase the implementation process on Environment Impact Access (EIA) for all activities in the islands. Scientific research is needed urgently to find solutions to help land crab overcome physical barriers such as the road around the island to access the tidal area for spawning. Consequently, the current development, the land crab is exploited everywhere: healthy environment, habitat and food for crabs is reduced by decreasing quality and forest cover.

Figure 7: The circling road in the biggest island make barriers for crab spawning path (Thao. L.N).

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The circling road around the island and construction have resulted in fragmented forestation. The road was made as an added advantage for human mobility on the island: thereby reversing the natural distribution of land crab.

In the future, an island should be dedicated with suitable biological and ecological conditions to build an impregnable region (Sanctuary) as a land crab bank for saving land crab genetic resources and other species within the Cham island Biosphere Reserve.

How to solve the interruption of the spawning migration path

In the land crab life cycle, land crabs must move from the forest to the tidal area to spawn. However, the spawning migration path is interrupted by the road circling the island and is preventing access to the water's edge. Conservation agencies and scientists are currently trying to find solutions to protect the spawning migration path for land crab populations on Cham islands. However, no clear solution has been found or implemented and further research is needed.

How to protect the wild land crab spawning grounds

After accessing the waterfront, it is shown that land crabs continue to experience difficulties in tidal areas. There is a significant amount of activities such as snorkeling, scuba diving, fishing, sea embankments within this tidal area. There are too much silhouettes, sounds, lights and human activities in the tidal area which will hinder the spawning of land crab [8]. It is suggested that stakeholders need to discuss additional zoning and dedicate specific areas for the land crab spawning. For this reason Hoi An city has decided that Hon Dai island will be selected to build the land crab sanctuary as a crab bank for future generation.

How to reduce the conflicts between human and nature

Land crab exploitation is managed by the use of indicators. This process is currently being applied and is considered effective. However, habitat, food sources, migratory routes, the number of illegal catch, mining small crabs or catching crab carrying eggs still occurs. The distance between awareness and behavior of land crab cultivators is relatively large. Many weaknesses in management, implementation, operating system and a lack of a mechanism for cooperation between the four forces (government, scientists, entrepreneurs and community) still persists and no clear solutions are currently being implemented. Further research and an increase of the knowledge on management of and by the stakeholders is needed.

How to enhance the effectiveness of four forces combination in land crab conservation

The civilized exploitation managed production with four forces participation has described the process to enhance knowledge exchange, update the condition information and support local communities in the management and conservation process. This is a unique process, which should recognize ownership for the efforts of the community and stakeholders in the conservation and development of natural resources strategy of Cu Lao Cham-Hoi An Biosphere Reserve.

Conclusion

This study highlights that the need to conserve the land crab in conjunction with sustaining local livelihood. A set of criteria/indicators for exploiting and controlling the crab and monitoring team have been set up by agreed stakeholders under the regulation of local Authority. In order to implement effectively the initiative, we argue that the process should be participated by four forces including local government, scientists, entrepreneurs and farmers. Obviously the tourism would be benefits from UNESCO biosphere reserves, but consumption demand from tourists should be responded positively from local governance to meet the harmonizing three functions of biosphere reserves, i.e. conservation, development and logistic support.

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