Crab Banks: a Literature Review

Building Resilience to Climate Change Impacts in Coastal Southeast Asia (BCR)

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Table of Contents

1. Foreword

"Building Resilience to Climate Change Impacts – Coastal Southeast Asia (BCR)" is a four-year project supported by the EU and implemented by IUCN with partners VASI, SDF and GIZ, and operating in 8 provinces of Thailand, Cambodia and Vietnam, along the stretch of the South China Sea Coast between Bangkok and Ho Chi Minh City. The project has developed an integrated community-based and ecosystem-based approach which it is applying on the ground in pilot activities in 16 different communities or groups of communities within sub-districts (Thailand) or communes (Cambodia, Viet Nam).

A common feature of many of the communities the project is working with is the dependence on various forms of crab fisheries. Improved management of crab stocks and crab fisheries could therefore play an important role in increasing ecological and economic resilience in the face of climate change and other development pressures. Over the last decade or so, there have been a number of attempts in different places in the region, to restore crab populations and increase income from crab harvesting, through a variety of different activities and approaches collectively referred to as "crab banks".

BCR is supporting one form of crab bank activity in Mai Root sub-district of Trat Province, and lessons learned for this will be used to promote crab banking over a wider area. As a first step to understand the range of techniques available, their applicability in different situations, and the strengths and weaknesses inherent in each approach, this desk review study compiled available information on crab banking projects in the region. As such it provides a valuable addition to our knowledge in an area that is not yet well understood. A number of conclusions and recommendations are provided, which will be further taken up by the BCR project.

Robert Mather, Bangkok

2. Executive Summary

Populations of blue swimming crabs and other crab species in the Gulf of Thailand have been declining in recent years due to overfishing, and crab banks have been established in order to promote the rehabilitation and sustainable management of crab resources. This literature review has found evidence of crab bank projects in Japan, Thailand, Malaysia, Cambodia and Viet Nam, with the greatest number being in Thailand and Cambodia. Four main models have been developed: the Japanese model where the gravid crabs are marked and released back to the sea, the donation model where gravid crabs are donated to a crab bank with rearing cages, as well as the purchase and the loan models, where the gravid crabs are either purchased by the crab bank or provided in lieu of interest on loans.

The reviewed articles highlight important enabling factors and constraints that can serve as lessons learned for future projects. Indeed, factors such as field visits and awareness campaigns prior to implementation, support from NGOs, strong leadership, involvement and active participation of fishers, and learning and adaptation interactions contribute to the successful implementation of a crab bank. External factors also need to be taken into account, such as the governance mechanisms in place, existing governance challenges, the commitment of fishers to resource protection, the presence of illegal fishing, the availability of gravid crabs and the seasonality of crab resources. The crab bank location, the design of the crab-bank cages and other technical aspects are also important variables.

The case studies provide evidence of an increase in catch rates in the project sites, particularly when the crab banks are combined with other fishery management measures. However, there is limited availability of research, particularly on the long-term impacts of crab banks. Other perceived benefits of crab banks include access to credit in the loan model, increased awareness on sustainable resource use, the strengthening of community-based management institutions, and possibly the potential of crab banks as a tourist attraction.

From an economic perspective, the loan system requires the highest start-up investment, but is financially sustainable. In contrast, models based on the purchase of gravid crabs are not sustainable due to the high mortality of the crabs. Also, several crab banks were inactive after the first one or two years of operation or encountered a lack of active participation. In addition, undesirable effects need to be taken into account, in order for the positive effects not to be cancelled out by increased fishing efforts or exploitation of juvenile crabs. Impacts of climate change also need to be considered.

In conclusion, this literature review recommends the completion of a situation analysis prior to the implementation of crab banks, the active involvement of stakeholders, the development of transparent governance mechanisms, and, most importantly, a comprehensive approach of sustainable fishery resource management. It also emphasizes the importance of research to assess the impacts of crab banks, with a particular focus on the survival rates of crab larvae, the long-term sustainability of crab bank projects, and the improvement of technical issues.

3. Introduction

The Gulf of Thailand has significant populations of mud crab (*Scylla serrate*) and blue swimming crab (*Portunus pelagicus*), both of which create high economic value for the communities. However, populations of these and other crab species have been declining in recent years due to overfishing. As explained by Etoh and Chanthana (2010), "as one of the most important marine species harvested from the area, the swimming crab resource has the tendency to decrease especially with the practice of crab fishing using more than 250 traps."[1] Furthermore, crab populations are vulnerable to the impacts of climate change such as increased sea temperatures and changes in salinity levels. Crab banks have been established to address the issue of declining populations and to ensure sustainable crab harvesting.

This literature review examines existing studies related to crab banks, in order to evaluate the current status of knowledge about crab banks as a strategy to improve both local livelihoods and crab stocks while strengthening community-based management institutions.

No information on crab bank activities outside Southeast Asia and Japan has been found. Other stock enhancement initiatives, such as crab hatcheries and nurseries, have not been examined in this literature review.

4. History and location

4.1. History of crab banks

This literature review has identified the presence of crab bank systems as a strategy to enhance crab stocks in Japan, Thailand, Malaysia, Cambodia and Viet Nam. As explained by Chap Sopanha *et al.*, "the origin of the term 'crab bank' is not clear, but can be found in the documents produced by SEAFDEC [the Southeast Asian Fisheries Development Centre]"[2]. The origins of the crab bank system go back to a model developed by the Settsu-Harima Fishermen Cooperative in Hyogo Prefecture, Japan, in the second half of the 1980s[3].

At around the same period, the Bay Of Bengal Programme introduced the model to Phang Nga province, Thailand. Later, in 2002, "SEAFDEC, the Department of Fisheries (Thailand) and a local NGO revitalized the crab bank approach in Chumphon province"[4]. Since 2002, several crab banks have been established in Thailand, followed some years later by Cambodia, Malaysia and Viet Nam.

[1] Etoh, S. and Chanthana, Y. "Establishment and management of Crab Bank System", in: *Proceeding of the Regional Seminar on Integrated Coastal Resources Management Approach in Southeast Asia: Review of the ICRM-SV Project, 26-27 January 2010*, p. 145.
[2] Chap Sopanha *et al.* (2012), p. 15.
[3] Suanrattanachai, P. *et al.* (2009), p. 25 and Chap Sopanha *et al.* (2012), p. 15.
[4] Chap Sopanha *et al.* (2012), p. 15.

4.2. Location of crab bank projects

This review has found evidence of the following crab bank projects and sites. The list is not exhaustive, as some projects may not have been documented or may be documented in a different language or under a different designation.

4.2.1. Japan

Location	Year of Implementation	Project support	Crab bank system
Hyogo Prefecture	Second half of the 1980s	Fisheries cooperative association (FCA)	Japanese model: Gravid female crabs are marked on their carapace and released back to the sea.[5]

4.2.2. Thailand

Location	Year of Implementation	Project support	Crab bank system
Phang Nga province	Second half of the 1980s	Bay Of Bengal Program	Similar to Japanese model[6]
Tambon Bang Toey, Phang Nga province	1997	Department of Fisheries, Royal Development Project	Donation of gravid female crabs to a 'crab bank'[7]
Pakklong, Pathew District, Chumphon province	2002	SEAFDEC	Donation of gravid female crabs + Japanese method during the monsoon season[8]
Pred Nai, Trat Province	2002	RECOFTC / community-based	Donation (requested), combined with other rules[9]
Bang Saphan Bay, Prachuab Khiri Khan province	2005	Bang Saphan Bay Pilot Project (BSBPP)	First Chumphon model, then batch system using hatching tanks; crabs are returned to the owner after spawning[10]
Chonburi Province (several coastal communities)	2006	Members of the fishers group	Crab Condominiums (submerged resting cages); donation or sometimes returned to the owner after spawning[11]
Ban Sam Nak, Ranong province	2005-2007	Raks Thai Foundation (CARE International)	Donation of gravid female crabs[12]

[5] See Suanrattanachai, P. *et al.* (2009), p. 25.
[6] Chap Sopanha *et al.* (2012), p. 15.
[7] Hongkhao, V. and Tirasatayapitak, A. (2012), p. 2.
[8] Suanrattanachai, P. *et al.* (2009), p. 24-26.
[9] Soontornwong, S. (2006).
[10] Suanrattanachai, P. *et al.* (2009), p. 26.
[11] Suanrattanachai, P. *et al.* (2009), p. 26-27.
[12] CARE Australia, Tsunami Report, May 2010, p. 27.

3 coastal villages in the Kapoe estuary in Phang Nga and Ranong provinces	2005-2009	Mangroves for the Future (MFF) / community-based	Donation (requested); crab conservation area[13]
Ban Panern, Phetchaburi province	2007-2009	Thai Sea Watch Association	Donation of gravid female crabs[14]
Ban Klongthian, Phetchaburi province	2007-2009	Project introduced by the government (fishery biologists)	Donation of gravid female crabs[14]
Pang Nga Bay Ramsar Site, Krabi River Estuaries Ramsar Site	2008	Not specified	Not specified[15]
Amphur Langsuan and Amphur Sawee, Chumphon province	2010	PTTEP (PTT Exploration and Production Public Company Limited)	Not specified[16]
Kung Krabaen Bay, Chanthaburi province	Ongoing	National Fisheries Institute and other institutions	Research project[17]
Mai Root and Laem Klat sub-districts, Trat province	Ongoing	BCR Project	Donation of gravid female crabs
Kantang district, Trang province	Ongoing	Trang provincial administration	Gravid female crabs "deposited" to crab bank until they spawn[18]

4.2.3. Malaysia

Location	**Year of Implementation**	**Project support**	**Crab bank system**
Kuala Teriang, Pulau Langkawi	2007	KEN (Fishermen's Economic Group), later restructured into KPSP (Fishery Resources Mgmt. Community)	Japanese model[19]

[13] "Ban Chi Mee, Ban Dan and Ban Bang Lam Poo: Conserving community mangroves in Kapoe estuary", IUCN, March 2010.
[14] Thiammueang, D. *et al.* (2012).
[15] National Report on the Implementation of the Ramsar Convention on Wetlands, Thailand, 2008, p. 13.
[16] Online from http://www.pttep.com/en/CSRnewsDetail.aspx?ContentID=62 (21 June 2010) [retrieved 10 April 2013]
[17] Online from http://www.fis-net.com/fis/worldnews/worldnews.asp?monthyear=11-2012&day=19&id=56908&l=e&country=&special=&ndb=1&df=1 (19 November 2012) [retrieved 10 April 2013]
[18] Online from http://www.mcot.net/site/content?id=504600080b01da9213000064#.UXn5doJMZwQ (4 September 2012) [retrieved 10 April 2013]. In addition, the setup of a crab bank project for Sikao district was recommended by Nitiratsuwan, T. *et al.* (2005).
[19] Suanrattanachai, P. *et al.* (2009), p. 27-28.

4.2.4. Cambodia

According to Chap Sopanha *et al.*, "in Cambodia, crab bank development has been strongly promoted by the central government and the Minister of Agriculture, Forestry and Fisheries. Since 2008, there have been 19 crab banks developed in the three coastal provinces, namely Kampot, Preah Sihanouk, and Koh Kong provinces."[20] The crab banks have been "developed within the framework of Community Fisheries (CFis) and thus [imply] a community-based approach"[21]. Chap Sopanha *et al.* provide a case study of the following four projects, representing a variety of crab bank models.

Location	Year of Implementation	Project support	Crab bank system
Prey Nop II, Preah Sihanouk province	2008-2009	SEAFDEC	Donation of gravid female crabs[22]
Tomnop Rolok, Preah Sihanouk province	2008-2009	FiA	Purchase of gravid female crabs from fishers[22]
Phum Thmey, Kep province	2009	CORIN-Asia (Coastal Resources Institute-Foundation)	Access to loans, gravid female crabs provided as interest on loans[22]
Kampong Samaki, Kampot province	2009	Children and Women Development Center in Cambodia (CWDCC)	Purchase of gravid female crabs from fishers[22]

4.2.5. Viet Nam

Location	Year of Implementation	Project support	Crab bank system
Cham Island, Hoi An City, Quang Nam Province	2011	Global Environment Fund, Hoi An City budget	Not specified[23]
Kien Giang	Ongoing	US' National Fisheries Institute (NFI) and VASEP	Not specified[24]
Con Truong, Hoang Chau Commune, Thanh Hoa Province	Ongoing	UNDP ALM (Adaptation Learning Mechanism)	Not specified[25]

[20] Chap Sopanha *et al.* (2012), p. 16.
[21] Chap Sopanha *et al.* (2012), p. i.
[22] Chap Sopanha *et al.* (2012).
[23] "Marine protection: the experiences from the rock crab bank" (2 October 2011) http://english.vietnamnet.vn/en/politics/13632/committee-sets-socio-economic-tasks-and-party-re-organisation.html [retrieved 23 April 2013]
[24] http://www.aboutseafood.com/press/press-releases/nfi-crab-council-welcomes-crab-sustainability-group (December 2011) [retrieved 10 April 2013]
[25] http://www.undp-alm.org/projects/spa-cba-viet-nam-minimizing-climate-change-impacts-sustainable-aquaculture-con-truong-hoang/expected-key-results (2012) [retrieved 10 April 2013]

5. Technical and biological aspects

5.1. Types of crab banks

Crab banks have been developed as a strategy to enhance crab stocks and to ensure the sustainable use of crab resources by allowing gravid female crabs to spawn before or instead of being sold, in order to improve local livelihoods and livelihood security. Simultaneously, the crab bank projects also focus on strengthening community-based management institutions. Four basic models can be identified[26].

5.1.1. Japanese model

In the Japanese model, the cooperative purchases the gravid female crabs from the fishers, marks them on their carapace and releases them back to the sea. When fishers catch marked crabs, they return them to the sea. Female crabs generally moult after spawning several times, making the marks disappear. As explained by Chap Sopanha *et al.*, "this system is based on the cooperative's own funds and trust among the crab fishermen. It is also aligned with regulations on legal minimum crab size which state that crabs smaller than a certain carapace length have to be released."[27]

Suanrattanachai *et al.* provide the following additional details about the Japanese model[28]:

> - Under normal environmental conditions, a crab spawns 3-4 times a year (from May to September)
> - A gravid female crab hatches about 1.8 million (between 1 to 3 million) zoea per spawning […]
> - Crabs with under 12 cm carapace length and with soft-shells should not be harvested and should be returned to the sea once caught
> - Control season is limited for the spawning period of 5 months from May to September
> - The expenses for purchasing the gravid crabs are shouldered by the SCREA [Swimming Crab Resource Enhancement Association] funds contributed by its members
> - Anyone can become a member of SCREA not necessarily those engaged in fisheries but also ordinary people
> - Members of SCREA are provided with membership cards
> - Annual contribution of each member is 1,000 Yen equivalent to 330 Baht
> - The major advantage of this scheme lies in the high survival rate of gravid crabs and zoea

In a modified version of the Japanese model, the fishers themselves directly mark the carapaces of gravid crabs and release them to the sea[29].

[26] Based on Chap Sopanha *et al.* (2012).
[27] Chap Sopanha *et al.* (2012), p. 15.
[28] Suanrattanachai, P. *et al.* (2009), p. 24-25.
[29] Etoh, S. and Chanthana, Y. "Establishment and management of Crab Bank System", in: *Proceeding of the Regional Seminar on Integrated Coastal Resources Management Approach in Southeast Asia: Review of the ICRM-SV Project, 26-27 January 2010*, p. 146.

5.1.2. Donation of crabs to a crab bank

In this model, the fishers donate the gravid female crabs to a 'crab bank', managed by a committee or members of the community fisheries. The gravid crabs are kept in rearing cages until they spawn, after which the zoeae are released to the sea. The female crabs can then be sold, and the income of the sale is generally used for the maintenance and operation of the crab bank.

Some crab banks accept only gravid crabs in the last stage of spawning (with black coloured eggs)[30], in order to reduce the length of time until hatching and to avoid difficulties related to the feeding of the crabs.

For the SEAFDEC project in Chumphon Province, Thailand, Suanrattanachai *et al.* mention the donation of "small-sized and gravid crabs", suggesting that the crab bank not only targets gravid, but also juvenile crabs. Additionally, the Chumphon model promotes the use of a larger mesh size of crab traps (2.5 in instead of 1.25 in). To become members of the Crab Bank Group, the fishers should have at least 300 crab traps per member per boat and bring at least one gravid crab per day or 30 gravid crabs per month[31]. Furthermore, as the crab bank method is not applicable during the southeast monsoon due to heavy waves, this project adopted the Japanese method during the monsoon season.

Also in Chumphon Province, the income of the sale of female crabs after spawning is divided as follows: "50% as common funds which the members of the Group can borrow with interest, 30% for cage maintenance, 10% for crab feeds, and 10% for operating expenses of the crab bank"[32]. Hence, there can be a micro-finance aspect in the donation model.

There are different designs of crab bank cages, but the most commonly used cages seem to be floating cages with width, length and height of 3 metres[33].

In Bang Saphan Bay, Prachuab Khiri Khan province, a batch system using hatching tanks was developed with aerated plastic tanks (100 litres). Indeed, the Chumphon model "was discontinued due to problems such as daily feeding, maintenance of cages, etc. and unfavorable sea conditions considering that the coastline of Bang Saphan is very much exposed to the open sea"[34]. The disadvantages of this system are the relatively high investment costs and the low survival rate of the zoeae, as they are not in their natural environment[35].

5.1.3. Purchase of crabs by the crab bank

In the purchase model, the crab bank purchases the gravid female crabs from the fishers instead of relying on voluntary donations[36]. Like in the donation model, the gravid crabs are then kept in crab bank cages until they spawn.

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[30] See Suanrattanachai, P. *et al.* (2009), p. 26.
[31] Suanrattanachai, P. *et al.* (2009), p. 25.
[32] Suanrattanachai, P. *et al.* (2009), p. 25.
[33] Etoh, S. and Chanthana, Y. "Establishment and management of Crab Bank System", in: *Proceeding of the Regional Seminar on Integrated Coastal Resources Management Approach in Southeast Asia: Review of the ICRM-SV Project, 26-27 January 2010*, p. 145 and Hongkhao, V. and Tirasatayapitak, A. (2012), p. 2.
[34] Suanrattanachai, P. *et al.* (2009), p. 26.
[35] Suanrattanachai, P. *et al.* (2009), p. 29.
[36] See Chap Sopanha *et al.* (2012), p. 28.

5.1.4. Loan model

This literature review has found evidence of five crab banks based on the loan model, all implemented by CORIN in Kep, Kampot and Koh Kong provinces, Cambodia. As explained by Chap Sopanha *et al.*, "originally, 'crab bank' referred to stock enhancement and not to micro-finance aspects"[37]. The loan model can notably be found in Phum Thmey, Kep Province, where "CORIN applied a model based on access to loans as an incentive to get fishers involved in the development of crab banks. Through this approach, crab bank participants were selected based on the fishers' fishing capacity, specialization in crab fishing, capacity to repay the loan and willingness to provide gravid crabs. Loan interest was paid in nature, with 1 gravid crab per day. This approach integrating crab banks with micro-finance functions is unique to Cambodia."[38] The operation of the crab bank is the same as in the donation and in the purchase model.

A different model has been developed by the communities in Phang Nga and Ranong provinces under a Mangroves for the Future (MFF) project in 2009-2010. The project included a mud crab nursery area for small-size crabs: "If you catch a small size crab you must give it to the crab bank to put into the crab conservation area. If you deposit 25 small crabs to the crab bank you will get 3 big crabs in return."[39]

5.2. Biological aspects

5.2.1. Crab species

The following crab species are mentioned in the crab bank studies and related articles:

Crab species	Presence mentioned for
Blue swimming crab (*Portunus pelagicus*)	Thailand[40], Cambodia[41], Viet Nam[42], Malaysia[43]
Red swimming crab	Malaysia[43]
Mud crab (*Scylla serrate*)	Thailand[44], Cambodia[45]
Grapsoil (Grapsid) crab (*phu samae, Metapographus sp.*)	Thailand[44]
Blood spotted swimming crab (*Portunus sanguinolentus*), crucifix crab (*Charybdis feriatus*), sentinel crab (*Podophthalmus vigil*), two-spine arm swimming crab (Charybdis *anisodon*), spotted belly rock crab (*Ozius guttatus*)	Cambodia[45]
Rock crab (*Gecarcoidea lalandii*)	Viet Nam[46]
Swimming crabs (*Ovalipes punctatus*)	Japan[45]

[37] Chap Sopanha *et al.* (2012), p. 15.
[38] Chap Sopanha *et al.* (2012), p. 17.
[39] "Ban Chi Mee, Ban Dan and Ban Bang Lam Poo: Conserving community mangroves in Kapoe estuary", IUCN, March 2010, p. 2.
[40] Thiammueang, D. *et al.* (2012), p. 428.
[41] Chap Sopanha *et al.* (2012), p. 7.
[42] http://www.aboutseafood.com/press/press-releases/nfi-crab-council-welcomes-crab-sustainability-group (December 2011) [retrieved 10 April 2013]
[43] Suanrattanachai, P. *et al.* (2009), p. 27.
[44] Soontornwong, S. (2006), p. 192 and Pisupati, B. (2008), p. 25.
[45] Chap Sopanha *et al.* (2012), p. 7.
[46] "Marine protection: the experiences from the rock crab bank" (2 October 2011) http://english.vietnamnet.vn/en/politics/13632/committee-sets-socio-economic-tasks-and-party-re-organisation.html [retrieved 23 April 2013]

5.2.2. Crab development

According to Chap Sopanha *et al.*, "the development from zoea to megalopa takes 12 days in a controlled environment with a 99% mortality rate"[47]. Estimates of the number of eggs per spawning range between 0.14 and 3 million.

Salinity levels are important for the development and survival of zoeae and need to be taken into account in the setup of crab bank projects. "The monitoring of megalopae catch found that the abundance of larvae is higher near reefs compared to low salinity areas near the shore. Research suggests that even if the salinity tolerance of the zoea is between 16.2 to 35 ppt, the daily fluctuation due to tidal patterns and irregular amounts of rainfall can affect the presence and survival rate of larvae."[48]

Peak crab season and spawning season vary according to the location. For the blue swimming crab, "catch monitoring demonstrates that gravid crabs can be found all year round, but two main seasons were highlighted: February to April and July to October […]. A study conducted in the Philippines shows that *Portunus pelagicus* are sexually mature when they reach a carapace size of 10.5 cm for females and 9.6 cm for males. […] Studies on other swimming crabs (*Ovalipes punctatus)* in Japan show that the spawning grounds of crabs are offshore (40-60 m depth*).* The main spawners were adult crabs with a carapace of 7.5 to 8 cm in width (2 years old), while smaller crabs spawned less often. Immature crabs are normally found near the shore, while adult crabs are found more offshore."[49]

Gravid crab with black eggs in a crab bank in Trat Province, Thailand

[47] Chap Sopanha *et al.* (2012), p. 7.
[48] Chap Sopanha *et al.* (2012), p. 7.
[49] Chap Sopanha *et al.* (2012), p. 7-8.

6. Lessons learned: Enabling factors and constraints

The studies of Thiammueang *et al.* (2012)[50] and Chap Sopanha *et al.* (2012) highlight the following enabling factors and constraints of different crab bank projects in Thailand and Cambodia, that can be used as lessons learned for future projects.

	Enabling factors	**Constraints**
Project setup	- Detailed study of the 'step zero' or the pre-implementation stage[51] - Organization of a field visit to an ongoing crab bank project (e.g. Ban Panern, Thailand and Pulau Langkawi, Malaysia[52]) - Awareness campaigns and information on future benefits "in order to create sufficient interest among the CFi members and to ensure that they share the same understanding"[53] - Additional incentives such as access to loans or small gifts for participation[54] - Development of transparent governance mechanisms, especially for crab banks with access to loans[55]	- Low awareness and limited information sharing[56] - Lack of transparency and mistrust of leadership[57] - Limited participation, unclear or limited membership[58] - Limited sustainability of purchase model due to the high mortality of crabs[59]
Project support	- Technical and financial support from NGOs[60] (and/or the Department of Fisheries, local authorities) - Strong leadership, commitment of committee members	- Limited loan capital or financial support for crab bank operation[61] - Lack of leadership[62] - Lack of knowledge and skills (e.g. feeding of the crabs, crab cage design)[63]
Involvement of stakeholders	- Active involvement of fishers[64] - Involvement and active participation of middlemen[65] - Representation and participation of stakeholders, learning and adaptation interactions[66]	- Absence of direct involvement of fishers in the early discussions[67] - Lack of consultation with primary stakeholders, the crab fishers[68]

[50] The study by Thiammueang et al. (2012) of two crab bank projects implemented in Phetchaburi Province, Thailand, applied the 'interactive governance framework' to assess the "characteristics of the natural and social systems associated with the fisheries, of the governing system, and of their interactions that may contribute to successful implementation of the crab bank project" (p. 427).
[51] Thiammueang, D. *et al.* (2012), p. 428.
[52] Thiammueang, D. *et al.* (2012), p. 431 and Suanrattanachai, P. *et al.* (2009), p. 27.
[53] Chap Sopanha *et al.* (2012), p. 28.
[54] Thiammueang, D. *et al.* (2012), p. 437 and Chap Sopanha *et al.* (2012), p. 18.
[55] Chap Sopanha *et al.* (2012), p. 23.
[56] Chap Sopanha *et al.* (2012), p. 24.
[57] Chap Sopanha *et al.* (2012), p. 25.
[58] Chap Sopanha *et al.* (2012), p. 21. "In Kampong Samaki and Tomnop Rolok the crab bank is associated only with the CFi Committee. Membership was not clearly stated and fishers did not participate in donation of gravid crabs."
[59] Chap Sopanha *et al.* (2012), p. 28.
[60] Chap Sopanha *et al.* (2012), p. 23.
[61] Chap Sopanha *et al.* (2012), p. 25-26.
[62] Thiammueang, D. *et al.* (2012), p. 437.
[63] Chap Sopanha *et al.* (2012), p. 26.
[64] Thiammueang, D. *et al.* (2012), p. 427.
[65] Chap Sopanha *et al.* (2012), p. ii.
[66] Thiammueang, D. *et al.* (2012), p. 434-435.

Environment	- High diversity of the system-to-be-governed and high level of interactions (high governability)[69] - Strong commitment of fishers to Community Fisheries and resource protection[70] - Smaller and more active CFi rather than a large CFi[70] - Type of crab fishery giving access to gravid females (i.e. a certain level of fishing capacity to ensure access to diverse fishing grounds) - "Areas where crab fishing occurs during the peak season and spawning season seemed to be more suitable as they had a higher gravid crab catch."[71]	- Governance challenges (e.g. presence of foreign workers, exchange with tourists and scale issues)[72] - Presence of illegal fishing, illegal trawlers[73] - Ineffective Community Fisheries and absence of social cohesion[73] - Less diverse and complex ecosystems (e.g. less mangrove forests and smaller mudflat areas)[74] - Low availability of gravid females (e.g. limited period of availability, location of fishing mainly near the shore)[75]
Location	- Easy access to the cages, close to the village or to the landing site "to shorten the transportation time of gravid females and reduce the mortality rate"[76] - "Natural environmental conditions – such as the low influence of fresh water in the rainy season and protection from strong waves – must be taken into account when selecting crab bank sites. […] Technical options for running crab banks in the rainy season when water salinity decreases need to be identified."[77]	
Crab cage design	- Adequate cage structure[78] - Adequate cage size to avoid over-populated cages and thus higher mortality rates[79]	

[67] Thiammueang, D. *et al.* (2012), p. 427.
[68] Chap Sopanha *et al.* (2012), p. 18.
[69] Thiammueang, D. *et al.* (2012), p. 427.
[70] Chap Sopanha *et al.* (2012), p. 23.
[71] Chap Sopanha *et al.* (2012), p. 28.
[72] Thiammueang, D. *et al.* (2012), p. 436.
[73] Chap Sopanha *et al.* (2012), p. 25.
[74] Thiammueang, D. *et al.* (2012), p. 435. "The importance of these ecosystems in mitigating damage and protecting coastal areas, livelihoods and assets makes governance challenging."
[75] Chap Sopanha *et al.* (2012), p. 26.
[76] Chap Sopanha *et al.* (2012), p. ii and 26.
[77] Chap Sopanha *et al.* (2012), p. 28-29.
[78] Chap Sopanha *et al.* (2012). "Cage structures made of metal are not suitable in saline water and bamboo structures seems better for this environment […]. With different landing sites for different seasons, floating bamboo cages are more easily manageable and transportable than fixed metal cages with poles. In addition, floating cages are less prone to poaching." (p. 29) "On the other hand, small cages made of bamboo were not strong enough to withstand waves during the rainy season." (p. 26)
[79] Chap Sopanha *et al.* (2012), p. 29.

7. Benefits and long-term considerations

7.1. Evidence of positive results

7.1.1. Increase in catch rates

There is limited availability of data assessing the impacts of crab banks, and notably limited research on the long-term benefits. As indicated by Chap Sopanha *et al.* (2012), "from a crab bank perspective, the benefits of stocking crabs will likely be observed on a long- or medium-term (more than 2 years) timescale."[80] Nevertheless, several studies provide evidence of an increase in catch rates after the implementation of crab banks.

Thiammueang *et al.* (2012), citing a study of Petchkamnerd *et al.* (2004), mention an increase in catch rates in Thailand: "Since its conception, the crab bank project has been implemented in many coastal provinces, and according to an assessment in 2004, catch rates have increased."[81] In Chumphon Province, Thailand, "a significant impact on the catch and size of the crabs was found after 2 years of crab bank implementation"[82].

In Chonburi Province, Thailand, "there were no scientific surveys conducted before in the project area that can serve as baseline for assessment. [Nevertheless,] the fishers have reported an increase in crab catch in 2007 compared with that of 2006."[83]

In Phum Thmey, Cambodia, after one year of operations, "more than 60% of the members interviewed reported an increase in crab catch, mainly in juvenile and immature ones. However, these statements could not be verified by official catch records."[84] In Prey Nop II, Cambodia, "the concerned crab fishermen themselves clearly recognized and stated that great numbers of baby swimming crabs had been observed near the crab bank cages which had never been seen before. […] Still, the FiA should continue the scientific monitoring to convince the fishers of its effectiveness in terms of measuring the sizes of crabs and the CPUE [catch per unit effort]."[85] No evidence of an increase of catch rates is provided for the other two project sites in Cambodia, Kampong Samaki and Tomnop Rolok, which have been less successful and were (at least temporarily) inactive as of January 2010. However, Chap Sopanha *et al.* note that each of the four sites "had only been in operation for a short time. […] For this reason, it was too soon to say whether these crab banks were working."[86]

In Pulau Langkawi, Malaysia, where the Japanese system was applied, "after the introduction of the system, the fishers have reported that the crab landings have since then increased slightly "[87]. In general, the visibility of impacts is lower in the

[80] Chap Sopanha *et al.* (2012), p. 8.
[81] Thiammueang, D. *et al.* (2012), p. 428.
[82] Chap Sopanha *et al.* (2012), p. 27.
[83] Suanrattanachai, P. *et al.* (2009), p. 27.
[84] Chap Sopanha *et al.* (2012), p. 26.
[85] Etoh, S. and Chanthana, Y. "Establishment and management of Crab Bank System", in: *Proceeding of the Regional Seminar on Integrated Coastal Resources Management Approach in Southeast Asia: Review of the ICRM-SV Project, 26-27 January 2010*, p. 149.
[86] Chap Sopanha *et al.* (2012), p. 20.
[87] Suanrattanachai, P. *et al.* (2009), p. 28.

Japanese model, as highlighted by Etoh (2007)[88]. On the other hand, the survival rate of gravid crabs is higher compared to the Chumphon model, where the survival rate is only of about 50%[89].

Chap Sopanha *et al.* estimate that "each spawning female stocked in a crab bank can result in 1,410 more adult crabs in the wild […], but to make a significant impact on crab stocks, and in turn, to increase the catch, the crab bank schemes [in Cambodia] will need to have a much larger number of female crabs [estimated between 3,058 and 7,645]."[90] By comparison, in Chumphon Province, Thailand, "from 2002 until 2007, the crab bank […] received a total of 19,475 gravid crabs"[91].

Several studies suggest that the crab banks are most effective when combined with other measures to regulate the crab fisheries[92]. For instance, a first assessment of the use of increased mesh size in Chumphon Province, Thailand, showed an "increasing trend in terms of carapace size and volume of catch"[93]. Suppanirun (2010) suggests that "the enlarged mesh size resulted in higher benefits in terms of exploitation"[94].

In Pred Nai, Trat Province, Thailand, the crab bank was combined with several other rules. For instance, the fishers were not allowed to catch small-size crabs. "After a few years of monitoring, the *phu samae* (Grapsoil Crab) has increased from 5 kg/harvest to 8-10 kg/harvest." [95] Pisupati (2008) indicates that "part of the community's strategy has been to close the fishery voluntarily during the crab's reproductive season each October. This has helped to increase harvests of grapsoid crabs (*Metapographus sp*) from 8 kg per day by six collectors to 15 kg per day by thirty collectors in about five years."[96] Regarding the crab bank for mud crabs, "since beginning their efforts, families have seen their incomes from each 'crab crop' rise from 10,000 baht for 6 families to 15,000 baht for 10 families"[97].

7.1.2. Other perceived benefits

Other benefits of crab banks include access to credit in the loan model, increased awareness on sustainable resource use, the strengthening of community-based management institutions, and possibly the potential of crab banks as a tourist attraction.

In Phum Thmey, Cambodia, which applied the loan model, "access to credit and higher catches were highlighted as the main reasons for livelihood improvement by 11% of the respondents and access to credit was the main benefit of this initiative for 72% of the members interviewed."[98]

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[88] Cited in Suanrattanachai, P. *et al.* (2009), p. 29.
[89] Etoh (2007), cited in Suanrattanachai, P. *et al.* (2009), p. 29.
[90] Chap Sopanha *et al.* (2012), p. 27.
[91] Suanrattanachai, P. *et al.* (2009), p. 25.
[92] Chap Sopanha *et al.* (2012), p. 29.
[93] Suanrattanachai, P. *et al.* (2009), p. 25.
[94] Thitiporn Suppanirun, "Integrated Coastal Resources Management in Pathew District (ICRM-PD) Chumphon Province, Thailand", in: *Proceeding of the Regional Seminar on Integrated Coastal Resources Management Approach in Southeast Asia: Review of the ICRM-SV Project, 26-27 January 2010*, p. 52.
[95] Soontornwong (2006), p. 192.
[96] Pisupati, B. (2008), p. 25.
[97] Pisupati, B. (2008), p. 25.
[98] Chap Sopanha *et al.* (2012), p. 26.

Under the Integrated Coastal Resources Management (ICRM) projects implemented by SEAFDEC, and perhaps under all of the studied crab bank projects, "the Crab Bank System has inspired the local people to ensure that the crab resources are protected and conserved in a sustainable manner"[99]. The Crab Condominium project in Chonburi Province, Thailand, has also "promoted awareness and recognition of responsible fishing and resource conservation"[100].

As for the strengthening of community-based management institutions, "generally, through the crab bank method, a sense of ownership has been developed since the fishers themselves are managing the activity, giving the opportunity to improve their livelihoods and source of income"[101]. In Pred Nai, Trat Province, Thailand, "through this group learning process, the Pred Nai community has moved to additional projects, such as managing herbal products, honey collecting and collecting other local foods"[102].

Additionally, a study by Hongkhao and Tirasatayapitak (2012) mentions the potential of crab banks as a tourist attraction: "If there is a guideline for crab bank development and improvement of tourist attraction as well as an availability of tourist information, the crab bank must possibly become a core tourist attraction of Tambon Bang Toey, Changwat Phang Nga in the future."[103]

7.1.3. Economic considerations

Chap Sopanha *et al.* provide an overview of the capital investment costs of the different sites studied. Indeed, the loan system "requires the highest start-up investment to provide the revolving funds for the loans to crab bank participants" (3,250 USD compared to less than 600 USD for systems based on the purchase of crabs)[104]. Nevertheless, loan systems are financially sustainable:

> Capital investment costs varied among the different systems. Crab banks with loans were the most costly, with more than 3,250 USD financed by CORIN in Phum Thmey (of which 2,750 USD was used to provide revolving funds for loans) compared to 590 USD in Kampong Samaki or 580 USD in Tomnop Rolok (and an additional 90 USD/month operational cost for feeding). In Prey Nop II the financial details of investment and return of the crab bank were not available. SEAFDEC covered the monthly operational cost of 10 USD (including feed with trash fish).
>
> Even with a crab mortality rate higher than 20%, the crab bank in Phum Thmey has proven financially sustainable. Operational costs (fuel and food) were between 3 and 13 USD/month and the crab bank generated a net return of over 50 USD/month. Some of the benefits were re-invested in the crab bank through the purchase of equipment (a boat and bicycle) the first year. The net benefit was divided equally between the members of the committee, as a financial incentive.[105]

Two issues encountered in the loan model were the limited availability of loan capital and delayed repayment due to the seasonality of crab catches, as "fishers may not be able to catch enough crabs to repay the interest on the crab bank loans during the low season"[106].

[99] Suanrattanachai, P. *et al.* (2009), p. 24.
[100] Suanrattanachai, P. *et al.* (2009), p. 27.
[101] Suanrattanachai, P. *et al.* (2009), p. 26.
[102] Soontornwong (2006), p. 192.
[103] Hongkhao, V. and Tirasatayapitak, A. (2012), p. 12.
[104] Chap Sopanha *et al.* (2012), p. ii and 21.
[105] Chap Sopanha *et al.* (2012), p. 21.
[106] Chap Sopanha *et al.* (2012), p. 25-26.

The models based on the purchase of gravid crabs encounter the highest difficulties in terms of financial sustainability: "Due to the high mortality rate of crabs kept in cages, crab banks based only on the purchase of gravid females from markets (instead of voluntary donations or as a loan repayment) are likely to be unsustainable because of the cost of having to purchase gravid females every cycle."[107] In addition, "the total weight of purchased crabs after spawning is lower than before spawning; thus, even with 0% mortality the funds generated from selling the crabs after they spawned were not sufficient to purchase the same number of new gravid crabs for the next cycle"[108].

7.2. Unsuccessful implementation and undesirable effects

7.2.1. Evidence of inactivity

Several studies mention the inactivity of some of the crab banks after the first one or two years of operation. In Ban Klongthian, Phetchaburi Province, Thailand, "there has not been any activity for some time because of the scarcity of gravid female crabs and due to the health problems of the crab bank project leader"[109]. The two project sites in Kampong Samaki and Tomnop Rolok, Cambodia, were also inactive as per January 2010[110].

Although the project in Pulau Langkawi, Malaysia, has been at least partially successful, Arunasalam (2008) mentions a lack of active participation of the fishermen: "It was understood that the participation of the members was not active and they seemed not willing to use traps because the gears either drifted or were stolen. A new group consisting of 10 members using traps and gill-nets volunteered to take part in the project."[111] Suanrattanachai *et al.* explain that "considering that [the Japanese] model does not require any cages, it could be cost effective. However, this system requires the voluntary commitment by the members."[112] Despite some difficulties with participation, "the system appeared to be more practical, applicable and acceptable for implementation"[113].

7.2.2. Undesirable or cancelling effects

If the crab banks are not combined with other fishery management measures, the efforts can in some cases be cancelled out by other activities. For instance, "the new market in Vietnam for juvenile mud crabs provides Cambodian fishers with new opportunities […]. Overfishing juvenile crabs may cancel out any positive effect from crab banks."[114]

Crab banks might even have undesirable negative effects. As explained by Chap Sopanha *et al.*, "one interesting point is that loans were used mainly to intensify crab catch, to replace or invest in traps, hire crew members, or cover fuel costs. In this context, the increased catch could be the consequence of greater fishing effort and not a greater abundance of crabs. The fact that the loans are used to increase fishing effort might have an effect on crab stocks that is the opposite of the one

[107] Chap Sopanha *et al.* (2012), p. 28.
[108] Chap Sopanha *et al.* (2012), p. 21.
[109] Thiammueang, D. *et al.* (2012), p. 431.
[110] Chap Sopanha *et al.* (2012), p. i.
[111] Arunasalam, K. (2008), p. 102.
[112] Suanrattanachai, P. *et al.* (2009), p. 27.
[113] Suanrattanachai, P. *et al.* (2009), p. 28.
[114] Chap Sopanha *et al.* (2012), p. 11.

intended by leading to over-exploitation of the crab fishery. Within this scenario, the crab bank has to be efficient enough to counter the effect of increased fishing effort."[115]

7.3. Climate change considerations

In the context of climate change, the successful rehabilitation of crab populations has the potential to improve the long-term resilience of local ecosystems and local communities. However, there is a risk that climate change may cancel out any efforts to increase crab stocks, which is why stock enhancement initiatives need to be combined with broader measures to increase resilience and livelihood security, such as habitat conservation and restoration and livelihood diversification.

Several studies show that blue swimming and other crabs are sensitive to the impacts of climate change. According to the Department of Agriculture, Fisheries and Forestry of the State of Queensland, Australia, "climate change may influence population dynamics of blue swimmer crab stocks such as spawning events, juvenile mortality and recruitment"[116].

Bezuijen *et al*. (2010) indicate that mud crabs are sensitive to changes in sea temperature, ocean chemistry, ocean circulation and precipitation, as well as infectious diseases and secondary impacts on their food supply. However, the study also highlights that further research is needed.

> Larvae of the mud crab reared in laboratories have been shown to be highly sensitive to changes in temperature and salinity, with mass mortality occurring above 25 degrees C and in low saline conditions (Hill, 1974). […] If predicted regional warming of the [sea surface temperature] in the areas where mud crab are cultured increases to over 32 degree thresholds, larval development could be severely impacted. [However,] increased temperature might be beneficial to the development of juvenile mud crabs in culture systems. […]
>
> Altered water quality conditions have the potential to affect both wild and cultured mud crabs. An altered pH presents a significant problem for calcifying organisms such as crustaceans, as it interferes with shell formation (Przeslawski et al., 2008). Fragile mud crab larval skeletons may be particularly vulnerable to changes in pH, potentially resulting in recruitment failure (Przeslawski et al., 2008). As with other calcifying organisms in the project region (mussels, oysters and cockles), there is a paucity of knowledge on the specific effects of gradual decreasing pH in mud crab. Opinion appears to be divided about how well calcifying organisms, like mud crabs will be able to adapt to increasing pH. […]
>
> Since wild populations of mud crab rely on ocean currents to disperse their larvae, and the larvae themselves rely on currents to bring them back in-shore, it can be surmised that wild crabs will be vulnerable to any changes in current or ocean circulation, however the extent to which this will happen is unknown. […]
>
> Correlation of catches of mud crab with rainfall suggests changes in rainfall (and therefore salinity) will undoubtedly affect some or all of the life cycle stages of both wild populations and cultured populations (FAO, 2011). […]
>
> Significant differences amongst wild populations of *Scylla serrata* have led authors to believe that local environmental conditions have a large influence on life history traits in this species, as they exhibit strong site fidelity (Ewel, 2008). This means that wild populations are highly vulnerable to changes in optimum breeding conditions and the synergistic effects from climate impacts and other anthropogenic impacts (habitat destruction, pollutants) may have distinct negative

[115] Chap Sopanha *et al.* (2012), p. 27.
[116] State of Queensland, Department of Agriculture, Fisheries and Forestry (2012), p. 12.

> consequences for species survival. More information is needed about the adaptive capacity of wild populations of mud crab before any accurate predictions regarding their future survival can take place.[117]

Regarding the blue swimming crab, Bezuijen *et al*. explain that increases in extremes in water temperature "are likely to have significant effects both on survival of larvae and adults blue swimmer crabs as well as affecting growth and reproduction". Within their thermal tolerance, "a sea surface temperature rise would therefore likely increase developmental rate overall, resulting in a net increase in production in culture systems". Furthermore, "as with mud crabs, wild populations of blue swimmer crabs may be sensitive to sea level rise as they depend on intertidal habitats during their life cycles". Blue swimming crabs are also likely to be affected by changes in ocean chemistry, ocean circulation, precipitation and by an increase in the severity and frequency of extreme events. However, they appear to be "less sensitive to climate related impacts on their food supply than more specialist feeders"[118].

Talpur and Ikhwanuddin (2012) conducted a study in Malaysia where "Zoea I and Zoea 2 larvae of *P. pelagicus* were exposed to various regimes of activity stress tests such as oxygen, starvation, pH, temperature, and salinity to examine larval competency against these factors. […] The findings of this study indicate that the larval survival of *P. pelagicus* was compromised with certain level of stressor, elevated and low stressor had shown unfavourable effect on larval survival."[119]

A study conducted along the east coast of America has shown that climate change negatively affects the development of Horseshoe Crabs. "Our results also show that future climate change may further reduce the already vastly diminished population."[120] The Western Australian Department of Fisheries has initiated an intensive research and monitoring programme studying the declining numbers of blue swimmer crabs (*Portunus armatus*) in Shark Bay, citing "adverse environmental conditions such as flooding and warmer water temperatures" as likely causes[121].

On the other hand, some studies mention a possible increase in the number and size of certain crab species due to climate change, for instance the Blue Crab in Chesapeake Bay in the United States.

> "Higher levels of carbon in the ocean are causing oysters to grow slower, and their predators — such as blue crabs — to grow faster," Justin Baker Ries, a marine geologist at the University of North Carolina's Aquarium Research Center, said in an recent interview.
>
> Over the next 75 to 100 years, ocean acidification could supersize blue crabs, which may then eat more oysters and other organisms and possibly throw the food chain of the nation's largest estuary out of whack.[122]

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[117] Bezuijen, M. R. *et al.* (2011), p. 65-66.
[118] Bezuijen, M. R. *et al.* (2011), p. 67.
[119] Allah Dad Talpur, Mhd. Ikhwanuddin (2012), p. 1909. Zoea 1 are newly-hatched larvae and Zoea 2 are larvae four day after hatch (p. 1910).
[120] http://www.science.gu.se/english/News/News_detail/climate-change-affects-horseshoe-crab-numbers.cid954894 (24 September 2012) [retrieved 30 April 2013]
[121] http://www.sciencewa.net.au/topics/fisheries-a-water/item/2038-marine-heatwave-likely-cause-for-blue-swimmer-crab-decline.html (2 April 2013) [retrieved 30 April 2013]
[122] http://www.washingtonpost.com/blogs/post-partisan/wp/2013/04/08/climate_change_effects_crabs_ carbon_emissions/ (8 April 2013) [retrieved 30 April 2013]

Bezuijen *et al*. indicate that "the adaptive capacity of the majority of marine and coastal organisms to the majority of climate change impacts is largely unknown […]. Climate change may favour some species of tropical marine organism over others, thereby changing the biogeography of fish stocks and their relative abundance"[123]. Regarding the adaptive capacity of mud crabs and blue swimming crabs,

> Natural populations of mud crab have been shown to extend their ranges south into the lower latitudes of Australia, and have been found nearly 1000kms outside of their normal range (Gopurenko et al, 2003). […] Studies have also shown that blue swimming crab migrate en masse in Australia due to influxes of freshwater flood plumes (Potter et al., 1983), suggesting their natural adaptive action to unfavourable conditions is migration. […] Cultured crab species are limited in their ability to adapt as they cannot migrate, making them more vulnerable to climate change impacts than wild populations.[124]

Wyatt *et al.* (2012) suggest that "raising mud crabs within mangroves where there is shade may reduce the effect of increasing temperatures. This will also reduce the risk of transferring white spot syndrome virus to ponded shrimp crops."[125]

The destruction of mangrove habitat is possibly the biggest threat to both mud crabs and blue swimming crabs. Indeed, "overall vulnerability is high if habitat destruction and climate change impacts act synergistically"[126]. Accordingly, crab banks need to be associated with other conservation and management measures, particularly habitat conservation:

> Habitat destruction, in particular, is a concern for mud crab species. […] Mangrove habitats are […] vital to the survival of wild mud crab species (Badjeck et al., 2010). […] Mangroves provide crucial conditions, such as detritus and surface algae, which support large amounts of invertebrates and juvenile fish species which in turn provide food for crustaceans (Przeslawski et al., 2008).[127]

[123] Bezuijen, M. R. *et al.* (2011), p. 79.
[124] Bezuijen, M. R. *et al.* (2011), p. 81.
[125] Wyatt, A. B. *et al.* (2012), p. 20.
[126] Bezuijen, M. R. *et al.* (2011), p. 62.
[127] Bezuijen, M. R. *et al.* (2011), p. 66 and 68.

8. Conclusions

The different studies suggest that there are advantages and pitfalls inherent in each crab bank model and that the success of a crab bank project is primarily dependent on its setup and implementation. The following main recommendations can be made based on this literature review.

- The context of each project site needs to be analysed prior to implementation, including the levels of interaction and cooperation among fisheries stakeholders, the presence of other fishery management measures or institutions, external support and environmental factors.
- The active participation of fishers and a positive interaction among fisheries stakeholders need to be encouraged[128]. Indeed, "although there is high diversity and high complexity in the system-to-be-governed, high levels of interactions, through learning, adaptation, and participation, contribute to making the system more governable"[129].
- The development of transparent governance mechanisms with clear roles and responsibilities will also contribute to the successful implementation of a crab bank project[130].
- There needs to be a comprehensive approach of sustainable fishery resource management. "For a higher impact, crab banks need to be linked with measures to regulate crab fishing itself, as is done in Thailand, with a change in crab traps and a minimum mesh size. […] The success of crab banks is closely related to effectiveness of CFis and enforcement of laws related to illegal fishing practices."[131] Several examples also show that crab banks can be combined with mangrove restoration projects[132].
- More research is needed to assess the impacts of crab banks, and particularly the survival rates of crab larvae[133]. "Crab catch should be monitored in the early steps of crab bank development and after its implementation"[134]. Evidence has been found of an ongoing research project in Kung Krabaen Bay, Chanthaburi province on the effectiveness of crab-bank cages[135]. From a long-term perspective, it would be particularly interesting to evaluate the sustainability of crab bank initiatives beyond the lifetime of the initial projects.
- Addressing technical issues, including those related to high crab mortality, "could substantially improve the economic sustainability of crab banks"[136]. Impacts of climate change and their implications for crab banks should also be considered and further researched.

[128] Thiammueang, D. *et al.* (2012), p. 427.
[129] Thiammueang, D. *et al.* (2012), p. 437.
[130] Chap Sopanha *et al.* (2012), p. 28.
[131] Chap Sopanha *et al.* (2012), p. 29.
[132] See Pisupati, B. (2008), p. 25.
[133] Chap Sopanha *et al.* (2012), p. 29.
[134] Chap Sopanha *et al.* (2012), p. 29.
[135] Online from http://www.fis-net.com/fis/worldnews/worldnews.asp?monthyear=11-2012&day=19&id=56908&l=e&country=&special=&ndb=1&df=1 (19 November 2012) [retrieved 10 April 2013]
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