Perspectives of Farmers and Experts in Ca Mau, Vietnam on the Effects of Climate Change on Shrimp Production

A. V. Quach, F. Murray, and A. Morrison-Saunders

Abstract—**Shrimp farming production sustains livelihoods for hundreds of thousands of inhabitants. Vietnam is one of the most vulnerable countries in the world to climate change and Ca Mau Province was ranked as one of the most vulnerable province in Vietnam in aquaculture sector and shrimp farming. This paper aims to discover how climate change affects different shrimp farming systems and what climate issues affected shrimp production from the perspectives of shrimp farmers and experts in Ca Mau. The field research mainly focuses on interviewing local experts and surveying farmer households involved in four types of shrimp farming systems: rice-shrimp rotation, integrated shrimp-mangrove, separated shrimp-mangrove, and intensive shrimp farming system in the coastal area. The findings from the study give a detailed understanding of climate change effects in shrimp farming and help local government and inhabitants to gain a better sense of how climate change poses risks to shrimp farmers.**

Index Terms—**Climate change issues, effects, farming systems, shrimp farmer.**

I. Introduction

Vietnam is one of five countries in the world that will be the worst affected by climate change [1], [2]. The risks are already apparent in coastal areas [3]. Natural disasters cause economic loss of 2.8 billion USD from 1991 to 2000 [4]. Predicted sea level rises by one meter by 2100 will directly affect 22 million people who will have lost their homes, with a possible 10% loss in gross domestic product (GDP), 45% of production land in the Mekong Delta will be lost to sea level rise [5], [6]. The country has been badly affected by climate change because of its 3,260 km of coastline with high population concentration and economic activities [6]. From 1997 to 2006, Vietnam has lost about 1.5% of GDP per year due to disasters and extreme climate events as a result of climate change [7]. Coastal inhabitants are particularly vulnerable as the number of extreme weather events is increasing in intensity and frequency [2], and about half of them depend on aquaculture and shrimp farming, especially in the Mekong Delta. The region is considered to be one of the three most vulnerable deltas in the world to climate change [8] where shrimp farming are very important for the local economy and inhabitants' livelihoods [9].

Ca Mau Province, with its huge shrimp farming systems, is the most vulnerable province in the Mekong Delta in terms of possible damage by climate change [10]. The impacts of storms and sea level rise in the province are likely to pose a serious threat to both the existing biophysical and socio-economic environments for both the short-term and long-term [11]. High temperature and irregular weather patterns cause massive losses for shrimp farming because of too much rain, sea level rise and storms [12]. Although, there is important literature available, the majority of the literature discusses climate change impacts on a macro scale, regional and national levels. There is little understanding of shrimp farming with accompanying analysis of local farmers and experts' perspectives of climate change impacts on local communities.

Therefore, the research aims to discover how climate change affects different shrimp farming systems and what climate issues affected shrimp production from the perspectives of farmers themselves. The research results support local governments and inhabitants to gain a better sense of how climate change poses risks to shrimp farmers. Surveys mainly focus on local experts and shrimp farmers involved in four main shrimp production systems in Ca Mau Province, Vietnam: rice-shrimp rotation, integrated shrimp-mangrove shrimp, separated shrimp-mangrove, and intensive shrimp farming system.

The following sections review climate change impacts on aquaculture and shrimp farming, and then sets out the methodological basic of the research. The next section introduces the field study highlighting information on climate change effects on shrimp farming based on responses of shrimp farmers and key informants. The discussion section then detailed on how climate change affects shrimp farming and what climate change issue is mostly negative effect shrimp production.

II. Review of Climate Change Effects on Aquaculture and Shrimp Farming

The main parameters of climate change impacts to be presented include extreme weather events, sea level rise, increased temperature, and rainfall changes [13]. These are addressed in turn.

Impacts of climate change are mostly through extreme climate events [14]. The frequency of extreme weather events has increased dramatically over the last five decades [15]. Typhoon patterns are changing and increasing the intensity that hits Vietnam [16], likely shifting from one-in-30-year to one-in-10-year [17], and trending to move to the southern coast of Vietnam [18]. Its landfalls' peak month has shifted from August in 1950s to November in the 1990s and moved towards the south [19]. According to statistics in the last 50 years (1961-2010), areas that have not typically suffered from storms may increasingly be vulnerable [20]. The analysis of [21] also showed that the typhoon season is ending later,

Manuscript received October 20, 2014; revised January 5, 2015.

The authors are with the Murdoch University, Australia (e-mail: quachvanan@yahoo.com, F.Murray@murdoch.edu.au, A.Morrison-Saunders@murdoch.edu.au).

DOI: 10.7763/IJESD.2015.V6.687

happened from October to December, and appeared most frequently in November. The impacts of storms are likely to pose a serious threat to Ca Mau Province for both the short-term and long-term [11]. For example, in November 1997, Typhoon Linda struck Ca Mau, thousands of people were lost, and an estimate of 200,000 homes was destroyed, along with much of the Ca Mau fishing fleet [17]. Extreme rainfall events in Ca Mau will increase about 6% in 2030 and 10% in 2050 based on B2 scenario (medium emission) [21]. Extreme climate events will lead to a reduction in aquaculture productivity, agricultural crops, forestry plants and cash plants and the extinction of many local species, which would have serious consequences for the economy [17].

Sea levels in Vietnam have risen by 20cm during the period of from 1958 to 2007 [17] and are expected to rise from 28 to 33cm by 2050 and 65-100cm by the end of the 21st century. Saline intrusion is also a big issue for the Mekong delta. According to the B2 scenario, within the next 40-50 years the seawater level in the Mekong delta would rise by 65cm and flood over 5,100 square kilometers, or 12.8% of Delta land. The models predict an increase in area of high salinity with more than 28‰ (parts per thousand) [22]. Currently, however, 20 million farmers in the region are facing serious drought and risks from saline intrusion. In some places, salt water is encroaching more than 60km inland [17]. All districts in Ca Mau are already affected by salinity [21]. Moreover, coastal erosion has also been reported as a result of sea level rise, such as in Ca Mau area where more than 600 hectares of land have been eroded, with 200m wide strips of land loss in some locations [16], and the coastline has receded by between 100 meters to 1,400 meters over the last twenty years [23]. The local inhabitants have been experienced with a higher sea level over the last five-year period [10]. Impacts on the aquaculture could include damage and loss of ponds due to increased coastal erosion and rising sea level, loss of suitable land area for aquaculture caused by coastal inundation, and rising feed costs [24]. Moreover, aquaculture farms will have to be relocated and saline water intrusion and reduction of the mangrove area will create loss of habitat [25].

The data recorded from 1958 to 2007 in Vietnam shows that the average temperature has increased from 0.5 to 0.7 ℃ over the past 70 years [17]. It has become hotter in summer and the temperature in winter has risen faster than in summer [16]. The annual mean temperature, according to medium scenario (B2), is likely to rise by from 0.8 to 1.5 ℃ in 2050 and 1.6 to 2.8 ℃ by 2100. In Ca Mau Province, the data recorded from 1972 to 2007 shows that the average annual temperature in Ca Mau has increased by 1 ℃ with greatest increase in recent years, a rise of 0.5 ℃ from 1996 to 2007 [26]. Modeling studies show that Ca Mau may experience a warmer seasonal air temperature increase up to 0.7 ℃ in 2030, 1.4 ℃ in 2050, and 2.6 ℃ at the end of this century [21]. In the whole 50-year period, the average temperature would increase by from 1.2 to 1.6 ℃ by 2050 and from 1.9 to 2.8 ℃ by 2100. Increased temperature could have the positive impacts on aquaculture, but adverse impacts must be more severe [13]. Temperature increase exacerbates the occurrence of algal blooms [27] cause toxin release into the water, reduction of dissolved oxygen concentration, spread of pathogens, and threaten of fish health and growth [28].

Rainfall pattern change is complicated in the South of Vietnam [17], with sharply increases during the rainy seasons and expected decreases in the sunny season. Projected changes in annual average rainfall would increase up to 6% by 2100 in the low emission scenario (B2), 7% in medium emission (B2), and 10% in the high emission scenario (A1F1) [29]. Rainfall would increase in rainy months by up to 25% and decrease in dry months from 30% to 35% [17]. In Ca Mau, the average annual rainfall has increased by 97 mm during the period of 1972-2007, a relative increase of 2.5mm per year. However, there have been big fluctuations in rainfall in the last 15 years; e.g. in 1999 it increased by 45% and in 2004 it decreased by 20.9% [26]. Projected changes in average rainfall would are for 2-3% by 2050 and 4-5% by 2100 and would have a trend to decrease in the dry season and increase in the rainy season [29]. Therefore, the dry season will be drier and rainfall in the rainy season will be more intense with larger volumes in shorter periods. These will exacerbate both flooding and drought conditions [20].

III. Methodology

The field study was undertaken in Ca Mau Province, Vietnam from November 2012 to February 2013. Four communes were selected as case studies for the field investigation. The focus was on how climate change affected shrimp farming systems in the last ten years determined through household surveys and interviews with shrimp farmers in four shrimp farming systems as well as local experts (key informants). These study participants were asked to rank effects of climate change on shrimp production.

The selection of households was firstly consulting with local key informants, to select four communes representing for four types of shrimp farming systems. Second, a list of complied households in the selected communes was made. Third, a target number of households were allocated for each commune with from twenty to twenty-five shrimp farmers to be interviewed. Finally, a systematic random selection was used in the surveys [30]. Interviews were conducted with one adult shrimp farmer who responded on behalf of the household because, based on a study of household level [31], it was not necessary to sample for individual characteristics. All interviews were semi-structured and interview questionnaires were composed of both open ended and closed questions [30], [32]. Interviewers and participants communicated in Vietnamese during face-to-face interviews [30], [33]. Eleven key informants who are local experts related in climate change and shrimp farming were also interviewed. After interviewing, focus groups [34] were conducted with five groups that included four groups of shrimp farmers in the four shrimp farming systems and one group of local experts. The focus groups were asked to rank the climate issues that affect shrimp production the most.

IV. Study Sites and Shrimp Farming Systems

A. Overview of Ca Mau Province

Ca Mau Province is a flat and low-lying coastal region, situated on Ca Mau Peninsula, the southernmost extent of

Mekong River Delta [35]. The province occupies 5,392 square kilometers, making up more than 13% of the Mekong Delta area and equal to 1.6% of the whole country [10]. It is surrounded by sea on its two faces and regulated by the tidal regimes of both the West Sea and East Sea with 245 km of coastline and only 0.75 m of elevation compared with sea level. The climate of Ca Mau is tropical monsoon with two distinct seasons.

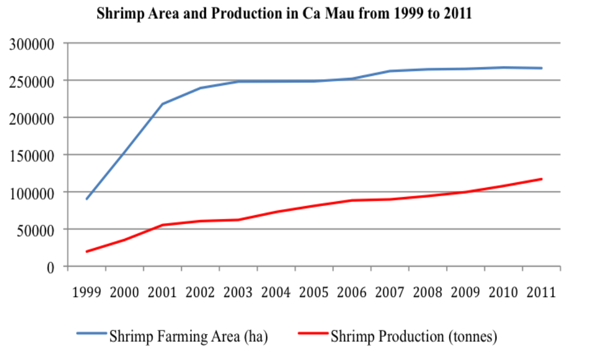

Fig. 1. Shrimp farming area (ha) and shrimp production (ton) in Ca Mau province from 1999 to 2011.

With a population of more than 1.2 million in 2011, the provincial GDP growth rate is 12% in the period of the last 10 years. The total provincial GDP reached US$1.107 million and GDP per capita increased from US$640 in 2006 to US$923 in 2009. The majority of Ca Mau households are engaged in aquaculture and fishing (69%). The remaining households work in agricultural and forestry production (16%), the construction industry (2%) and services (13%). Therefore, aquaculture is an important component of Ca Mau's economy and is strongly supported by an increasing demand for processed shrimp from both national and international buyers [20].

Aquaculture area has grown significantly in Ca Mau in recent years from 154,036 ha in 1997 to 295,864 ha in 2011 [36]. With mollusk and fish in the past, now shrimp farming with an area of 226,166 ha [36] dominates the entire aquaculture sector. The province's shrimp farming area represents over 40 percent of the shrimp farming of all of the coastal provinces in the Mekong Delta [37] and focuses on the black tiger shrimp (*Penageus monodon*) [38]. Shrimp farming has become the major livelihood and increasingly important [39]. Shrimp farming area (ha) and shrimp production (tones) in Ca Mau province over the last 10 years are illustrated in Fig. 1.

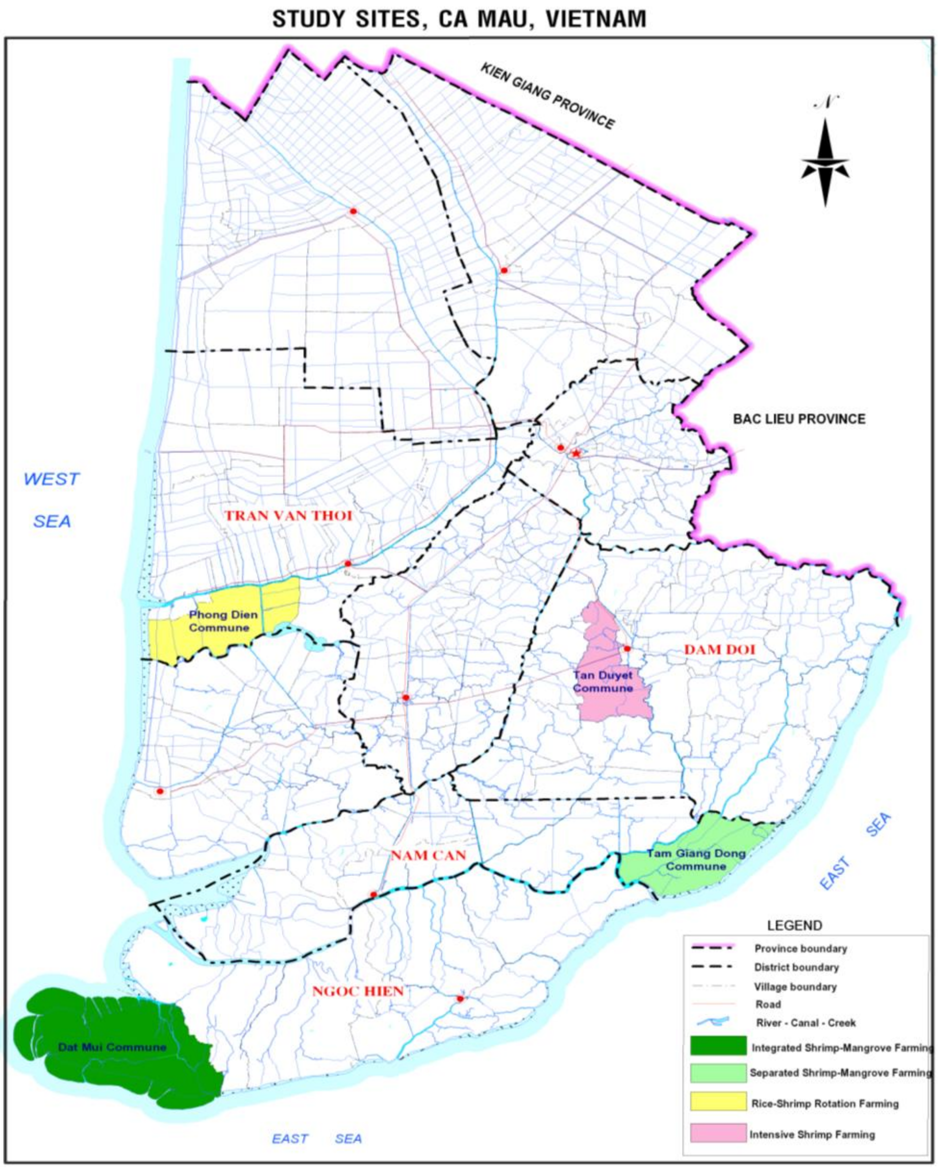

Fig. 2. Location of the study.

B. Shrimp Farming Systems in Ca Mau Province

There are four main shrimp farming systems in Vietnam categorized as extensive, improved-extensive, semi-intensive, and intensive [40], [41]. The locations of farming systems targeted in this research are shown in Fig. 2. In Ca Mau, shrimp farming models are classified not only by pond size, method of water exchange, feed and chemical use, and stocking density [42], but also by land holding rights, harvest and farming practices [43]. Moreover, shrimp farmers can apply extensive, improved-extensive, and semi-intensive methods in different systems such as mangrove-shrimp combinations or rice-shrimp rotation. Therefore, shrimp farming systems in Ca Mau are popular with combination models. Small-scale farmers with less than 3ha in farm area per family [44] dominated in Ca Mau province and they have tended to change from extensive to improved-extensive shrimp farming [45]. A brief description of each the four shrimp farming systems investigated in this research follows.

C. Integrated Shrimp-Mangrove Farming System (ISMF)

In the past, was a traditional extensive farming, which relied on wild seeds to be trapped during high tides, and there was no feed supply to be provided in the shrimp ponds. In this system, farm size varies from 2-17ha [46], [47]. Vietnamese government policy requires the area of mangroves to be conserved on 70% of pond area, but in reality, shrimp farmers typically violate this rule and ditch area (shrimp pond area) was up to 33-43% of pond area [48]. However, shrimp farmers no longer practice this farming system because of declining natural seed sources [44]. Currently, most of shrimp farmers have practiced ISMF based on artificial stock with a density of 1-3 individuals/m^2. Shrimp productivity in this system yields 300-400 kg/ha/year.

D. Separated Shrimp-Mangrove Farming (SSMF)

Which is similar to ISMF, but 60% mangrove area is separated with shrimp pond area in the same piece of land. SSMF in Tam Giang Dong commune has farm sizes varying from 3.5 to 20 ha. Beside black tiger shrimp product, both ISMF and SSMF also harvest other products such as wild shrimp species, fish and crab, and cockle [39]. Productivity of this model varies from 333 to 400 kg/ha/year of shrimp alone (i.e. not including other products in the system).

E. Rice-Shrimp Rotation Farming (RSRF)

Which has been practiced for many decades in the saline affected areas of the coastal provinces in the Mekong Delta [49]. This system is an integrated rice-shrimp farming approach with alternative cropping of rice in the wet season and shrimp during the dry season, all on the same field [50]. In this farming model, farmers in coastal provinces allow salt-water into the fields to farm shrimp during the dry season when water salinity is high. In the rainy season, they use rainwater to flush the field of residual salinity and then grow rice when the water salinity is suitable. Rice fields were designed with a trench, providing a refuge for shrimp, and a protective dike around the periphery of each field [50]. Shrimp productivity of this system is 200-300 kg/ha/year for extensive farming and 250-500 kg/ha/year for improved extensive farming. Rice-shrimp rotation farming has been promoted by the Vietnamese government sine 1998 [39] to meet rice demand locally and to maintain exports [50]. This model has been expanding during the last 15 years and recently has been considered as the most sustainable farming system [51].

F. Intensive Shrimp Farming Started

Which in Khanh Hoa province in central of Vietnam in 1989. Pond size for this system varies from 0.2 to 1.0 ha, with a stocking density from 15 to 30 post larvae per m^2, and shrimp productivity of 2,500 to 4,000 kg/crop/ha/year [39]. The farming system reached 3,428 ha in 2011 [38] with pond size from 1,000 to 6,500 m^2, stocking density from 14 to 40 post larvae per m^2, and productivity varying from 3.5 to 6.6 ton/ha/crop in Ca Mau province [52].

V. Perception of Climate Change Effects on Shrimp Farming

Perceptions of shrimp farmers in different shrimp farming systems from effects of climate change were investigated using both household surveys and local experts interviewees. Interviewing began with general perspectives of shrimp farmers to recognize whether any adverse effects of climate change on shrimp production. Questions then focused on detail of climate change issues that have negatively affected shrimp farming in the last 10 years. Finally, shrimp farmer groups and experts were asked to rank a list of climate issues with respect to which affect shrimp production the most.

Interviews were carried out with a total of one hundred shrimp farmers and eleven local experts (key informants). The majority of respondents (83%) identified climate change in the areas and perceived negative effects on shrimp production in the last 10 years. However, interviewees differed regarding different shrimp farming systems with 94% of farmers in integrated shrimp-mangrove farming (ISMF), 81% in separated shrimp-mangrove farming (SSMF), 72% in rice-shrimp rotation farming (RSRF), 71% of farmers in intensive shrimp farming (ISF), and 91% of experts indentifying climate change as having significant effects on shrimp farming (Table I). Interviewee rankings for the five main climate change impacts for Ca Mau discussed previously follow.

TABLE I: Adverse Effects of Climate Change on Shrimp Production in the Last 10 Years

Respondents	Yes		No		Not sure	
	F	Percent	F	Percent	F	Percent
RSRF (*n*=22)	17	77.3%	0	0%	5	22.7%
ISMF (*n*=31)	29	93.5%	0	0%	2	6.5%
SSMF (*n*=26)	21	80.8%	2	7.7%	3	11.5%
ISF (*n*=21)	15	71.4%	5	23.8%	1	4.8%
Expert (*n*=11)	10	90.9%	0	0%	1	9.1%
Total 111	92	82.9%	7	6.3%	12	10.8%

Shrimp farmer perspectives on climate change issues and shrimp farming

A. Extreme Climate Events

Only a small number of shrimp farmers overall agreed that extreme climate events have negatively affected shrimp farming systems in the last 10 years; 59% of disagreed or strongly disagreed, 30% agreed or strongly agreed, with 11% of shrimp farmers unable to judge the issue. In individual cases, a majority of respondents in three shrimp farming systems: 65% in RSRF, 61% in ISMF, and 67% in ISF disagreed or strongly disagreed with the issue; while only 41.1% in SSMF shared this view.

B. Sea Level Rise and High Tides

A high percentage of farmers in RSRF, ISMF, and SSMF believed that sea level rise and high tides have harmfully affected their shrimp farming. However, a majority of shrimp farmers in extensive shrimp farming thought that the above issues haven't affected their shrimp production. Overall 78% of total respondents agreed with the adverse effects of sea level rise on shrimp farming, while 14% disagreed, and 8% of farmers were unable to judge with the issue. 73% of shrimp farmer respondents in RSRF, 90% in ISMF and 96% in SSMF agreed that sea level rise has adversely affected their shrimp farming systems in the last 10 years; in contrast, only 43% in ISF was of this perspective. Perspectives of respondents regarding in high tides are similar to the sea level rise issue. Overall, 66% of total shrimp farmers agreed or strongly agreed that high tides are having adverse effects on shrimp farming systems, while 25% disagreed or strongly disagreed, and 7% of farmers were unable to judge the above issue.

C. Seasonal Pattern Changes

The vast majority of all shrimp farmers were of the view that seasonal pattern changes have adversely impacted on shrimp production. Overall 86% of total farmers agreed or strongly agreed with the statement, 5% disagreed or strongly disagreed, and 9% of farmers were unable to judge. With respect to each farming system, 96% of farmers in SMSF, 91% in RSRF, 82% in ISMF, and 78% in ISF chose the agreed or strongly agreed rankings. They also agreed that more intensity of irregular rain and a drier dry season has harmfully affected shrimp production, but perspectives of them were more variable regarding the issue of a longer dry season. Overall 84% of all respondents agreed with the issue of greater intensity or irregular rains, comprising respectively 82% of farmers in RSRF, 84% in ISMF, 84% in SSMF, and 86% in ISF. While overall of farmers in all farming systems had the opinion that a drier dry season has negatively affected their shrimp production, this comprised 86% in RSRF, 77% in ISMF, 92% in SSMF, and 90% of shrimp farmers in ISF.

D. Temperature Increase

Overall most shrimp farmers agreed or strongly agreed that increasing fluctuations of temperature (74%) and salinity (68%) in the shrimp ponds were adversely affecting production. Regarding temperature, 73% of farmers in RSRF, 64% in ISMF, 81% in SSMF, and 81% in ISF agreed or strongly agreed on this climate change impact while for salinity fluctuation, the distribution was respectively 73% in RSRF, 61% in ISMF, 79% in SSMF, and 62% in ISF.

A majority of farmers in all farming systems (75%) agreed or strongly agreed that as a result of climate change effects, water quality has decreased in shrimp ponds over the last 10 years. On the farming basis, 87% in ISMF, 85% in SSMF, 64% in RSRF, 57% in ISF held this view.

E. Perception of Local Experts about Adverse Effects of Climate Change Issues on Shrimp Production

Eleven local experts were asked to give their perception about the consequences of climate change on shrimp production in Ca Mau Province in the last 10 years. All experts agreed that seasonal pattern changing, drier dry season, and greater intense or irregular rains have adversely affect shrimp production. Ten experts identified the issue of increase in sea and water level; nine respondents agreed about increased intensity of high tides, and increases in water temperature fluctuations, seven informants agreed in extreme climate events, and increases in salinity fluctuations. Only two local experts agreed that a longer dry season has negatively affect shrimp production, while five respondents disagreed and strongly disagreed, and four experts were unable to judge the problem.

F. Perceptions of Climate Change Issues on Shrimp Diseases and Shrimp Productivity

TABLE II: TO WHAT EXTENT DO YOU AGREE OR DISAGREE WITH THE STATEMENT THAT CLIMATE CHANGE ISSUES HAVE INCREASED SHRIMP DISEASES IN THE LAST 10 YEARS?

Respondents (%)	Strongly agree	Agree	Disagree	Strongly disagree	Unable to judge
RSRF (*n*=22)	27.3%	40.9%	9.1%	0.0%	22.7%
ISMF (*n*=31)	22.6%	48.4%	12.9%	0.0%	16.1%
SSMF (*n*=26)	3.9%	61.5%	11.5%	0.0%	23.1%
ISF (*n*=21)	57.1%	28.6%	4.8%	0.0%	9.5%
Experts (*n*=11)	54.5%	45.5%	0%	0.0%	0%
Total 111	28.8%	46.0%	9.0%	0.0%	16.2%

TABLE III: TO WHAT EXTENT DO YOU AGREE OR DISAGREE WITH THE STATEMENT THAT CLIMATE CHANGE ISSUES HAVE ADVERSELY AFFECTED SHRIMP PRODUCTIVITY IN THE LAST 10 YEARS?

Respondents (%)	Strongly agree	Agree	Disagree	Strongly disagree	Unable to judge
RSRF (*n*=22)	13.6%	54.6%	9.1%	4.5%	18.2%
ISMF (*n*=31)	32.3%	45.1%	0.0%	0.0%	22.6%
SSMF (*n*=26)	15.4%	57.7%	11.5%	0.0%	15.4%
ISF (*n*=21)	23.8%	47.6%	9.5%	4.8%	14.3%
Experts (*n*=11)	27.3%	72.7%	0.0%	0.0%	0.0%
Total 111	22.5%	53.2%	6.3%	1.8%	16.2%

Shrimp farmers and local experts alike were asked the same two questions regarding their level of agreement to the statement that climate change issues have increased shrimp diseases (Table II) and negatively affected shrimp productivity (Table III) in the last 10 years. Regarding shrimp diseases, 72% of all shrimp farmers agreed with the statement representing, 70% of farmers in SSMF, 73% in ISMF, 78% in RSRF, and 86% in ISF agreed that climate change issues caused an increase of shrimp diseases. The majority (73%) of farmers in all farming systems agreed about adverse effects of climate change on shrimp productivity. All local experts agreed that climate change issues have increased shrimp diseases and negatively affected shrimp productivity.

G. The Five Most Important Climate Change Issues Have Adversely Affected Shrimp Production

The five most important climate change issues to negatively affect productivity identified by shrimp farmers across four farming systems and the experts are shown in Table IV. The list of climate change issues that interviews were presented with an answering this question included: greater intensity or irregular rains, seasonal pattern changes, high tides, sea level rise, drier dry season, water temperature fluctuations, and salinity fluctuations. The issue of greater intensity or irregular rains was ranked as the most important problem by RSRF, ISMF, and ISF; the second most important by SSM; and the third by the Experts. Seasonal pattern changes was ranked as the second most important by shrimp farmers in RSR and Experts, the third in both ISM and SSM, and the four in ISF. High tides was ranked as the second most important in ISM, the third in RSR, and the four problem in SSM and Experts. Drier dry season has been ranked as the third most important by shrimp farmers in ISF, fourth in RSR, and fifth in ISM. Increased fluctuation of water temperature was considered to be the most important by Experts, the second most problem in ISF and the fifth in RSR. Sea level rise was the highest concern only for farmers in mangrove areas (SSMF), being otherwise only ranked fourth in ISMF, and fifth by Experts.

TABLE IV: A RANKING OF FIVE-MOST CLIMATE CHANGE ISSUES HAVE ADVERSELY AFFECTED SHRIMP PRODUCTION IN THE LAST 10 YEARS

Climate change issues	Ranking				
	RSRF	ISMF	SSMF	ISF	Experts
Greater intensity or irregular rains	1	1	2	1	3
Seasonal pattern changes	2	3	3	4	2
Increases intensity of high tides	3	2	4		4
Drier dry season	4	5		3	
Sea level rise		4	1		5
Increased fluctuations of water temperature	5			2	1
Increased fluctuations of salinity			5		

VI. DISCUSSION

From the literature presented previously, it is clear that there is evidence of substantial climate change being experienced in Ca Mau province. This is born out by the perceptions of shrimp farmers in all four shrimp farming systems. Overall 83% of all respondents acknowledged adverse effects of climate change on shrimp farming, represented as 94% of farmers in ISMF, 81% in SSMF, 72% in RSRF, 71% in ISF, and 91% of experts. Particularly, climate change issues and its negative effects on shrimp production have been also recognized by a majority of respondents in the last 10 years such as greater intensity or irregular rains, seasonal pattern changes, sea level rise and increasing intensity of high tides, a drier dry season, and increased fluctuations of salinity and water temperature. Further to the numerical data, shrimp farmers and experts provided insightful comments and explanations regarding their perspective of climate change effects, which are now briefly addressed.

Shrimp farmers in the four shrimp farming systems and local experts agreed that irregular weather has negatively affected shrimp production. Information recorded through the survey shows that there are two seasons in the region, but the seasonal pattern has been changing, especially in recent years. Respondents suggested that is have more difficult to recognize the transition point between two seasons. Consequently, shrimp farmers increasingly find it difficult to forecast the weather based on traditional experiences and knowledge.

There was a perception that the rainy season is arriving earlier and lasting longer even continuing to November and December; and this was especially so in 2009, 2010, and 2012. The research results show that 86% of all shrimp farmers and local experts agreed that seasonal pattern changing has negatively affected shrimp farming in the last 10 years. For example, shrimp farmers explained that scattered showers happened frequently during the dry season in 2010, which had never previously occurred. Moreover, based on farmers' experiences, while May 5th is traditionally regarded as the beginning of the rainy season, now rains come earlier, with heavy rains also occurring in the sunny season.

Rainfall fluctuations are greatest at the beginning and the middle of the dry season and to increase at the end of the dry season in the last 10 years [53]. In the rainy season, there is too much rain, irregular rains, and localized torrential rains. This causes the surface water of shrimp ponds to change rapidly, especially in water temperature, salinity, and dissolved oxygen. This reduces productivity, as shrimps do not adapt easily with wide ranges of those environmental factors.

Sea level rise and high tides have negatively affected the RSRF, ISMF, and SSMF systems as perceived by these shrimp farmers. However, the majority of farmers in ISF stated that it has not adversely affected their productivity because they farm in a closed system and have invested in shrimp pond embankments and sluice gates to reduce impacts from high tides. However, most shrimp farmers in the other systems stated that water levels in the rivers and high tides have been increasing in the last 10 years, especially the intensity of high tides that have frequently occurred on October and November in the last three years. Farmers in coastal and mangrove areas are particularly vulnerable to high tides. For example, 81% of shrimp farmers in ISMF, 79% in SSMF, and 61% in RSRF claimed that high tides overflowed or damaged sluice gates and embankments caused shrimp shocks, losses and deaths in mangrove areas and damaged rice fields in RSRF areas. The majority of local experts (82%) said that there have been more high tides than previous years, especially more severely high tides in the last two years. The experts also claimed that high tides increased erosion in sea dyke, river mouths and river embankments. Especially in coastal areas, sea level rise accompanied with high tides has overflowed shrimp embankments and sluice gates, caused shrimp losses and other damage. For example, from 2007 to present, water level has been increased and frequently flooded by high tides in ISMF and SSMF systems. It damaged about 13,000-14,000 ha of shrimp farming in 2011 in coastal areas [54].

The majority of shrimp farmers in all shrimp farming systems disagreed that extreme climate events have negatively affected their shrimp farming in the last 10 years, but most local experts (64%) agreed that shrimp production has been likely to be affected by this issue. Overall, only 30% of shrimp farmers agreed that extreme climate events have adversely effected shrimp production. 59% of shrimp farmers explained that there were no storm surges and tropical cyclones have occurred in their areas during the last 10 years, although the Tropical Cyclone Linda Storm of 1997 was recalled. In contrast, local experts stated that there are more frequent of tropical depressions and storms in the South of East Sea, which affect Ca Mau Province. Those statements of the local experts are supported by various published studies [13], [17]-[21].

Shrimp farmers in the four shrimp farming systems (72% agreement overall) and all local experts agreed that climate change issues have increased shrimp diseases and negatively affected shrimp productivity in the last 10 years. However, there were different perspectives between shrimp farmers and local experts on what climate issue has had the most effect on shrimp production. The research results show that shrimp farmers in RSRF, ISMF, and ISF agreed that more intense or irregular rains was the most impact on their farming, while shrimp farmers in SSMF were more concerned about sea level rise. Meanwhile the study of [55] reported that farmers in improved extensive shrimp farming mostly considered on irregular season as their greatest concern. Local experts interviewed in this research identified increased water temperature fluctuations as having the most effect on shrimp production in Ca Mau. This latter perspective matches with finding of a study of shrimp farmers in improve extensive farming in Bac Lieu Province, which showed that the high water temperature was ranked as the greatest risk for shrimp production [12]. The local experts in Ca Mau stated that climate change would have more impacts on extensive shrimp farming than intensive because water quality control and environmental water management in intensive production is better than in extensive systems.

Overall this research demonstrates that serious adverse effects of climate change are being experienced by shrimp farmers in the Ca Mau region of Vietnam. While there are some differences between local experts and farmers in the four farming systems examined as to which climate change effects pose the greatest risk to shrimp production, clear consensus emerges overall that a range of climate change effects are occurring. Having identified an understanding of the priority effects for the different farming systems, it is intended that this information is used to help local government and residents of Ca Mau (as well as the wider Mekong Delta inhabitants potentially) to gain a better understanding of how climate change poses a risk to the livelihoods of shrimp farmers and what they might do to reduce these risks.

References

[1] A regional review of the economics of climate change in Southeast Asia, *Study Financed by the Government of the United Kingdom*, Manila: Asian Development Bank (ADB), 2007.

[2] Oxfam. (October 2008). Vietnam: Climate change, adaptation and poor people. A Report for Oxfam. [Online]. Available: http://policy-practice.oxfam.org.uk/publications/vietnam-climate-change-adaptation-and-poor-people-112506

[3] ISPONRE. (2009). Vietnam assessment report on climate change (VARCC). [Online]. Available: http://www.unep.org/pdf/dtie/VTN_ASS_REP_CC.pdf

[4] CCFSC, *Second Strategy and Action Plan for Disaster Mitigation and Management in Vietnam 2001-2020*, Ministry of Agriculture and Rural Development, Ha Noi.

[5] IPCC, "Fourth assessment report: impacts, adaptation and vulnerability: summary for policy makers," *Inter-governmental Panel on Climate Change and World Meteorological Organization*, Geneva, 2007.

[6] Vietnam: economics of adaptation to climate change, *World Bank*, vol. 108, pp. 29-42, 2010.

[7] M .T. Son, L. D. Phung, and L. D. Thinh, "Climate change: Impacts, Response ability and some issues on policy: A case study on ethic groups in mountainous western region," CCWG, Ha Noi, Vietnam, 2011.

[8] L. A. Tuan, "Impacts of climate change and sea level rise to the integrated agriculture-aquaculture system in the Mekong River Basin: A case study in the Lower Mekong River Delta in Vietnam," in *Proc. the International Workshop on Climate Change Responses for Asia International Rivers: Opportunities and Challenges*, China, 2010, pp. 26-28.

[9] N. T. Phuong, "Aquaculture in Vietnam: a focus on key farmed species," *SEAT Project*, Bangkok, Thailand, 2003.

[10] Actionaid and CRES, *Losses and Damages: Research on Climate Impacts on Poor Communities in Vietnam and Their Responses*, Hanoi, 2010, p. 61.

[11] NEDECO, "Mekong delta master plan study. A perspective for suitable development of land and water resources," *World Bank*, vol. I, 1993.

[12] Network for Aquaculture Centre in Asia-Pacific (NACA), "Progress report for the project, 'strengthening adaptive capacities to the impacts of climate change in resource-poor small-scale aquaculture and aquatic resources-dependent sector in the south and southeast asian region," *Aqua Climate*, NACA Secretariat, Bangkok, Thailand, p. 60, 2011.

[13] S. S. De Silva and D. Soto, "Climate change and aquaculture: Potential impacts, adaptation and mitigation," in *Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge*, K. Cochrane, C. D. Young, D. Soto, and T. Bahri, Eds. Rome, 2009, no. 530, pp. 151-212.

[14] Department of the Environment, Australian Government. Extreme Climate Events. [Online]. Available: http://www.climatechange.gov.au/climate-change/grants/australian-climate-change-science-program/extreme-climate-events

[15] IPCC, "Fourth Assessment Report: Impacts, Adaptation and Vulnerability," presented at Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, 2007.

[16] P. Chaudhry and G. Guyssachaert. (2007). Climate change and human development in Vietnam, human development report 2007/2008, UNDP. *Occasional Paper*. [Online]. Available: http://hdr.undp.org/sites/default/files/chaudhry_peter_and_ruysschaert_greet.pdf

[17] MONRE, *Climate Change and Sea Level Rise Scenarios for Vietnam*, Hanoi, 2009.

[18] P. V. Tan, "Nghiên cứu tác động của biến đổi khí hậu toàn cầu đến các yếu tố và hiện tượng khí hậu cực đoan ở Việt Nam, khả năng dự báo và giải pháp chiến lược ứng phó," Final Report of KC08.29/06-10 Research, MOST, 2010.

[19] M. Waibel. (February 2008). Implications and challenges of climate change for Vietnam. [Online]. Available: http://www.pacific-news.de/pn29/pn29_waibel.pdf

[20] P. Mackay and Russell, "Climate change impact and adaptation study in the Mekong Delta – Part A," Technical Assistance Consultant's Report (Ca Mau Atlas), ADB, Project Number: 43295, pp. 49, 2011.

[21] IMHEN, *Sea Level Rise-Scenarios and Possible Risk Reduction in Vietnam*, Vietnam Institute of Meteorology, Hydrology and

Environment (IMHEN) and Danish International Development Agency (DANIDA), 2010.

[22] IMHEN, *Impacts of Climate Change on Water Resources and Adaptation Measures*, Vietnam Institute of Meteorology, Hydrology and Environment (IMHEN) and Danish International Development Agency (DANIDA), 2010.

[23] N. N. Cat, H. P. Tien, D. D. Sam, and N. N. Binh. (2005). Status of coastal erosion of Vietnam and proposed measures for protection. [Online]. Available: http://www.fao.org/forestry/11286-08d0cd86bc02ef85da8f5b6249401b52f.pdf

[24] J. Smyle and R. Cooke, "Climate change analysis and adaptation responses: Prepared for informing IFAD's country strategic opportunities program 2012-2017 for Vietnam," Working Paper, IFAD, 2011.

[25] J. Huxtable and N. T. Yen, "Mainstreaming climate change adaptation: a practioner's handbook," *CARE International*, Vietnam, p. 60, 2009.

[26] Department of Natural Resource and Environment of Ca Mau Province (DONRE), *Action Plan to Adapt with Climate Change and Sea Level Rise in Ca Mau Province*, Ca Mau, Vietnam, 2011.

[27] R. G. Najjar, C. R. Pyke, M. B. Adams, D. Breitburg, D. Hershner, M. Kemp, R. Howarth, M. R. Mulholland, M. Paolisso, D. Secor, K. Sellner, D. Wardrop, and R. Wood, "Potential climate-change impacts on the Chesapeake Bay," *Estuarine, Coastal and Shelf Science*, vol. 86, pp. 1-20, 2010.

[28] World Fish Centre, Centre for Marine Life Conservation and Community Development, Can Tho University, Sub-National Institute for Agricultural Planning and Projection, "Inception report: Economics of adaptation to climate change- the case study of Vietnam's aquaculture sector," *World Bank*, 2009.

[29] MONRE, *Climate Change and Sea Level Rise Scenarios for Vietnam* (*Updated Version)*, Hanoi, 2012.

[30] P. D. Leedy and J. E. Ormrod, *Practical Research: Planning and Design*. 7th ed. Merrill Prentice Hall, Upper Saddle River, New Jersey, 2001.

[31] R. Few and P. G. Tran. (August 2010). Climatic hazards, health risk and response in Vietnam: Case studies on social dimensions of vulnerability. *Global Environmental Change*. [Online]. 20(3). pp. 529-538. Available: http://www.sciencedirect.com/science/article/pii/S0959378010000105

[32] B. Kolb, *Marketing Research: in-Depth, Intercept and Expert Interviews*, SAGE Publications, Murdoch Library, Murdoch University, pp. 141-157, 2008.

[33] S. Kvale, *Doing Interview: Planning an Interview Study*, SAGE Publications, Murdoch Library, Murdoch University, pp. 34-50, 2007.

[34] C. Puchta and J. Potter, *Focus Group Practice*, London, England: SAGE Publications Ltd, Murdoch Library, Murdoch University, 2004.

[35] Southern Institute for Water Resources Planning (SIWRP), "Study on climate change scenarios assessment for Ca Mau province", Technical Report of SIWRP, Ho Chi Minh, Vietnam.

[36] Ca Mau Statistic Office, Annual Statistics Report, Ca Mau, Vietnam, 2011.

[37] VASEP. (2011). Vietnam seafood trade statistics from 1997 to 2011. *Vietnam Association of Seafood Exporters and Producers*. [Online]. Available: http://www.eng.vasep.com.vn/412/VASEP-Vietnam-seafood-trade-statistics.htm

[38] Department of Agriculture and Rural Development of Ca Mau Province (DARD), *Aquaculture Planning to 2015 and Strategy to 2020*, Ca Mau, Vietnam, 2010.

[39] N. T. Hung, "District based climate change assessment and adaptation measure for agriculture in Ca Mau, Vietnam," *Young Scientist Support Program 2001*, APEC Climate Center, Busan, 2012.

[40] T. V. Nhuong, L. T. Luu, T. Q. Tu, P. M. Tam, and T. T. A. Nguyet, "Vietnam shrimp farming review," Individual Partner Report for the Project: Policy Research For Sustainable Shrimp Farming in Asia. European Commission INCO-DEV Project PORESSFA No.IC4-2001-10042, CEMARE University of Portsmouth UK and RIA1, Bac Ninh, Vietnam, 2002.

[41] N. D. A. Thi, "Shrimp farming in Vietnam: current situation, environmental-economic-social impacts and the need for sustainable shrimp aquaculture," in *Proc. 7th Asia Pacific Roundtable for Sustainable Consumption and Production*, Hanoi, 2007.

[42] P. T. Anh, C. Kroeze, S. R. Bush, and A. P. J. Mol, "Water pollution by intensive brackish shrimp farming in Southeast Vietnam: Causes and options for control," *Agricultural Water Management*, vol. 97, pp. 872-882.

[43] T. T. P. Ha, "Resilience and livelihood dynamics of shrimp farmers and fishers in the Mekong Delta, Vietnam," Ph.D. dissertation, Wageningen University, Wageningen, 2012.

[44] T. T. Be, H. Clayton, and D. Brennan, "Socioeconomic characteristics of rice– shrimp farms in the study region. In Rice–shrimp farming in the Mekong Delta: Biophysical and socioeconomic issues," ACIAR Technical Reports No. 52e, Australian Centre for International Agricultural Research, 2003.

[45] G. J. De Graadf and T. T. Xuan, "Extensive shrimp farming, mangrove clearance and marine fisheries in the southern provinces of Vietnam," *Mangrove and Salt Marches*, vol. 2, pp. 159-166, 1998.

[46] B. Clough, D. Johnston, T. T. Xuan, M. J. Phillips, S. S. Pednekar, N. H. Thien, T. H. Dan, and P. L. Thong, "Silvofishery farming systems in Ca Mau province, Vietnam," *The World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment, Work in Progress for Public Discussion*, The Consortium, 2002.

[47] T. H. Minh, "Management of the integrated mangrove-aquaculture farming system in the Mekong Delta of Vietnam," M.S. thesis, AIT, Bangkok, Thailand, 2001.

[48] T. N. K. D. Binh, M. J. Phillips, and H. Demaine, "Integrated shrimp-mangrove farming systems in the Mekong delta of Vietnam," *Aquaculture Research*, vol. 28, no. 8, p. 599, 1997.

[49] D. Q. T. Vuong, "Status and Planning for rice-shrimp farming in seawater intrusion zone of Soc Trang province, Vietnam," M.S. thesis, AIT, Bangkok, Thailand, 2011.

[50] D. Brennan, N. Preston, H. Clayton, and T. T. Be, "An evaluation of rice-shrimp farming systems in the Mekong Delta," Report Prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment, Work in Progress for Public Discussion, The Consortium, 2002.

[51] Center for Ecosystem Science, UNSW. Improving the sustainability of rice-shrimp farming systems in the Mekong Delta, Vietnam. [Online]. Available: https://www.ecosystem.unsw.edu.au/content/rivers-and-wetlands/sustainable-aquaculture/sustainable-rice-shrimp-farming-in-the-mekong-delta

[52] M. H. Chinh, "Dieu tra danh gia hien trang nuoi tom cong nghiep tinh Ca Mau va de xuat giai phap (Vietnamese)," Ca Mau DOST, Vietnam, 2012.

[53] Ca Mau Hydro-Meteorological Center, *Hydro-Meteorological Statistics*, Ca Mau, Vietnam, 2012.

[54] Department of Agriculture and Rural Development of Ca Mau Province (DARD), Annual Report: Agriculture, Aquaculture, and Rural Development in 2012, Ca Mau DARD, Vietnam, 2012.

[55] N. W. Abery, N. V. Hai, N. V. Hao, T. H. Minh, N. T. Phuong, S. Jumnogsong, V. Dulyapurk, M. Kaewnern, N. S. Nagothu, and S. S. De Silva, "Perception of climate change impacts and adaptation of shrimp farming in Ca Mau and Bac Lieu, Vietnam," Farmer Focus Group Discussions and Stakeholder workshop Report, NACA, Bangkok, Thai Lan, 2009.

An Van Quach was born in Ca Mau, Vietnam. He has 3 years' working experience in environmental management, 6 years' working experience in project management, and 2 years' working experience in biosphere reserve consultants. He started his PhD in environmental science in Murdoch University in March 2012. Prior to his education, he completed a BSc degree in environment management at Can Tho University, Vietnam in 2000. He become an IFP (International Fellowship Program) fellow, supported by Ford Foundation and completed his master degree of arts in environmental science and policy in 2008 in Clark University, Massachusetts, the United States. In 2010, he got a grant supported by UNESCO to conduct a research on using sustainable natural resources and inhabitants' livelihoods: "Promoting traditional honey bee keeping in Low Minh Ha National Park, Vietnam".

Frank Murray is a recognized air pollution and climate change expert, he is also the technical editor of the first comprehensive review of urban air quality management at a country level across Asia. He is currently collaborating with government agencies across Asia to identify and manage the impacts of air pollution and climate change.

Professor Murray has worked with the World Health Organization in Geneva, United Nations

Environment Program in Nairobi and Bangkok, the Asian Development Bank, the Clean Air Initiative for Asia in Manila and the Stockholm Environment Institute. He was also the lead author of the atmosphere chapter of GEO4, UNEP's state of the world environment report published in 2007.

Angus Morrison-Saunders is an associate professor in environmental assessment in Murdoch University, Australia, an extraordinary professor in environmental sciences and management in North West University, South Africa and a tutor in University of Cambridge Institute for Sustainability Leadership, England. He got the PhD degree in environmental impact assessment from Murdoch University, Australia.

Angus has 25 years' experience in impact assessment research, education and training with a particular focus on how impact assessment contributes to sustainable development. He is currently a principal investigator of an Australian Government funded (Australian Development Research Awards Scheme (ADRAS)) project (May 2013-May 2015) entitled "Driving policy in mine closure and abandonment management, environmental risk mitigation, and rehabilitation of abandoned mine sites as a pro-poor development strategy" investigation how recent innovations in mine closure planning and rehabilitation funding legislation in Western Australia might be adapted for implementation in South Africa, Nigeria, Mozambique, Ghana and Zambia. He is also a principal investigator for an Australia Africa Universities Network funded project entitled: "Integrating HIV and gender-related issues into environmental assessments for Australian mining companies operating in Africa".

In 2004 Angus co-authored the first international handbook on environmental impact assessment follow-up *Assessing Impact: Handbook of EIA and SEA Follow-up*, Earthscan, London, co-edited *Sustainability Assessment Pluralism, Practice and Progress*, Taylor & Francis in 2013 and is the lead editor for a new Handbook of Sustainability Assessment to be published by Edward Elgar in 2015. He has collaborated with many impact assessment practitioners worldwide and published more than 70 international refereed works. He has also conducted numerous workshops and training in sustainability assessment and environmental impact assessment follow-up at international conferences.