Final Technical Report

AQUADAPT: Inland Aquaculture and Adaptation to Climate Change in Northern Thailand

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Abstract

The aquaculture sector in Thailand is important to livelihoods, food security, and economic development; and is potentially vulnerable to the impacts of climate change. The objective of the AQUADAPT project was to improve understanding of effective ways to reduce climate-related risks to aquaculture farms under current and plausible future climates. The empirical emphasis was on Tilapia grown in farm ponds or floating cages in rivers and reservoirs in Northern Thailand. Key findings of the research and assessment activities were: (1) climate-related risks to the profitability of fish farms vary seasonally, spatially, and with culture system; (2) individual risks, both climate-related and not, are often addressed through multiple practices and strategies which, in turn, vary with perceptions and appraisal of risks; (3) underlying mechanisms for adverse impacts and risks to production and profits from extreme high and low water flows, poor water quality, or unusual weather conditions, are now fairly well understood as a result of direct observations, monitoring in the field, and modeling studies; (4) the social consequences of the losses and damages to fish farms caused by extreme weather and climate vary with household characteristics and community settings; and, (5) successful adaptation is plausible over the next few decades, but will require a combination of actions on multiple spatial and temporal scales, along pathways that cannot be fully pre-determined, but in which innovation will be an important dimension. The project has already had significant impacts on understanding, stakeholder collaboration, capacities, and practices. The findings and relationships built also provide strong foundations for future research that produces useable knowledge, as well as inform the refinement of aquaculture policies, so that they take into better account climate variability and change.

Keywords: aquaculture, risks, climate, extreme events, adaptation, water management

Table of Contents

1 Introduction

The AQUADAPT project is concerned with how the aquaculture sector could adapt to climate change. The empirical focus is on Tilapia grown in farm ponds or floating cages in rivers and reservoirs in Northern Thailand. The project ran from July 2012 to December 2015. It was led by the Unit for Social and Environmental Research at Chiang Mai University (CMU-USER), with major contributions from students and senior researchers at the Faculty of Social Sciences and Faculty of Economics at Chiang Mai University, and the Faculty of Fisheries Technology and Aquatic Resources at Maejo University. Other individual team members were based at the Stockholm Environment Institute (Asia Center), and the Department of Fisheries. This final technical report summarizes the achievements and lessons learned from the AQUADAPT project.

2 Project design

2.1 Research problem

The aquaculture sector in Thailand, and many other countries in Asia, is important to livelihoods, food security, and economic development [1]. Although aquaculture has some characteristics that help buffer organisms from the immediate effects of climate variability, most culture systems still appear to be vulnerable to high temperatures, water availability, sea-level, or the frequency and severity of extreme events [2, 3], as well as other interacting stressors influencing water quality and diseases [4, 5]. Looking to the future, the expectation is that aquaculture will expand in importance, making it imperative that adaptation strategies also improve sustainability [6].

The key research problem addressed by this project is how to improve the capacity of inland, freshwater aquaculture in Northern Thailand, to sustainably adapt to changing and uncertain climates through better farm and water management. Major floods in 2011, and intense dry seasons in 2013-15, had major impacts on inland aquaculture production, thus providing this project with opportunities to measure and observe impacts of extreme events, as well as responses at various scales. A key premise of the project is that, understanding risks and their management under current climate variability, is an important foundation for exploring how aquaculture could adapt to a changing climate.

2.2 Objectives

The main objectives of the project as defined in the proposal were [7]:

1. To improve understanding of effective ways to reduce flood- and low-flow related losses of aquaculture farms under current climate conditions, through research on historical events and existing risk management practices at farm and watershed scales;
2. To assess risks of flood- and low-flow related losses of aquaculture farms under plausible future climates and watershed management practices, through qualitative and quantitative scenario-based analyses;
3. To improve understanding of how the integration of aquaculture into livelihood systems affects the resilience of rural households to climate-related changes in water quality and quantity, and thus adaptive capacity, through research on impacts of historical events;
4. To identify effective ways to reduce flood- and low-flood related losses of aquaculture farms, as well as build resilience of livelihood systems under plausible future climates through deliberative, multi-stakeholder assessment of individual and watershed-level adaptation options, and pilot local planning actions;
5. To engage with key stakeholders, including aquaculture farmers, extension agents, local governments, line agencies, other water consumers upstream and downstream, and water resource managers in key locations in Thailand, in order to share understanding through presentations, briefings, dialogue, and documents.

These objectives were retained throughout the project with the modest extension in practice to also consider, as appropriate to location and culture system, other climate-related risks, such as those due to extreme temperatures, prolonged cloud cover, and heavy rainfall events.

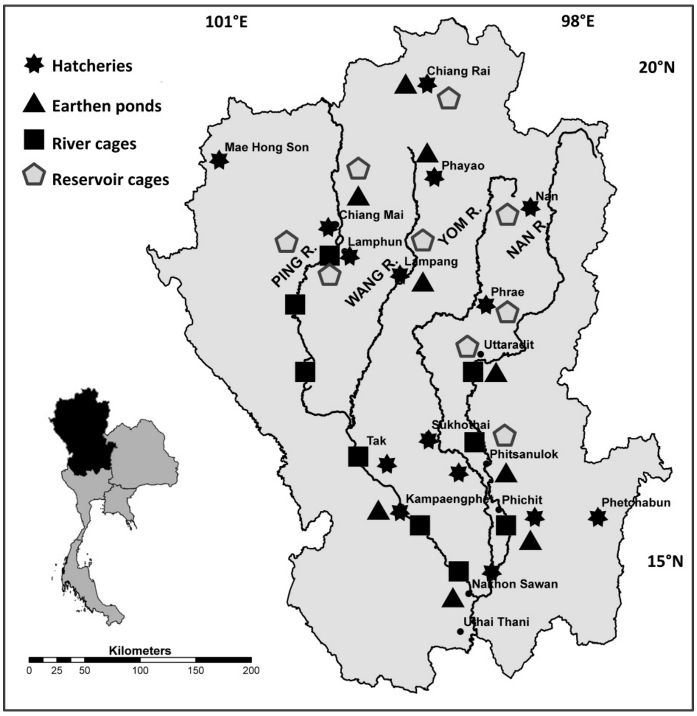
As will be seen later with respect to outputs and outcomes, the five objectives were all largely met. Understanding was improved (O1-3), effective management practices were identified (O4), and knowledge was shared (O5). Of course there is always more that could be done, in particular, with respect to crafting more useable knowledge. In later sections of the report we briefly summarize research users and other stakeholder views on what follow-up research and activities they would most like to see.

2.3 Methodology

As an interdisciplinary project, the range of research methods used was thus diverse. Many individual studies adopted a mixed method approach, incorporating both qualitative methods and analysis with more quantitative observations, surveys or secondary datasets. Several studies collected water samples and analyzed these in the laboratory. One behavioral experimental study used a role playing simulation game to explore risk decision behaviors. Other studies made direct observations of human behavior and interactions while participating in activities; for example, work trips of fish traders.

A key feature of the study designs used in the project was to compare locations across Northern Thailand, and thus include some significant variation in river flows, water resources, and temperature extremes in the analyses (Figure 1). The inclusion of multiple sites over a broad geographical range increased variation in key variables of interests, and helped make the findings more generalizable. Details of study designs and methods are available in the individual working papers. The main lesson learnt was that there was high value in combining qualitative and quantitative methods, as well as integrating social science and natural science perspectives, for understanding issues related to behavior and the management of climate-related risks.

Figure 1 Map of study region in Northern Thailand showing provinces in which different culture systems were investigated.

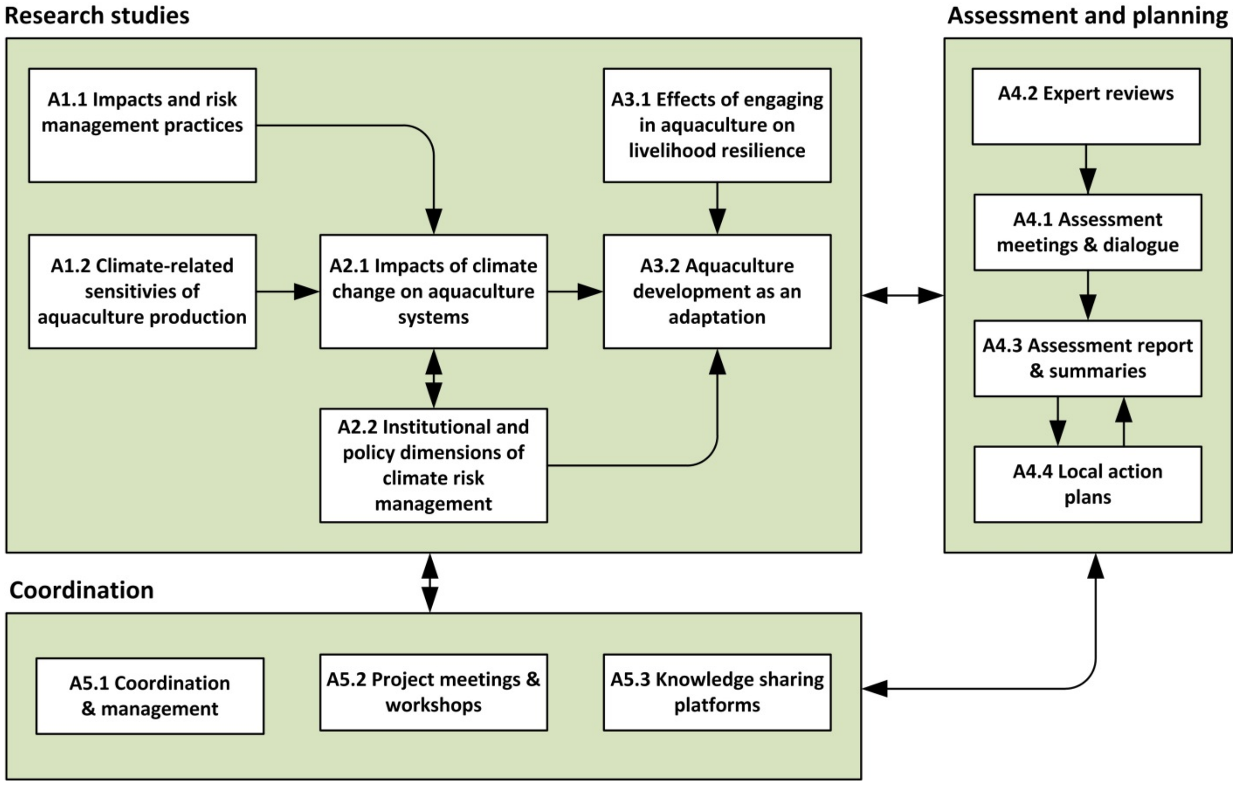


As the project matured it became increasingly transdisciplinary [8], with significant participatory elements; for instance, in carrying out joint analysis of problems and evaluation of adaptation options with fish farmers or agency officials. This shift was important to creating more useable knowledge. At the same time, it was clear that the assessment and dialogue process did not eliminate 'knowledge politics' [9]. Thus, there were tensions related to differences in interest, responsibilities, and power among stakeholders; in particular, between fish farmers, agents from private firms, and water managers in state agencies that led to strategic claims or positions, and which had to be taken into account in facilitation of events and interpretation of perspectives.

2.4 Project Activities

Implementation of the project was organized around a set of research studies, assessments, and supporting coordination activities (Figure 2) carried out over 42 months (Appendix 4).

Figure 2. Activity structure of the AQUADAPT project.



3 Research studies

The research studies were organized around 5 clusters (Figure 2) with A2.1 and A3.2 being jointly managed (Appendix 3). The studies were carried out by for-degree and post-graduate students, alongside and under the guidance of more senior researchers (as Activity Leaders). Most research studies, regardless if they were biophysical or social science oriented, involved extensive periods of field work across multiple sites in Northern Thailand (Figure 1). A1.1, for example, included surveys of earthen ponds in 9 provinces, and of river cage culture systems in 8 provinces. A1.2 involved monthly sampling of 15 ponds in 5 provinces over a period of 12 months. Studies in A3.1 required repeat visits to households engaged in earthen pond and river cage farming in different seasons. A3.2 included surveys of government hatcheries in 15 provinces. Much of the field work and secondary data collection in A2.1 and A2.2 was carried out in the provinces in the lower Nan River Basin.

Key findings from the research studies will now be very briefly summarized.

3.1 Impacts of climate-related risks

The most obvious and important difference in culturing practices is that between farming fish in earthen ponds on private land, and in floating cages in public rivers or reservoirs (Table 1). Levels of intensification, in terms of nutrient inputs and stocking densities, vary greatly among pond farms, and when combined with differences in water management practices, can substantially modify several climate-related risks [WP6] [*]. For floating cages, the culture system tended to be more standardized than that for earthen ponds [WP2].

Table 1. Major features of different culture systems studied (Source: WP2, WP16, WP36).

Pond feature	Earthen Ponds			Cages	
	Integrated	Commercial	Subsistence	River	Reservoir
Stocking Rate (fish/m^2)	2-3	2-3	1	100	50-100
Culture Period (months)	6	6-7	14	4-5	4-5
Feed type	Pellet feed	Pellet feed	Vegetable and food scraps, pellet feed	Pellet feed	Pellet feed
Manure inputs	Yes	No	No	No	No
Water Renewal Rate	seldom	10% per day	seldom	Continuous (except in very low flows)	Continuous (at cage scale)
Harvest	Simultaneous	Simultaneous	Staggered	Simultaneous	Simultaneous

The most important climate-related risks to the profitability of inland aquaculture are season, culture-system, and place-specific; meaning that the risk profiles of individual farms vary substantially [WP3]. Important climate-related risks for river-based cage culture are extreme high and low flows [WP9]. For earthen pond culture, floods, droughts, and heavy rains were the three most important risks [WP6]. In reservoirs, important climate-related risks include those related to high or changing temperatures and droughts; in particular, the sharp drop in temperature at the transition period from the wet to cool season results in mixing of previously stratified water column, bringing low dissolved oxygen (DO) bottom water to the surface where fish are grown in cages.

Temporal variation in risks is both seasonal and inter-annual; with monsoonal climate, the difference in precipitation and river flows between the wet and dry season are substantial. Risks associated with high flows or floods are a major concern for river-based cage aquaculture, in particular, during August to October [WP9]. Low flows or droughts are also an important seasonally varying risk, with highest risks typically in February to April. Pond culture is also affected by extreme floods and seasonal water shortages, as well as other unusual weather conditions [WP5, WP7].

Spatial variation in risks is multi-scale. At river-basin or major reach scales topography, river morphology and presence of major infrastructure regulating and diverting flows are important to relative risks from high or low flows [WP3, WP9]. Indeed, for cage aquaculture, infrastructure operations can effectively nullify or completely change seasonal flow conditions in a river from that which would expect based on rainfall and climate in some locations [WP9].

[*] Throughout this report references in this format [WPnn] are to the AQUADAPT working paper products (many now published) listed in Table 5 (p21). References with just a number [nn] are to non-project documents listed under Literature Cited (p40).

For earthen pond culture systems, the spatial relationships are more complex as they often depend on local patterns of water allocation in irrigation systems or streams. Experienced impacts and perceived risks from different climate-related phenomenon also vary along an elevation-latitude gradient [WP6].

3.2 Sensitivities to climate

In addition to identifying patterns and variation in climate-related risk, both biophysical measurements and social queries have been used to improve understanding of the underlying mechanisms and conditions involved in climate-related impacts and elevated risks (see also Table 2).

High flows impact river-based cage culture negatively by: physically deforming cages so that there is much less space for fish to move; breaking cages, and thus allowing fish to escape; or, exhausting fish as they try to maintain their position in the current. Associations between mass mortality events and direct measurements during key events with flow conditions in the upper Ping River suggest discharges at monitoring stations above 200-250 m^3s^{-1} are likely to lead to losses [WP9, WP30].

Low flows also damage cages, but the biggest impacts appear to be on water quality, though more direct and systematic field measurements in critical periods are needed. At typical stocking densities of 50 fish m^{-3} [WP2], when effective cage volumes are reduced to half or less because of low river depth, effective densities of fish can be very high. If many cages are in close proximity and fish are reaching market size, then there is a strong likelihood of waste products becoming highly concentrated [WP30]. Dissolved oxygen concentrations are also likely to fall, especially at night, and conditions in river pools may possibly exceed detrimental conditions in ponds where stocking densities are much lower.

A role-playing simulation game was created to capture some of the key features of the decision-making context, and explored with farmers in the field on hand-held tablets [WP14]. As hypothesized, more frequent or larger impact floods reduced cumulative profits. Farmers reduced their stocking densities when playing in games with high likelihood of floods, but did not do so as expected when impacts were larger. Contrary to initial expectations, farmers found it's harder to learn (choose most optimal density or improve score within a game) when floods were common or had large impacts. Farmers learnt most when risks were decreasing, and least when they were increasing. The findings of this study underline the importance of understanding decision-making behavior around risks for climate risk management, and revealed limitations in common assumptions about the ease of learning about likelihoods and consequences from experience [WP14].

Low levels of dissolved oxygen in fish ponds are clearly a major cause of mass mortality [WP18]. Phytoplankton, it should be underlined, consumes oxygen at night and thus together with consumption by fish, may deplete levels by early morning. Amount of chlorophyll-a, as might be expected, was higher in high input system than in low input systems as a result of higher phytoplankton biomass, and DO in surface waters [WP11]. DO levels lag those of photosynthetically active radiation (PAR) over the diurnal cycle [WP18]. Phytoplankton biomass respond to changes in light and nutrients [WP7], in turn, influencing light penetration to the deeper water layers. Cloud cover effects oxygen production by photosynthesis in earthen fish ponds [WP18].

Shallow aquaculture ponds undergo diurnal cycles of thermal and chemical vertical stratification, as a consequence of differences in density between warm and cooler water arising, in turn, from absorption of solar radiation as it passes through the water column [WP5]. Stratification followed by rapid turnover, or exchange of surface and bottom water layers, can expose fish to dangerously low DO levels [WP18]. Detailed monitoring shows that turnover occurs more slowly in lower elevation than in higher elevation zone sites, and occurred earlier during the rainy season than in the winter. Turnover improves distribution of dissolved oxygen through the water column, and also minimizes organic matter accumulation. Culture systems, because of influence on nutrient loadings, modifies these climate-related risks to production [WP18].

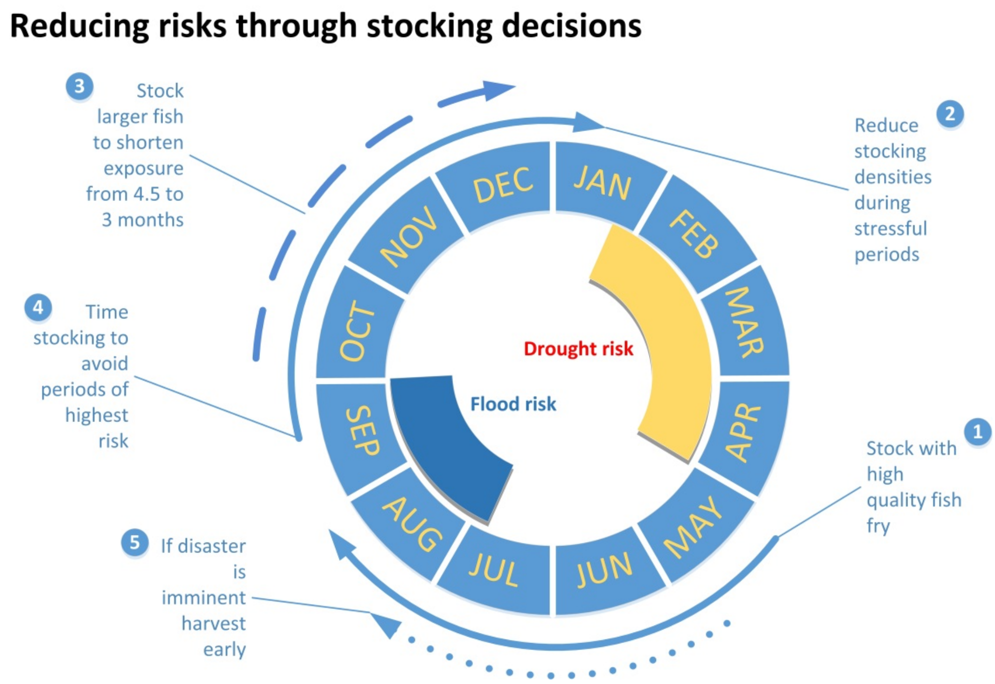
Cyanobacteria blooms are also associated with the production of geosmin and other off-flavor substances (imparting the flesh of fish an "earthy" taste), which greatly reduces the value of harvested fish [WP15, WP22]. Analysis of total bacteria and filamentous cyanobacteria shows that there is a significant interaction observed between elevation, culture system, and season [WP7]; thus suggesting complex set of controls. Research to determine the levels of odorous compounds (geosmin or 2-meyhylisoborneol (MIB)) showed that the concentration of geosmin was positively correlated with the density of cyanobacteria and chlorophyll-a in the water. The highest concentration of MIB was observed at start of the dry season, in October. Concentrations of MIB were positively correlated with culture period, but negatively correlated with light intensity. The detailed patterns of association with off-flavor periods suggest that cyanobacteria *Anabaena* sp. and *Oscillatoria* sp. were the biological origins of geosmin, whereas the source of MIB was *Pseudanabaena* sp.

A study of cage culture in reservoirs was launched based on advice from a mid-term reviewer, and comments during a stakeholder advisory group. Mass mortality events have been observed, but causes are not well understood. From previous research on water quality changes in earthen ponds, we understand that temperature changes drive daily stratification and mixing [WP18]. Observations collected from water profiles in a dam in Chiang Mai province, indicate vertical mixing of previously stratified waters being an important process that occurs at the onset of cooler, dry season (November). Seasonal, vertical mixing causes low oxygen concentrations near the surface, which kills fish. Surveys of fish farms in reservoirs across Northern Thailand found that the most important climate-related risks was drought or low water levels, as this had the largest financial impact [WP36]. Other climate-related risks perceived as important, included: over-turning of stratified cooler and anoxic bottom water layers; prolonged cloud cover; sharp changes in temperature; heat waves; and cold spells.

3.3 Management of climate-related risks

To manage climate-related risks under current climate, fish cage farmers use a combination of adjustments to rearing practices, cropping calendars (Figure 3), as well as financial and social measures to manage those risks which they perceive as being manageable [WP8,WP18].

Figure 3. One of the key findings of the research studies was the importance of stocking decisions as a way to reduce and manage risks (modified after WP29).



Perception also plays a role in the evaluation of and response to risks. Experience of past events, as well as site and individual characteristics, influence or are associated with differences in perceptions of climate and understanding of climate change [WP3]. Gender also has a significant bearing on risk perceptions; with women ranking several climate-related risks higher than men, and being more concerned with future climate change [WP3, WP40]. Commonly used scales to measure risk attitudes however, do not explain differences in risk perception or management. Detailed analysis of interviews with fish farmers revealed that emotions were important, alongside analytical cognitive processes in making decisions [WP38]. This led to a study focused on use of emotional appeals and other types of inserts in messages providing advice or encouraging fish farmers to manage risks in certain ways [WP44]; for instance, through stocking decisions that take into account the seasonal risk calendar (Figure 3).

Some risks are understood to require longer-term and indirect action to influence water and watershed management at higher spatial levels. Many risks are both season and river- or place-specific, meaning that the risk profiles of individual farms can vary substantially. A key finding of this study is that individual risks are often addressed through multiple practices and strategies, and that a specific practice can have a bearing on several different risks [WP8].

Results suggest some additional actions can be taken. Fish farmers could improve the quality of floating open-top cages by making them sturdier by using three dimensional metal-based frames. Early warning systems based on either upstream rainfall or flow [WP9] could help with risk management; providing 8-48 hours in advance information on likely high flow conditions.

Fish pond farmers are not uniformly aware that phytoplankton consumes oxygen at night, and thus very intense blooms combined with certain weather conditions that lead to stratification can be an important cause of mortality. The various findings taken together suggest that high input culture farmers should adapt sound and effective fish culture strategies (feed and waste reduction, use of aerators and pond water mixers) to reduce the risks of fish production losses from extreme weather that leads to low DO. Aeration is a particularly useful technology in fish ponds with high nutrient inputs and bigger fish. Measurements under field conditions showed substantial differences in aeration efficiency from various types of aerators in use, and that the levels of aeration were likely to be sub-optimal. Local assessment meetings also show that in some locations, many farmers still do not have aerators, because of concerns with costs. Further investigation and training on use of aerators is needed, and is recognized by farmers in consultation meetings. There may also be value in modeling studies to help optimize the use of aerators, given concern over energy costs.

In reservoirs, risks are primarily managed at the farm level with techniques like aeration and reducing feed during stressful periods [WP36]. Farmers however, also emphasize the importance of maintaining good relations with other stakeholders, monitoring weather news, and reservoir water management.

Institutional measures that help with managing climate risks were also investigated by the AQUADAPT project. An initial analysis, for instance, suggests mutual or weather-indexed insurance has some potential for aquaculture in Northern Thailand, but also evaluates some of the legal and other barriers [WP17]. To deal with challenges of a water management system that pays little attention to fish farming stakeholders, another policy explored was the co-benefits of environmental flow allocation. A third related option is to involve fish farmers more explicitly as stakeholders in water management decision bodies; something which has already happened in locations with strong fish farmer associations [WP20].

3.4 Risks of loss under future climate

The combination of the likelihood that climate-related condition occurring, and the magnitude of negative impact, is a climate-related risk. Table 2 summarizes our understanding of climate-related risks to the profitability of fish farms.

In the lower Nan Basin, one contributing study to the AQUADAPT project linked downscaled climate projections with a water accounting model, using the WEAP program to identify risks of exceeding specific low and high flow thresholds believed to be important for river-based cage culture [WP39]. This study is also looking at the interactive effects of changes in water use and dam operating rules, on water availability for in-river aquaculture.

Table 2 Mechanisms of impact of key climate-related risks and how risks might be influenced by climate change and other factors [WP27].

Climate-related risk	Impact mechanisms	Key climate driver	Climate change concern	Interacting factors
River-based cage aquaculture				
Fast flows and floods from high river discharge	Net deformation leading to collisions with fish Displace cages Fish swim until exhausted Flood debris damage	Tropical storms bringing 3-5 days rains to catchment upstream	Higher frequency and severity	Infrastructure failures (e.g. weir collapse)
Heavy rainfall and run-off	Influx of polluted water or sediments stressing or killing fish, increasing susceptibility to disease	Intense rainfall First rains after dry period	Increased frequency	Watershed land-uses and bank-riparian conditions
Low flows and shallow water depths	Poor water quality, low dissolved oxygen Lower cage volumes means increased effective fish densities Cages may be damaged	Late start to wet season (monsoon)	Increased likelihood and duration of episodes	Water storage and diversions for other uses
Earthen ponds				
River-bank overflow flood	Escapes Exotics introduced Damage to ponds and equipment	Tropical storms bringing 3-5 days rains to catchment of nearby water courses	Increased likelihood	Irrigation infrastructure
Flash flood or high run-off	Pollutants or sediment influx Stressing or killing fish	Intense rainfall	Increased likelihood	Watershed land-uses and bank-riparian conditions
Low flows, water storage	Low water quality and exchange Low DO leading to stress and death	Late start to wet season	Increased likelihood and duration of episodes	Water storage and diversions for other uses
Persistent, dense, cloud cover	Low photosynthesis in daytime leading to low DO levels at night, in turn causing stress or killing fish	Large storm systems with prolonged, thick cloud cover	Increased likelihood and duration of episodes	High nutrient inputs and phytoplankton blooms

Climate-related risk	Impact mechanisms	Key climate driver	Climate change concern	Interacting factors
Heat waves, extreme high temperatures	Phytoplankton blooms impacting water quality DO Thermal stress	Seasonal transition prior to onset of rains and wet season	Increased likelihood and severity of heat waves	High nutrient inputs, low water availability for exchange
Reservoirs				
Rapid changes in temperature	Thermal destratification, exposing fish to low dissolved oxygen Stress after sharp temperature decreases	Seasonal transition into cool/dry season Windy conditions mixing upper and lower water layers	Increased likelihood of sharp temperature changes	
Drought	Cages forced to move into less suitable higher density locations with risks of poor water quality	Low rainfall end of wet season Late start to monsoon	More severe or longer dry season	Dam operating rules reflecting irrigation and flood protection policies
Hatcheries				
Heat waves	Overly rapid development	Overall warmer conditions in already high average temperature periods	Extreme high temperatures more likely in future	
Water shortages	Insufficient water for exchange leading to low water quality	Longer dry season (delayed monsoon)	More likely if less rainfall	High water demand by other users

Another study that explored the sensitivities and vulnerability of freshwater fish fry production in 15 government hatcheries across Northern Thailand found that hatcheries have to consider several climate-related factors when planning production [WP26]. Most fry production is done in the wet season, when the risks of floods are highest, as cold spells and drought conditions disrupt hatchery production and reduce fish farm demand even more. Using a set of scenarios to capture major uncertainties and variability in climate, this study suggests a couple of strategies that should help make hatchery operations more climate change resilient, including ways of improving hatchery operations and management to deal better with risks under current climate variability.

3.5 Aquaculture and adaptive capacity

The social consequences of the losses and damages to fish farms caused by extreme weather and climate vary with household characteristics and community settings. Vulnerabilities depend on both physical (especially water resource conditions) and a wide range of socio-economic factors.

Most farmers engage in both farm and non-farm work. Large-scale farming households tend to have lower vulnerability than other households, and this is directly related to levels of mobility [WP20, WP35] and social capital [WP19, WP32]. Large-scale farming households earned remittances more than others, because they travelled further, for longer, more often, and had higher skills [WP35]. Large-scale fish farmers with higher financial assets are able to buy land with good water access and to develop farming systems; furthermore, have more opportunities to gain knowledge from other external sources than the smaller operators [WP33]. Large-scale operators are able to move and gain access to sites with better quality water resources, while smaller operators remain embedded in a peri-urban matrix with complex water pollution and allocation challenges. Fish farms with capital can invest in technologies to reduce risks such as aerators or paddle-wheel mixers. They can also afford larger plots of land where they may include water storage ponds for coping with dry season shortages.

Farmers learn about risks and potential management strategies from each other, as well as from external resource persons, such as academics and agri-business salespersons that they invite to regular group meetings. Local knowledge is being transformed alongside shifts from beliefs in preparatory ceremonies, to the application of modern information and technologies, while local experiences continue to be important [WP24].

Differences in knowledge, capital, and social networks result in fish farmers adopting different strategies or pathways to adapt [WP25]. Small- and medium-scale fish farming households are typically already diversified, and thus switch to other income sources to cope. Those with less knowledge, networks, and resources may quit fish farming temporarily or permanently. On the other hand, those with high levels of capital and knowledge, as well as capacities to learn and good social connections, are better able to adapt.

An ethnographic study of fish trade networks in Chiang Rai and Phitsanulok (one focused on pond-based and the other cage-based production), confirmed the important role of middlemen in linking producers to the market [WP31]. The study also explored how these social networks facilitate learning and adaptation to changing market conditions, including those arising from climate-related disturbances and stresses. In times of climate-related stresses, middlemen drew on their networks of relations to try and maintain supply and stabilize prices. Personal, semi-formal, and formal relationships were all relevant in particular situations.

While pond-based aquaculture benefits from irrigation projects, it also suffered from uncertainty in water quality and quantity caused by changes in rainfall patterns, floods, drought, water pollution, and water conflicts [WP23]. Fish farming in the past was a lucrative business which helped improve the livelihoods of many fish farmers. They used money earned from fish farming to build houses, buy cars or trucks, consumer goods, and invest in farming and children education. Nevertheless, during the time of study, fish farmers faced uncertainty in generating income from fish farming due to changes in weather, market, and state decisions in water management.

3.6 Assessment of risks and adaptation options

Insights from reviews of past efforts to bring science to bear on adaptation [WP4, WP13, WP21] were helpful for designing assessment and local pilot planning activities of the AQUADAPT project (Activity 4). A review of various efforts to close knowledge-action with respect to adaptation to climate change in the Asia-Pacific, for instance, suggested that many efforts take the form of: promoting communication and education activities; convening reviews and assessments; funding research programs; establishing coordination offices; and supporting pilot community-based actions [WP13]. Another meta-analysis to inform the local, pilot action plans examined how local governments have engaged communities in adaptation [WP21]. In general, the proposition that more participation is desirable was supported.

The importance of scale in adaptation is one of the key themes to have emerged in the assessment of response options so far. Management practices vary with spatial and temporal scale (Table 3). As move to larger spatial scales, additional actors become relevant or the roles shift. At the farm level, the primary actor is the farmer. Other actors like private firms supplying inputs, credit suppliers or fisheries officials, indirectly influence the practices of farmers or the vulnerability of fish farming households. At the river level, fish farmers are collectively important; but so are organizations with mandates at this intermediate level, like local governments or irrigation groups. At the national and sector level, most of the responsibility and effective representation of fish farmer interests, lies with the Department of Fisheries (DOF) or large companies.

A published analysis of a set of aquaculture and key development policies of the Government of Thailand [WP37] found that most policies are sensitive to the impacts of climate change; for example, the zoning policy is sensitive to spatial shifts in climate. while existing policies in Thailand are beginning to refer explicitly to climate change, they do not yet include much in the way of adaptation responses, underlining the need for identifying entry points as has been done in this analysis. Further mainstreaming is one option; another possibility is to adopt a more segregated approach, at least initially, and to collect various policy ideas under a new strategic policy for the aquaculture sector as a whole [WP37].

Similarly to space, as expand considerations to longer time frame (Table 3), additional actors apart from the farmer becomes important. In the shorter time frame, many of the key decisions and actions rest with farmers, as they respond to imminent threats or recent impacts. In the intermediate time frame, in which decisions like how much fish to stock are made, the calculations are based on seasonally varying risks from climate and market factors.

Table 3 Time and space scales of risk management practices relevant to adaptation. Illustrative examples only. If not relevant for all culture systems then indicated with subscript: R= river cage, E=earthen pond, D=dam (WP27).

Spatial and temporal scales	**Short-term reactions** Hours-days Imminent weather conditions and extreme events and emergency actions	**Mid-term tactics** Weeks-months (crop) Anticipated seasonally-varying conditions and risks and recovery actions	**Long-term strategies** Years-decade (multi-crops) Inter-annual climate variability and resilience-building actions
Farm and household level	Move cages towards banks ^{R} Harvest early Provide aeration Withhold feed Exchange water ^{E} Move fish from cages to ponds ^{R}	Adjust stocking date or density Strengthen cages ^{R,D} Water quality monitoring ^{E} Purchase and upgrade water & culturing technologies On schedule loan payments Share rearing knowledge Store water for dry season ^{E} Increase disease surveillance Adopt voluntary standards	Migration to diversify production locations Diversification of income sources Integration of farm activities for resource efficiency ^{E} Savings to help cope & recover
Watershed and Community-level	Share warning information Share market information Mutual assistance during emergencies	Adjust infrastructure operations on seasonal water allocation Coordinate purchase of inputs and sales of harvests Share rearing knowledge Engage in community and basin water management activities Share credit information Water quality monitoring ^{R,D}	Establish and strengthen growers' association to support innovation and learning of best practices Maintain natural biodiversity so watershed continues to provide services Support integrated water resources management Improve climate information systems to support regional seasonal forecasting Invest and build water infrastructure
National and sector-level	Provide disaster relief Share timely warning information with local authorities	Implement zoning- and season-dependent support or incentives Implement voluntary standards Regulate and monitor industry and market practices Provide timely compensation	Improve insurance and compensation schemes Develop alternative export markets Invest in research and development for alternative technologies and species

In the longer, multi-year time frame, support from other actors in the form of information or investment becomes even more important. Important actors here include municipalities, irrigation departments, and electricity generating authorities with responsibilities to operate key water infrastructure. Longer term management practices or strategies at the river and sector levels are particularly relevant to adaptation to climate change.

3.7 Managing research studies

From a project management perspective there were a couple of lessons learnt with respect to management of research studies important to project success.

First, was the division of the project into discrete but linked activities (or research studies) with teams led by different individuals (i.e. Activity Leaders). This allowed work to proceed in parallel, and led to a more comprehensive and multi-disciplinary analysis of issues. Synthesis and integration was supported by project meetings, but was still challenging due to different work speeds and progress.

Second, in the early stages of the project in particular, individual researchers working under different activities joined in each other's field trips, helping collect survey or water sample data. This helped social scientists and biophysical scientists appreciate each other's methods and work more, and it also brought them closer together around the problems faced by fish farmers.

Third, a strong emphasis was placed on deliverables in the form of draft and submitted working papers in sub-contracts with students, Activity Leaders, and fellows rather than activities. This encouraged researchers to scope their work carefully and not to leave analysis and writing to the end. The final result overall was that targets for project outputs were greatly exceeded.

Fourth, researchers were encouraged and supported to attend local and international conferences to share their findings, preferably while working papers were still in draft form so they could get feedback. These events acted as intermediate milestones to completing a piece of research.

Fifth, students had several layers of mentoring, and this redundancy was functional; for instance, ensuring they could get timely feedback on study designs and draft working papers in the case when formal supervisors or Activity Leaders did not have sufficient time. In addition, supervisory committees were led by an Activity Leader, and often included another project team member, helping to ensure that individual research studies aligned adequately with overall project objectives.

4 Assessment and planning

The assessment and planning activities centred around technical assessment work, including reviews, synthesis, and modelling; as well as meetings in which fish farmers jointly assessed problems and potential response options with researchers (Figure 5). The key assessment report aimed at policy and planning was released at the final multi-stakeholder dialogue meeting in November 2015. This report included specific suggestions for national planning and policy, in the fisheries and aquaculture sector [WP29].

These suggestions fell under ten headings: (1) strengthen the provision of weather and climate information to fish farmers; (2) adjust existing aquaculture development policies, plans, and strategies to take into account climate; (3) increase awareness of the importance of the aquaculture stake in inland water resources management; (4) enhance the sharing of good risk management practices among fish farmers; (5) collaborate with private firms and fish farmers to provide new risk sharing options; (6) establish and implement a zoning policy for aquaculture; (7) promote and support the improved regulation and management of pollution that enters rivers used for aquaculture; (8) invest in research and development on climate-resilient aquaculture technologies and rearing practices; (9) make use of understanding of risk perception in communication; and (10) draft a new climate and water strategy for inland aquaculture.

The local action plans (A4.4) built directly on the local participatory assessments (Figure 5) and focussed on supporting farmer defined priorities: one, for example, was on the merits and limitations of forming fish farming cooperatives or groups, which led to a small study and a facilitated exchange visit among fish farming groups. Another pilot action prioritized by two separate locations using different culture systems, was to support further investigations into the feasibility of introducing aquaculture insurance. Because many fish farmer groups were interested in this topic, it became a special roundtable session in the final dialogue event.

The dialogue event brought together 14 members of the project team and 93 other participants, including: farmers (27), Department of Fisheries officials (21), academics and researchers (21), private firms (11), water management agencies (8), international organizations (2), non-government organizations (2), and local government (1). Five media organizations were also represented at the opening plenary. The good representation of fish farmers had a constructive influence on discussions, often pushing experts and officials to consider more carefully the practical implications.

In evaluating the dialogue event with facilitators and selected participants, an important lesson learned was that the facilitated round-table sessions were more popular than the conventional presentation panels with question-and-answer sessions. In future dialogues, more of the sessions should be in the round-table formats, as it provides everyone with opportunities to ask questions and offer their views.

Figure 4 Local participatory assessment process in brief [WP29].

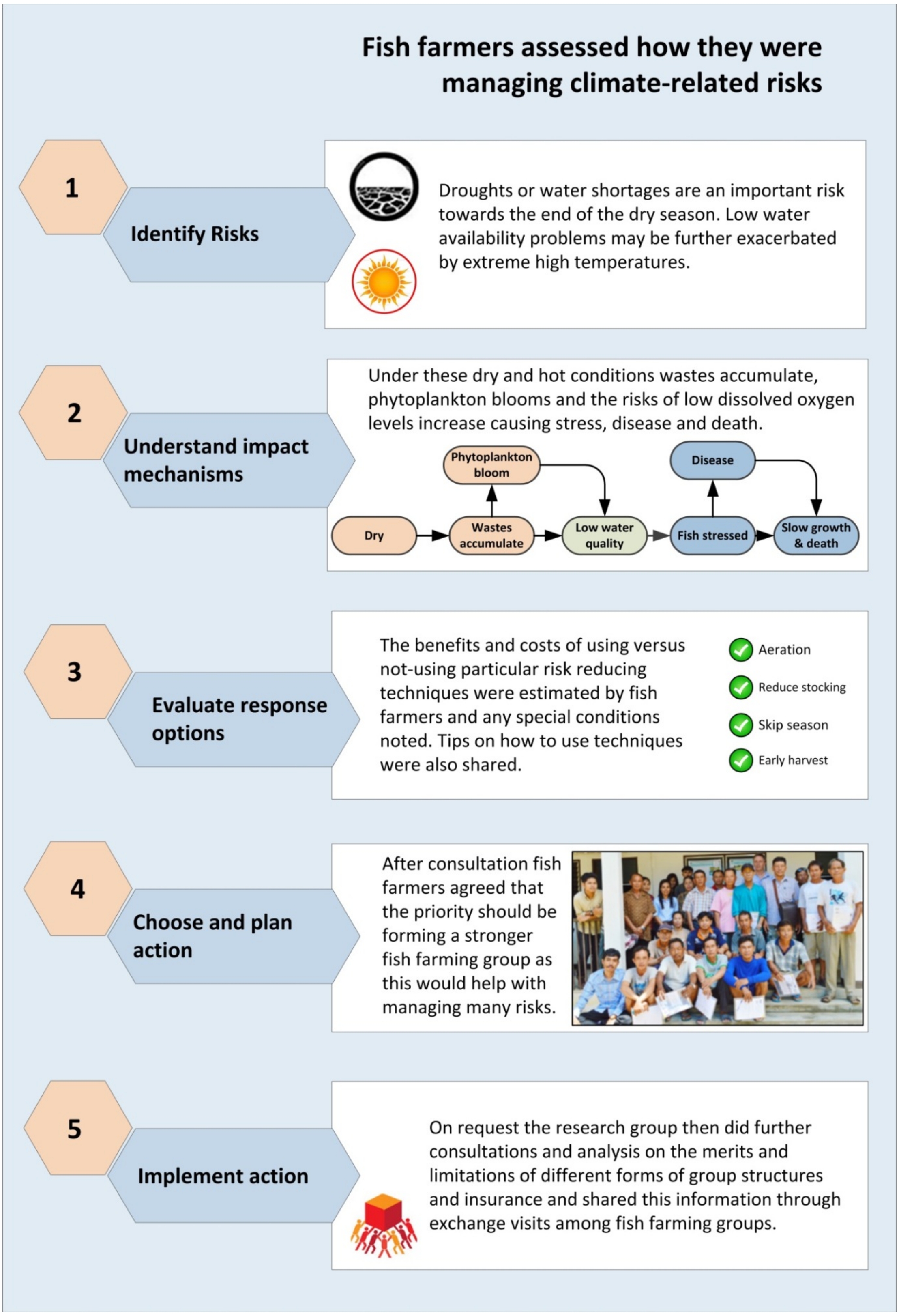


Figure 5 Assessment findings were shared in a series of six dissemination workshops around the country where aquaculture is an important sector. Cover of report documenting the events (in Thai).

In 2016 the findings of the assessment were shared more widely throughout the geographical regions of Thailand through a series of workshops. To ensure high local relevance and interest, half of the time in each workshop was allocated to facilitated identification of most important climate-related risks and evaluation of key climate risk management practices in those regions. An important conclusion from this exercise is that aquaculture in coastal areas faces some distinct risks from coastal storms, changes in salinity, and sea-level rise.

Taken together the various analyses in the assessment report [WP29] suggest successful adaptation is plausible over the next few decades, but will require a combination of actions on multiple spatial and temporal scales, along pathways that cannot be fully pre-determined [WP4].

The inclusion of an assessment process to complement the research studies into the project design was an important element of its success. The assessment acted, in part, as a boundary object around which the findings of different studies and disciplinary perspectives, as well as needs of farmers and planners, could be considered.

5 Coordination and management

The main coordination and management activities undertaken by the project secretariat were liaison with project members, especially with Activity Leaders (A5, Figure 2). Processing monthly payments of stipends, salaries, and reimbursements for expenses incurred were a significant part of the administrative load. Another important part was in mentoring to improve study designs, analysis, and writing. To this end, editorial support was also a significant activity, especially after the first year. A final set of tasks under this activity was supporting communications beyond the project, through printed material, web pages, and Facebook.

There were some important lessons learnt in this project with respect to overall project management important to its success.

First, was the establishment of an active multi-stakeholder advisory group to guide the project (Appendix 1). This group was demanding, and as a result, had a positive impact on the salience of the research undertaken; and thereby significantly increasing the amount of useable knowledge produced. Their inputs also had a strong bearing on the content and influence of the assessment report produced.

Second, the project was designed and pro-actively managed to be gender-sensitive. Women made up 9 of the 15 degree or post-graduate fellowship students supported by the project. Moreover, several of the research studies collected gender disaggregated data, and a few explicitly explored gender differences, relations or norms in the analysis. The project contributed to building capacity of women scientists, and for both men and women to consider gender in their research and work. Despite these efforts, there were also some clear limitations in implementation; for example, 4 of the 5 senior researchers were men, and the advisory group were also mainly men.

Third, an internal system of six-monthly reports was implemented from the start of the project as a way to monitor progress of the different project activities, and ensure milestones were actively pursued. The reports followed the same format as required by IRDC for annual reporting, and drew on individual reports submitted by each of the Activity Leaders. The draft report was then used as the foundations for reporting on progress to the multi-stakeholder advisory group, also held every six months.

Fourth, the Project Leader and coordination unit for the project were based in an office literally midway between the collaborating Chiang Mai and Maejo universities. Space was provided for students, fellows, and senior researchers, independent of supervisory relations, to work for short periods as needed; and many did, especially while preparing proposals. The neutral ground also became the main location for numerous small meetings to brainstorm and review proposals, findings, and manuscript drafts.

Fifth, including a mid-term review was strategic as it provided important, critical feedback which could be acted upon. First, was the need to examine the climate-related risks faced by fish farms using cage culture system in public reservoirs. This would fill an important gap in current understanding in the Department of Fisheries, as well as help ensure assessment for Northern Thailand is comprehensive across major culture systems. Second, was to place greater emphasis on integration of findings from separate student projects and activities. This advice was adhered to in the second half of the project.

6 Project outputs

Table 1 summarizes overall achievements of project against key milestones in the proposal and grant documentation, and a few other internally created indicators. The projects achievements exceeded targets in all categories of outputs. In the following sections these outputs are summarized in more detail.

Table 4 Selected output indicators of project achievements at end of formal project time period.

Output indicators	Target	Achievement
Working papers	**18**	**44**
Activity 1.1	3	15
Activity 1.2	3	7
Activity 2.1 & 3.2	4	4
Activity 2.2	2	4
Activity 3.1	3	9
Activity 4.2	3	5
Articles submitted	**11**	**26**
Published	**0**	**22**
Theses completed	**8**	**8**
PhD	3	3
MSc or MA	5	5
Post-grad fellowships completed	**2**	**8**
Post-Doc	2	5
Post-Master	0	3
Conference presentations	**32**	**61**
Activity 1.1	7	18
Activity 1.2	7	10
Activity 2.1 & 3.2	4	4
Activity 2.2	5	10
Activity 3.1	7	12
Activity 4.2	2	7
Policy and practice documents	**12**	**31**
Policy & Practice briefs	6	14
Educational posters	0	10
Advisory Group Meeting Reports	6	6
Educational video	0	1

6.1 Research working papers and publications

The project produced 44 working papers, 22 of which have been published in peer-reviewed journals before the end of the project. Four additional working papers had been submitted and were in review, and 1 assessment report was self-published (Table 5). The rest are still in draft form and being internally reviewed and finalized for submission. Overall the progress is better than targets, although for some individual activities the process of turning working papers into publications was slower than others. Nevertheless, the emphasis on writing up research as it is completed was a good strategy.

Some of the articles were published in highly respected international journals, such as Regional Environmental Change [WP14], Environmental Management [WP26], Climate Policy [WP37], and International Aquatic Research [WP9]. Others went to respected but lower impact factor international journals, or local journals as appropriate given their scope, significance, and originality. Three articles [WP12, WP15, WP16], and one self-published assessment report [WP29] were in Thai, while all the rest were written in English.

Table 5 Complete list of AQUADAPT working papers and their status at end of project period.

No.	Citation	Status
[WP2]	Lebel, P., N. Whangchai, C. Chitmanat, J. Promya, P. Chaibu, P. Sriyasak, and L. Lebel. 2013. Tilapia cage culture and business management practices in the Ping River, northern Thailand. Natural Resources 4:410-421 DOI: 10.4236/nr.2013.45051	Published
[WP5]	Sriyasak, P., C. Chitmanat, N. Whangchai, and L. Lebel. 2013. Effects of temperature upon water turnover in fish ponds in northern Thailand. International Journal of Geosciences 4:18-23. DOI: 10.4236/ijg.2013.45B004	Published
[WP1]	Lebel, P., N. Whangchai, C. Chitmanat, J. Promya, and L. Lebel. 2014. Access to fish cage aquaculture in the Ping River, northern Thailand. Journal of Applied Aquaculture 26:32-48. DOI: 10.1080/10454438.2014.877731	Published
[WP6]	Pimolrat, P., N. Whangchai, C. Chitmanat, J. Promya, and L. Lebel. 2013. Survey of climate-related risks to Tilapia pond farms in northern Thailand. International Journal of Geosciences 4:54-59 DOI: 10.4236/ijg.2013.45B009	Published
[WP7]	Kunlasuk K, Chitmanat C, Whangchai N, Lebel L. 2013. Relationships of dissolved oxygen with chlorophyll-a and phytoplankton composition in Tilapia ponds. International Journal of Geosciences 4:46-53. DOI: 10.4236/ijg.2013.45B008	Published
[WP13]	Lebel, L. 2014. Closing knowledge-action gaps in adaptation to climate change in the Asia-Pacific region. Int. J. Environment and Sustainable Development 13:204-221. DOI: 10.1504/IJESD.2014.060222	Published
[WP12]	Lebel, P., N. Whangchai, C. Chitmanat, J. Promya, and L. Lebel. 2014. Impacts of floods and drought on cage culture in rivers in Thailand [in Thai]. Khon Kaen University Research Journal 19:539-549.	Published
[WP16]	Sriyasak, P., N. Whangchai, C. Chitmanat, J. Promya, and L. Lebel. 2014. Impacts of climate and season on water quality in aquaculture ponds [in Thai]. Khon Kaen University Research Journal 19:743-751.	Published
[WP15]	Pimolrat, P., Whangchai, N., Chitmanat, C. and Lebel, L. 2014. Musty/earthy off-flavor in aquatic animals: impacts, causes, and solutions [in Thai]. Khon Kaen University Research Journal 19(6)	Published
[WP11]	Sriyasak, P., C. Chitmanat, N. Whangchai, Promya J, and L. Lebel. 2015. Relation of Light Intensity with Dissolved Oxygen and Chlorophyll-a in Nile Tilapia Ponds. Kasetsart Journal 53:1184-1191	Published
[WP3]	Lebel P, Whangchai N, Chitmanat C, Promya J, Lebel L (2015) Perceptions of climate- related risks and awareness of climate change of fish cage farmers in northern Thailand. Risk Management 17: 1-22. doi:10.1057/rm.2015.4	Published
[WP26]	Uppanunchai A, Lebel L. Planning production of freshwater fish fry for aquaculture in a seasonal, variable, and changing climate in northern Thailand. Environmental Management DOI 10.1007/s00267-015-0547-4	Published
[WP22]	Pimolrat, P. Whangchai N, Chitmanat C, Itayama T, Lebel L. 2014. Off-flavor characterization in high nutrient load tilapia ponds in northern Thailand. TrJFAS 15:275-283	Published
[WP9]	Lebel, P., N. Whangchai, C. Chitmanat, J. Promya, and L. Lebel. 2015. Impacts of extreme weather, climate and seasons on river-based Tilapia cage culture in northern Thailand. International Journal of Global Warming 8:534-554.	Published
[WP18]	Sriyasak, P., Chitmanat, C., Whangchai, N., Lebel, L., Pimolrat, P., Sangsawang, K. and Suwanpakdee, S. 2015. Effect of Water De-stratification on Dissolved Oxygen and Ammonia in Tilapia Ponds in Northern Thailand. International Aquatic Research 7(4):287-299 DOI: 10.1007/s40071-015-0113-y	Published
[WP14]	Lebel, P., P. Sriyasak, C. Kallayanamitra, and C. L. Duangsuwan, L. 2016. Learning about climate-related risks: decisions of Northern Thailand fish farmers in a role-playing simulation game Regional Environmental Change 16:1481-1494. DOI 10.1007/s10113-015-0880-4	Published
[WP8]	Lebel, P., N. Whangchai, C. Chitmanat, and L. Lebel. 2015. Climate risk management in river-based Tilapia cage culture in northern Thailand. International Journal of Climate Change Strategies and Management 7:476-498 DOI: 10.1108/IJCCSM-01-2014-0018	Published

No.	Citation	Status
[WP10]	C. Chitmanat, P. Lebel, N. Whangchai, J. Promya, and L. Lebel. 2016. Self-reported fish disease and management in river-based cage aquaculture in northern Thailand. Journal of Applied Aquaculture 28:9-16. DOI: 10.1080/10454438.2015.1104950	Published
[WP36]	Lebel, L., Lebel, P., & Lebel, B. (2016). Impacts, perception and management of climate-related risks to cage aquaculture in the reservoirs of northern Thailand. *Environmental Management, 58*(6), 931-945. doi: DOI 10.1007/s00267-016-0764-5	Published
[WP37]	Uppanunchai, A., Chitmanat, C., & Lebel, L. (2016). Mainstreaming climate change into inland aquaculture policies in Thailand. *Climate Policy*. DOI: 10.1080/14693062.2016.1242055	Published
[WP38]	Lebel, L., Lebel, P. (2016) Emotions, attitudes and appraisal in the management of climate-related risks by fish farmers. Journal of Risk Research, DOI: 10.1080/13669877.2016.1264450.	Published
[WP40]	Lebel P, Lebel L (2017) Gender and the management of climate-related risks in northern Thailand. International Social Sciences Journal,	Published
[WP27]	Lebel L, Lebel P, Chitmanat C, Potapohn M, Uppanunchai A, Apirumanekul C (2015) Improving climate risk management as an adaptation strategy in inland aquaculture in northern Thailand. Water International	In review, Water International
[WP30]	Whangchai N, Chitmanat C, Wanno S, Ramaraj R. 2015. Effects of water-flow rate and water quality on tilapia culture in the Mae Ping River, Thailand	In review, Chiangmai Journal of Science
[WP31]	Kampa T (2015) The role of middleman networks and markets in responding to climate variability and extremes in the aquaculture sector in northern Thailand	In review
[WP34]	Sin-ampol P (2015) Mobility as a Response for Fish Cage Farming Households in Northern Thailand to Multiple Risks in the Dry Season	In review, Asian Pacific Migration Review
[WP17]	Kallayanamitra, C., Potapohn, M. and Lebel, L. 2014. Aquaculture Insurance: Innovative Risk Transfer under a Variable and Changing Climate	In prep.
[WP4]	Lebel L, et al. 2012 Adaptation pathways and inland aquaculture in Asia	In prep.
[WP19]	Kengkaj, W. 2014. Sources of social capital in the networks of fish-pond farmers and their implications for adaptive capacity	In prep.
[WP20]	Sin-ampol, P. 2014. The contributions of different forms and periods of mobility to sustaining fish cage farming in the Ping River	In prep.
[WP21]	Lebel L, Krittasudthacheewa C, Poplanich O, Lebel P. 2014. How local governments engage communities in climate change adaptation.	In prep.
[WP23]	Santita Ganjanapan. 2014. Peri-urban Farmers' Vulnerabilities under Water Uncertainty in the Upper North Thailand.	In prep.
[WP24]	Santita Ganjanapan. 2014. Generating Local Knowledge under Extremes: A Case Study of Peri-urban Fish Farming in Northern Thailand	In prep.
[WP25]	Santita Ganjanapan. 2014. Weighing Costs, Weathering Risks: Adaptive Strategies of Fish Farmers Facing Climate Variability in Northern Thailand.	In prep.
[WP32]	Kengkaj W (2015) Fish Farmers' Utilization of Social Networks in Adapting to Drought and Water Pollution in Upper Northern Thailand	In prep.
[WP33]	Kengkaj W (2015) Forming Social Capital for Climate-Related Adaptation of Fish Pond Farming in Northern Thailand	In prep.
[WP35]	Sin-ampol P (2015) Fish farming household burdens influence decisions to move and reduce vulnerability to climate-related risks	In prep.
[WP39]	Apirumanekul C, Lebel L (2015). Impacts of climate change and water uses on availability of water for aquaculture in the Lower Nan Basin	In prep.
[WP41]	Sriyasak P, Lebel B, Lebel L (2015) Modeling the effects of weather and climate on thermal stratification and the risks of low dissolved oxygen episodes in aquaculture ponds	In prep.
[WP42]	Chitmanat C, Lebel P, Lebel L (2015) Alternative aquaculture and resilience to climate-related risks	In prep.

No.	Citation	Status
[WP43]	Pastpipatkul P, Pratumvan P, Potapohn M, Lebel L (2015) The effects of warning information about flow conditions on the performance of river cage aquaculture in the Nan River, Northern Thailand	In prep.
[WP44]	Lebel L, Uppanunchai A, Lebel P, Lebel B (2016) The effects of tactical messages on risk decisions and the implications for risk communication with fish farmers	In prep.
[WP29]	Lebel L, Chitmanat C (2015). Climate change and aquaculture in northern Thailand: an assessment of risks and adaptation options [in Thai & English]. AQUADAPT Project. Unit for Social and Environmental Research, Faculty of Social Sciences, Chiang Mai University.	Printed Report
[WP28]	Sutthi N, Lebel P, Lebel L. 2015. Thermal tolerance and preferences of key species and climate change adaptation options for inland aquaculture in northern Thailand	No plan to publish

While overall the project was a success in terms of getting a substantial fraction of findings published within the project time period, there were nevertheless some important problems and corresponding lessons learned. One problem that arose early on in the project was with respect to low quality open access journals. Three manuscripts were presented at a conference in China and published in an open access journal (Int. J. Geosciences) without any review or feedback to the authors at all [WP5, WP6, WP7]. A fourth paper was submitted to another journal from the same publisher [WP2] at the same time, after withdrawing from the conference because it looked "light-weight"; luckily this manuscript was reviewed and ultimately had two other rounds of revision with a responsive and responsible editor in a more typical interaction. When inquiries were sent, and matter investigated more closely, the journal and publisher turned out to be black-listed as a 'predatory publisher' for its unprofessional practices – a problem not unique to, but common, among the pay-to-publish open access publishers [10]. Since this incident, early in the project, we have more rigorously screened journals and academic publishers (and conference invitations) before submitting manuscripts (or abstracts).

Not all the working papers listed will be ultimately published as standalone journal articles. In a few cases we were working on combining closely related analyses into a single stronger journal article, with supplementary online material if necessary (e.g. [WP20,34,35] and [WP19,32,33]). The plan and expectation is that around 70% of the working papers now listed as 'in prep.' will be submitted to journals. In practice, it is recognized that this means actual publication of some outputs may not be until 2017 or even 2018, given the variable and sometimes slow turn-around time of journals and authors. One manuscript, for instance, took more than a year to be published after it was accepted [WP9].

Despite some limitations, the strategy of aiming to publish the products of the AQUADAPT project in peer-reviewed journals, rather than as self-published collections in books or reports, was judged worthwhile for a number of reasons. First, it increased the quality of the products as authors had to struggle with meeting peer-review standards. Second, it helped build the capacity and credentials of junior and more senior researchers. Third, it meant project outputs reached a very diverse scholarly audience.

6.2 Conference presentations

Another important output of the project was making presentations of findings to other researchers. Team members altogether made 61 presentations on the findings of AQUADAPT project at national and international conferences within Thailand and in other countries (Table 6). Giving presentations provided experience important for the future scientific careers of junior researchers, while at the same time linking these researchers and the project as a whole to other research groups working on climate change, water management or aquaculture.

Table 6 Presentations given by project team members in national and international events on the findings of the AQUADAPT project.

Date and venue	Event	Title of presentation	Presenter
6-7 Dec 12 Chiang Mai	Fifth International Fisheries Conference	Inland aquaculture in the tropics and adaptation to climate change	Louis Lebel
6-7 Dec 12 Chiang Mai	Fifth International Fisheries Conference	Climate-related risks, financial performance, and Tilapia cage culture practices in the Ping River, Northern Thailand (Poster)	Phimphakan Lebel
21-23 Jan 13 Chiang Mai	Governing critical uncertainties workshop	Governing uncertainties in transboundary river basins	Louis Lebel
29 Jan 13 Kunming, China	International Water History Association (IWHA) conference	Water, climate and fish farming in Nan river basin in northern Thailand	Manoj Potapohn
5-7 Mar 13 Ho Chi Minh City, Vietnam	Mekong Environmental Symposium	Tilapia cage culture, business management practices and climate risks in the Ping River, northern Thailand (Poster)	Phimphakan Lebel (Louis Lebel)
18-20 Mar 13 Incheon, Republic of Korea	Asia-Pacific Climate Change Adaptation Forum	Aquaculture and adaptation to climate change: climate risk management in Tilapia cage culture in northern Thailand	Phimphakan Lebel
16-18 Apr 13 Johor Bahru, Malaysia	International Symposium on Resilience to Climate Change in South East Asia	Climate risk, water and aquaculture adaptations in Northern Thailand	Manoj Potapohn
18-20 Jun 13, Kathmandu, Nepal	Adapting to Climate Change for Water Security in Asia	Fish farming, water and climate in northern Thailand: insurance and water management as two risk mitigation options	Manoj Potapohn
8-10 Aug 13 Chiang Mai	International Conference on Interdisciplinary Research and Development (ICIRD)	Perceptions of climate-related risk and awareness of climate change of fish cage farmers in northern Thailand	Phimphakan Lebel
8-10 Aug 13 Chiang Mai	ICIRD	Effects of Temperature upon Water Turnover in Fish Ponds in Northern Thailand	Patcharawalai Sriyasak
8-10 Aug 13 Chiang Mai	ICIRD	Survey of Climate-Related Risks to Tilapia Pond Farms in Northern Thailand	Pornpimol Pimolrat
8-10 Aug 13 Chiang Mai	ICIRD	Effects of Water Quality and Elevation on Quality of Phytoplankton, Chlorophyll and Bacteria in Tilapia Ponds	Kornkanok Kunlasak
15 Aug 13 Bangkok	Annual Meeting of Office of Agricultural Economics	The Economy of fish farming in Phan district Chiang Rai and the affiliated production site	Manoj Potapohn
20-22 Sep 13 Beijing, China	International Conference on Hydrology, Ocean and Atmosphere (HOAC 2013)	Effects of Temperature upon Water Turnover in Fish Ponds in Northern Tdhailand	Patcharawalai Sriyasak
20-22 Sep 13 Beijing, China	HOAC 2013	Relationships of Dissolved Oxygen with Chlorophyll-a and Phytoplankton Composition in Tilapia Ponds	Kornkanok Kunlasak
20-22 Sep 13 Beijing, China	HOAC 2013	Survey of Climate-Related Risks to Tilapia Pond Farms in Northern Thailand	Pornpimol Pimolrat
17-18 Oct 13 Bangkok	Managing water resources under climate uncertainty	Management of water under current climate variability and uncertainty: implications for Tilapia cage culture in the Ping River.	Chanagun Chitmanat
4-6 Dec 13 Chiang Mai	The Sixth International Fisheries Conference	Effect of Water-flow Rate on Tilapia Culture in the Ping River, Chiangmai, Thailand	Niwooti Whangchai

Date and venue	Event	Title of presentation	Presenter
3-5 Feb 14 Phnom Penh	IDRC Regional Partners Workshop	AQUADAPT: inland aquaculture and adaptation to climate change in northern Thailand project	Louis Lebel
15-16 Feb 14 Chiang Mai	Asia-Pacific Sociological Association (APSA)	Peri-urban Farmers' Vulnerabilities under Water Uncertainty in the Upper North Thailand	Santita Ganjanapan
15-16 Feb 14 Chiang Mai	Asia-Pacific Sociological Association (APSA)	Constructing Fish Farmer Social Capital in Building Adaptive Capacities	Weerakan Kengkaj
15-16 Feb 14 Chiang Mai	Asia-Pacific Sociological Association (APSA)	Dry-Season Mobility of Fish Cage Farmers as Adaptation to Climate-Related and Socio-Economic Risks in Chiang Mai, Northern Thailand	Phaothai Sin-amphol
22-24 Apr 14 Sydney, Australia	the 12th Thai Studies Conference	Generating Local Knowledge under Extremities: A Case Study of Peri-urban Fish Farming in Northern Thailand	Santita Ganjanapan
8-11 Jun 14 Sydney, Australia	World Aquaculture 2014	Perceptions and management of climate-related risks in river-based cage aquaculture in northern	Phimphakan Lebel
8-11 June 14 Sydney, Australia	World Aquaculture 2014	Tilapia Diseases and management in river-based cage culture in northern Thailand	Chanagun Chitmanat
11-13 June 14 Helsinki, Finland	The 16th International Conference: Sustainable Futures in a Changing Climate	Aquaculture Insurance: Innovative Risk Transfer under a Variable and Changing Climate	Chalisa Kallayanamitra
11-12 Sep 14 Ubon Ratchathani	The 3rd MSSRC International Conference	Climate Vulnerabilities and Adaptive Capacities of Fish Pond Farmers: in Upper Northern Thailand	Weerakan Kengkaj
11-12 Sep 14 Ubon Ratchathani	The 3rd MSSRC International Conference	Mobility of Fish Cage Farmers as an Adaptation to Reduce Vulnerability to Climate-Related Disasters in the Ping River Basin	Phaothai Sin-amphol
25-27 Sep 14 Trabzon, Turkey	FABA 2014	Effects of Water-flow Rate and Water Quality on Tilapia Culture in the Mae Ping River, Thailand	Niwooti Whangchai
25-27 Sep 14 Trabzon, Turkey	FABA 2014	Off-flavor Characterization in High Nutrient Load Tilapia Ponds in Northern Thailand	Pornpimol Pimolrat
25-27 Sep 14 Trabzon, Turkey	FABA 2014	Influences of De-stratification on Diurnal Dissolved Oxygen and Ammonia in Tilapia Ponds in Northern Thailand	Patcharawalai Sriyasak
1-3 Oct 14 Kuala Lumpur, Malaysia	4th Asia Pacific Adaptation Forum	Climate change adaptation in tilapia cage culture in Thailand	Chanagun Chitmanat
1-3 Oct 14 Kuala Lumpur, Malaysia	4th Asia Pacific Adaptation Forum	How local governments engage communities in climate change adaptation	Louis Lebel
25-28 Nov 14 Siem Reap, Cambodia	SEAGA Conference	Weighing Costs, Weathering Risks: Adaptive Strategies of Fish Farmers Facing Multiple Risks in Northern Thailand	Santita Ganjanapan
25-28 Nov 14 Siem Reap, Cambodia	SEAGA Conference	Fish Farmers' Utilization of Social Networks to Adapt to Drought and Water Pollution in Upper Northern Thailand	Weerakan Kengkaj
25-28 Nov 14 Siem Reap, Cambodia	SEAGA Conference	Household Burdens and Mobility Decisions of Fish Cage Farmers Interact with Vulnerabilities to Climate-Related and Socio-Economic Risks in the Ping River Basin	Phaothai Sin-amphol

AQUADAPT

Date and venue	Event	Title of presentation	Presenter
3-6 Feb 15 Bangkok, Thailand	The 53rd Kasetsart University Annual Conference	Relation of Light Intensity with Dissolved Oxygen and Chlorophyll-a in Nile Tilapia Ponds	Patcharawalai Sriyasak
3-6 Feb 15 Bangkok, Thailand	The 53rd Kasetsart University Annual Conference	Effects of season on phytoplankton causing off-flavor in integrated tilapia ponds	Pornpimol Pimolrat
25-29 May, Edinburgh, Scotland	World Water Congress XV	Improving climate risk management as an adaptation strategy in inland aquaculture in northern Thailand	Louis Lebel
26-30 May, Jeju, South Korea	World Aquaculture 2015	Planning production of freshwater fish fry for aquaculture in a seasonal, variable and changing climate in northern Thailand	Anuwat Uppanunchai
7-10 Jul 15 Paris, France	Our Common Future under Climate Change	Learning about climate-related risks: decisions of fish farmers in a role-playing simulation game (Poster)	Phimphakan Lebel
7-10 Jul 15 Paris, France	Our Common Future under Climate Change	Adaptation pathways for inland aquaculture in northern Thailand (Poster)	Louis Lebel
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Hatchery planning under climate change in Northern Thailand	Anuwat Uppanunchai
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Effects of climate on water quality in fish ponds	Patcharawalai Sriyasak
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Climate-risk management in river-based cage culture in northern Thailand	Phimphakan Lebel
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Effects of river flow and water quality on tilapia cage culture in upper Ping River	Suthida Wanno
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Adaptation in aquaculture sector to climate variability	Santita Ganjanapan
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Roles of non-agricultural activities in fish farmer adaptation	Phaothai Sin-amphol
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Social capital, learning and adaptation in fish culture	Weerakan Kengkaj
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Middlemen and the impacts of extreme weather on aquaculture in Northern Thailand	Tanyawat Kampa
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Good practices for adaptation of fish culture in the future	Chanagun Chitmanat
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Models and information for integrated water resource management: ideas from aquaculture research in Nan watershed	Manoj Potapohn
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Effects of climate change on water resource management in the lower Nan watershed	Chusit Apriumanekul
20-21 Nov 15 Chiang Mai	AQUADAPT 2015 Dialogue on Aquaculture Adaptation	Robust approaches to improving climate risk management in inland aquaculture	Louis Lebel
12-13 Dec 15 Kyoto, Japan	SEASIA 2015 Conference	Middle Men Network: Fish Marketing and Production Mobility in Northern Thailand	Tanyawat Kampa
14-16 Dec 15 Canberra, Australia	Earth System Governance 2015 Canberra Conference	Gender and the management of climate-related risks in aquaculture in northern Thailand	Phimphakan Lebel

Date and venue	Event	Title of presentation	Presenter
14-16 Dec 15 Canberra, Australia	Earth System Governance 2015 Canberra Conference	Making sense in the boundary between science and governance: experiences in aquaculture adaptation, ecosystem service assessments, and river management	Louis Lebel (Invited keynote)
3-7 Aug 16 Bangkok, Thailand	11th Asian Fisheries and Aquaculture Forum	Climate robust aquaculture as an adaptation strategy	Louis Lebel
3-7 Aug 16 Bangkok, Thailand	11th Asian Fisheries and Aquaculture Forum	Risk decisions of fish farmers in a role-playing simulation game	Louis Lebel and Phimphakan Lebel
3-7 Aug 16 Bangkok, Thailand	6th Global Symposium on Gender in Aquaculture and Fisheries	Gender and emotions in the management of climate-related risks in inland aquaculture	Phimphakan Lebel & Louis Lebel
12-14 Sep 16, Halifax, Canada	Livable Cities Forum: Changing Climate, Changing Communities	Communication and management of climate-related risks in the aquaculture sector	Louis Lebel, Anuwat Uppanunchai, Phimphakan Lebel & Boripat Lebel
18-21 Sep 16 St. John's, Canada	Aquaculture Canada and Cold Harvest 2016	Innovation and the capacity to manage climate-related risks in inland aquaculture	Louis Lebel, Anuwat Uppanunchai & Phimphakan Lebel
23 Sep 16 Ottawa, Canada	International Development Research Centre Seminar	AQUADAPT: Innovation and adaptation to climate change in the aquaculture sector in northern Thailand	Louis Lebel & Phimphakan Lebel
14 Nov 16 Singapore	Institute of Water Policy, National University of Singapore	Water for fish: innovation, risk management and adaptation in inland commercial fish aquaculture in Thailand	Louis Lebel & Phimphakan Lebel

A few lessons were learned by the management group, as well as by individual researchers with respect to participating in conferences. First, is that it is important to plan ahead if wish to participate in high quality meetings, as deadlines for submission of abstracts can precede events by many months or even a year. Second, it is important to carefully scrutinize invitations, and the credibility of conference organizers, as there is an increasing number of low quality or 'fake' conferences being organized each year to simply raise funds. Third, junior researchers (and often senior ones as well) should be strongly encouraged to share their slides and make 'practice' presentations before attending; as with a little feedback it is possible to significantly strengthen quality of presentations. Fourth, as English was a second language for most project team members, some help in editing slides and feedback on practice could help improve confidence and clarity of remarks.

6.3 Trained students

Capacity building was an important underlying aim of the project; an important output was thus trained students. Four Masters thesis and three PhD thesis were completed under the project (Table 7). A fifth Masters student that began as a research assistant and then decided to enroll, and thus started much later than the others, submitted his thesis during 2016. Some of the degree students continued on in the project as fellows after they submitted their thesis. Fellowships were typically from 6-24 month periods. One MA student in A1.2 quit after 5 months after failing to reach agreement on a suitable research topic; they were eventually replaced by a not-for-degree fellow. Overall, more 'fellow' level students were involved in the project than initially planned (Table 4), and this category ended up making a larger contribution to outputs such as working papers than initially anticipated.

As of the end of December 2016, several of the students supported by the project had moved on to new employment or secured support for further studies. Phaothai Sin-ampol, for instance, is now a lecturer in the Faculty of Social Sciences at CMU, and is expected to commence a PhD in Australia in 2017. Nantaporn Sutthi in now a lecturer in the Faculty of Agriculture at CMU. Tanyawat Kampa is now doing a PhD and a lecturer at Naresuan University. Pornpimol Pimolrat and Kornkanok Kunlasak now both work in the Department of Fisheries. Patcharawalai Sriyasak is a lecturer at a University in Northeast Thailand. Phiangkwaun Padang and Chalisa Kallayanamitra went to work with a Government Savings Bank and Central Bank respectively.

The academic writing skills of the Thai students, with a few exceptions, were poor. As a result, the Project Leader and a part-time editor ended up providing a lot of mentoring and multiple rounds of feedback on the drafts of working papers, before they reached a standard suitable for submission. The problems were not only related to writing in English (a problem which could be reduced for some students by first drafting in Thai or writing more simply), but also with selection and organization of material, and constructing logical arguments around evidence and theory. In one case a student plagiarized material in a draft literature review chapter of a thesis, and was admonished before given a second chance. Students got some feedback on the content of their working papers from supervisors and Activity Leaders. Providing critical feedback was an important role of the Project Leader, and ultimately meant that the students learned a lot from the experience of being part of the AQUADAPT project.

Table 7 Titles and topic areas of contributing student theses and not for degree fellows.

Act-ivity	Title	Student, Degree, (Place)
A1.1	Climate risk management in Tilapia cage culture in northern Thailand	Phimphakan Lebel, PhD, (MJU) [Completed]
A1.1	Climate Risk and Off-flavor Occurrence in Pond-raised Tilapia in Northern Thailand	Pornpimol Pimolrat, PhD, (MJU) [Completed]
A1.2	Climate Sensitivity of Tilapia Culture in Earthen Ponds in Northern Thailand	Patcharawalai Sriyasak, PhD, (MJU) [Completed]
A1.2	Effects of season and elevation on chlorophyll levels and phytoplankton dynamics in Tilapia ponds	Kornkanok Kunlasak , MSc, (MJU) [Completed]
A3.1	Mobility of fish cage farmers as a response to climate-related and socio-economic risks	Phaothai Sin-ampol, MA, (CMU) [Completed]
A3.1	Role of social capital in climate adaptation of fish-pond farming households in northern Thailand	Weerakan Kengkaj, MA, (CMU) [Completed]
A2.2	Economics analysis of Inland aquaculture industry in Northern Thailand and Adaptation to climate change	Pawassada Pratumvan, MA, (CMU) [Completed]
A2.2	Index-based aquaculture insurance: Innovative risk transfer for sustainability	Chalisa Kallayanamitra, Post Graduate Fellow, (CMU) [Completed]
A2.2	Water resources management study in lower Nan basin, using WEAP model	Phiangkwaun Padang, Post Graduate Fellow, (CMU) [Completed]
A2.2	Middle men network: Fish marketing and production mobility in northern Thailand	Tanyawat Kampa, Post Graduate Fellow, (CMU) [Completed]
A3.2	Implications of key aquaculture policies and plans for inland aquaculture in a variable and changing climate in northern Thailand	Anuwat Uppanunchai, Post-Doctoral Fellow [Completed]
A1.1	Communication of climate-related risks and decision-making behavior	Phimphakan Lebel, Post- Doctoral Fellow [Completed]
A2.2	Econometric modeling and water policy analysis	Pathairat Pastpipatkul, Post-Doctoral Fellow (CMU) [Completed]
A2.1	Impact of climate change on aquaculture systems	Chusit Apirumanekul, Post-Doctoral Fellow [Completed]

Act-ivity	Title	Student, Degree, (Place)
A2.1	Thermal tolerance and preferences of key species for inland aquaculture	Nantaporn Sutthi, Post-Doctoral Fellow [Partly Completed]
A1.1	The effects of the fish farmer associations on learning and evaluation of climate-related risks and risk decisions in northern Thailand	Chatta Duangsuwan, MSc, (MJU) [Submitted]

6.4 Events

Apart from supporting the writing theses and working papers, the project also convened several workshops and participated in exchange visits to help build capacities of team members and others (Table 8). Many other small group events were held throughout the project to help research teams with design, analysis, and writing. In 2016 the project convened an important series of workshops in six provinces outside the region of Northern Thailand, in order to disseminate findings and stimulate interest in improving the management of climate-related risks.

In December 2016 a workshop was held to develop a regional proposal for a follow-up project to AQUADAPT. This activity followed-up to a SEA-CCW meeting in January 2015 when various IDRC projects came to Chiang Mai; visits to Mekong Delta in Vietnam in 2015; and a set of exchanges in Canada In September 2016 where ideas for an innovation-oriented project were presented and discussed in various venues (see: Table 6).

Table 8 Significant training, exchange, and capacity building events conducted.

Date and venue	Event	Participants	Trainers/Leaders
21-23 Jan 13 Chiang Mai	Governing critical uncertainties: climate change and decision-making in transboundary river basins*	Trainers from around world, early career researchers primarily from South Asia, 5 AQUADAPT team members (ca. 25 pax)	Louis Lebel et al.
9-10 Apr 13 Chiang Mai	Intensive training workshop on using SPSS for research data analysis	AQUADAPT students, other invited students, and interested Activity Leaders (ca. 20 pax)	Louis Lebel Chanagun Chitmanat
20-24 May 13 Bangkok	WEAP and BBN modeling training workshop at SEI	AQUADAPT economic students, irrigation department colleagues (5 pax)	Stockholm Environment Institute (SEI) researchers
20-24 Oct 13 Chiang Mai	WEAP 2nd training workshop at CMU	AQUADAPT team members, irrigation department colleagues, economic students (20 pax)	Stockholm Environment Institute (SEI) researchers
17-18 Jan 15 Chiang Mai	2nd Southeast Asia Climate Change and Water Partners Meeting (SEA-CCW)	AQUADAPT team members, stakeholders, and members of other IDRC projects in Southeast Asia (ca. 30 pax)	Louis Lebel Charlotte McAllister (IDRC)
24-30 Apr 15 Mekong Delta, Vietnam	Joint field visit on climate-related risks and private sector in the Mekong delta	AQUADAPT team members, Vietnamese researchers, private sector (ca. 5 pax)	Chanagun Chitmanat Phimphakan Lebel
10-13 Nov 15 Bangkok	2nd SUMERNET regional workshop on robust decision support (RDS) framework for regional assessment†	Lecture/tutorial on RDS-Lite: a qualitative approach to robust decision modeling and analysis. Tool developed during assessment process in AQUADAPT	Louis Lebel
9-12 Dec 15 Canberra,	Earth System Governance Summer School‡	Lectures on (1) climate change adaptation and water governance in the	Louis Lebel

Date and venue	Event	Participants	Trainers/Leaders
Australia		Mekong Region, and (2) Roles of science in environmental governance to 40 PhD and Post-Doc Students from around the world	
9 Jun 16, Ubon Ratchathani, Thailand	Assessment regional workshop 3: Northeast Region of Thailand with Department of Fisheries**	Presentation and discussion of northern Thailand assessment findings followed by facilitated analysis of local climate-related risks and management practices with aquaculture stakeholders	Phimphakan Lebel, Anuwat Uppanunchai & Chatta Duangsuwan
10 Jun 16, Sisaket, Thailand	Assessment regional workshop 4: Northeast Region of Thailand with Department of Fisheries**	Presentation and discussion of northern Thailand assessment findings followed by facilitated analysis of local climate-related risks and management practices with aquaculture stakeholders	Phimphakan Lebel, Anuwat Uppanunchai & Chatta Duangsuwan
14 Jul 16, Nakhon-sri-thammarat, Thailand	Assessment regional workshop 5: Southern Region of Thailand with Department of Fisheries**	Presentation and discussion of northern Thailand assessment findings followed by facilitated analysis of local climate-related risks and management practices with aquaculture stakeholders	Phimphakan Lebel, Anuwat Uppanunchai & Chatta Duangsuwan
15 Jul 16, Songkla, Thailand	Assessment regional workshop 6: Southern Region of Thailand with Department of Fisheries**	Presentation and discussion of northern Thailand assessment findings followed by facilitated analysis of local climate-related risks and management practices with aquaculture stakeholders	Phimphakan Lebel, Anuwat Uppanunchai & Chatta Duangsuwan
4 Aug 16, Chainat, Thailand	Assessment regional workshop 1: Central Region of Thailand with Department of Fisheries**	Presentation and discussion of northern Thailand assessment findings followed by facilitated analysis of local climate-related risks and management practices with aquaculture stakeholders	Phimphakan Lebel, Anuwat Uppanunchai & Chatta Duangsuwan
5 Aug 16, DOF, Suphanburi, Thailand	Assessment regional workshop 2: Central Region of Thailand with Department of Fisheries**	Presentation and discussion of northern Thailand assessment findings followed by facilitated analysis of local climate-related risks and management practices with aquaculture stakeholders	Phimphakan Lebel, Anuwat Uppanunchai & Chatta Duangsuwan
12-23 Sep 16 Eastern Canada	Two conferences and meetings at IDRC offices in Ottawa	Climate Change (Halifax), Aquaculture (St. John's), and development/environment communities (Ottawa)	Louis Lebel & Phimphakan Lebel
10-11 Dec 16, Chiang Mai, Thailand	Regional Proposal Development Workshop	Representatives from Cambodia, Lao PDR, Myanmar, Vietnam and Thailand discussed a draft proposal for a regional project focused on innovation to support adaptation to climate change in the aquaculture sector	AQUADAPT Coordination Unit

* Hosted by Unit for Social and Environmental Research that leads AQUADAPT project, but fully funded by the Asia-Pacific Network for Global Change Research (APN)
† Hosted and funded by the Stockholm Environment Institute (SEI)
‡ Air-travel and accommodation funded by University of Canberra
** Hosted by Department of Fisheries

6.5 Policy and practice briefs

Thirteen issues of what was initially planned to be a six-issue set of policy and practice briefs were printed and distributed (Table 9). The briefs are all two-sided A4 sheets. Poster versions of most briefs have also been prepared and used in displays at meetings with stakeholders; in particular, farmer-oriented events. Hard copies of posters were shared with farmer cooperatives and extension service agents on request. All briefings and posters are available in Thai; some have also been produced in English. Briefs are available to download via the website and links on the AQUADAPT Facebook page.

Much of the information in the practice briefs was also summarized in a 30-minute video. The idea for the video came from fish farmers in the advisory group, whom argued that it would be an alternative way to reach more stakeholders. While the film begins with images of mass mortality events from newsreels, the main emphasis is on what farmers can do to reduce various kinds of climate-related risks. The video was professionally produced and contains some stunning footage taken from a camera mounted on a drone that captures farm layouts and siting very clearly. To ensure easy access, the film has been uploaded on YouTube with links from the Facebook page.

An important lesson learned in this project is that, it is important to tailor the format and language of communication materials to the intended audience. Thus, while the emphasis in preparing research products for a scholarly audience was to write in English, when it came to communication with all other stakeholders, Thai was the language used.

Table 9 Policy and practice briefings.

Nos.	Description	Thai Brief	English Brief	Thai Poster
1	Aquaculture and Climate: about the AQUADAPT project.	Yes	Yes	Yes
2	Risks to cage culture in rivers and their management.	Yes	Yes	Yes
3	Changing Climate and Tilapia Production in Earthen Ponds: risk to pond culture and risk management.	Yes	Yes	Yes
4	Farming Households' Vulnerabilities and Adaptation to Weather and Water: adapt to household vulnerability, and adaptation at the farm level.	Yes	Yes	Yes
5	Growing tilapia in earthen ponds: preparing pond for rearing tilapia, and choosing fish fry.	Yes	Yes	Yes
6	Feed preparation techniques: preparing feed from household materials.	Yes	Yes	Yes
7	Tilapia Diseases: diseases caused by parasites and bacteria, and which medicines to use.	Yes	Yes	Yes
8	Survey of climate-related risks to tilapia culture in Earthen Ponds: study about the effects of weather on fish pond culture.	Yes	Yes	Yes
9	Effect of temperature on thermal stratification and water turnover in fish ponds	Yes	Yes	Yes
10	Aeration techniques for earthen pond fish culture: how to apply aerations to fish pond culture.	Yes	No	Yes
11	Planning hatchery management in the face of climate change: how to adapt during the different seasons.	Yes	No	No
12	Aquaculture insurance: comparison of different systems of insurance for aquaculture, their strengths and weaknesses.	Yes	No	No
13	Summary of the final assessment report	Yes	No	No
14	Summary of the AQUADAPT project findings and products	No	Yes	No

6.6 The AQUADAPT brand

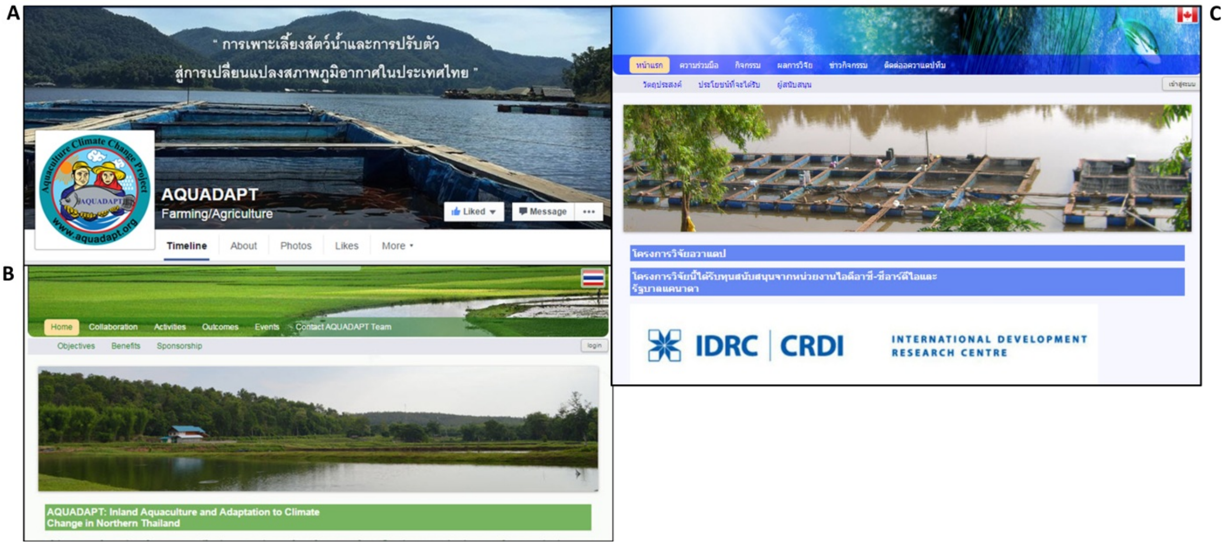
Branding was an important early strategy in the project that helped create a stronger identity for the project. In a short period 'AQUADAPT' became the preferred label for the project among team members and other stakeholders. Now the AQUADAPT brand can be considered an output of the project, as it is familiar, and thus useful for social-marketing in related follow-up activities.

Another important and related set of products were those created by the media based on interviews, notably around the November 2015 dialogue event (Figure 5). Two newspapers ran stories, as did two other web-based news services. Three local television stations included short stories as part of their news programs. The stories were largely descriptive, while interviews with Deputy Director-General of the Department of Fisheries and the AQUADAPT Project Leader tended to focus on the upcoming severe dry season or drought (Appendix 2). The short name of the dialogue was "AQUADAPT 2015" leaving open the possibility, and creating some expectations, that there would be other dialogue events in future years.

Figure 6 Collage of screen shots from news media coverage of the 20-21 November multi-stakeholder dialogue event with clips from Chiang Mai News (23 Nov), Naew Na News (1 Dec), LC TV station (20 Nov), WE TV station (23 Nov), and NBT TV station (20 Nov).

A website established for the project in its first year continues to be maintained at a modest level in two languages (www.aquadapt.org), but in 2015, we switched to making more use of Facebook in Thai (https://www.facebook.com/AQUADAPTthailand) as this was found to be a much more effective way to communicate and share information with relevant stakeholders in the Thai context (Figure 6); the page currently has 667 followers. Short online video clips accessed through the page, in particular, were widely viewed and shared. In 2016 we re-arranged and split the Facebook pages to introduce an English-language Facebook page (https://www.facebook.com/AQUADAPT) to support regional collaboration. The websites are being downplayed as the project closes.

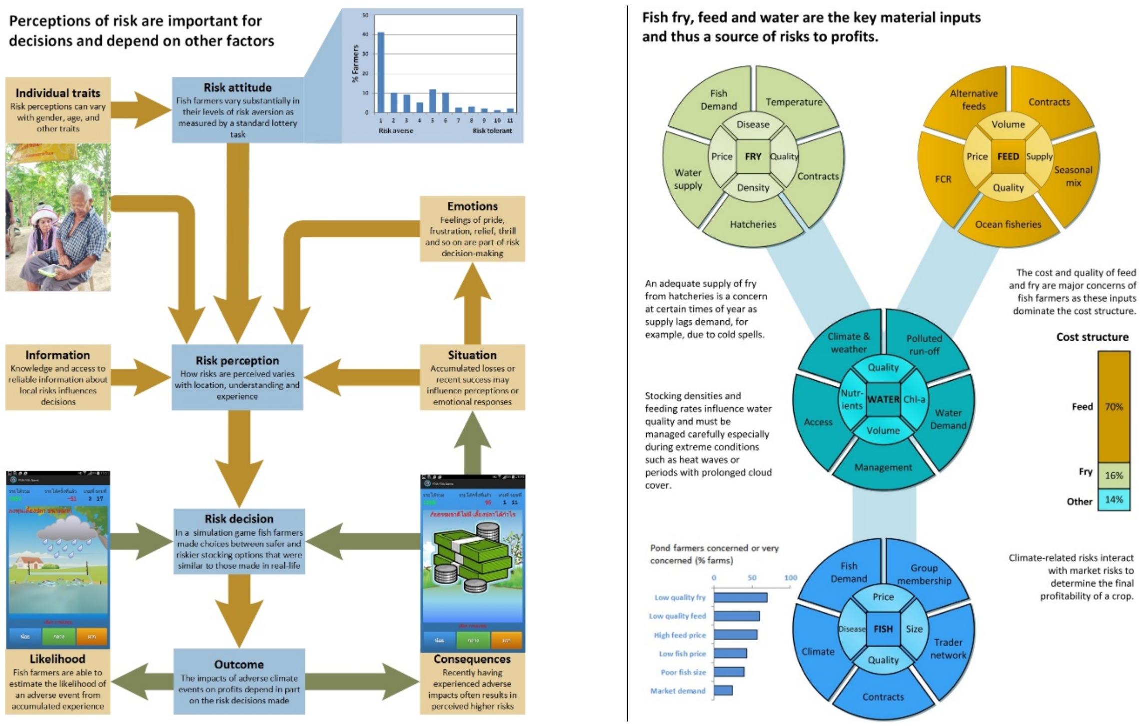
Figure 7 Screen shots of the (a) AQUADAPT Facebook page, (b) AQUADAPT web home page in English, and (c) AQUADAPT home page in Thai.



6.7 Assessment report

The AQUADAPT assessment report was one of the key policy documents of the project [WP29]. Versions in Thai and English were both produced, but the emphasis in dissemination was with the Thai version. The report was organized around two-page spreads with extensive use of figures and graphics (Figure 8).

Figure 8 The report made substantial use of figures, tables, images and info-graphics in an attempt to better communicate a lot of complex information more simply. These two example comes from the English language version of the report.



The recommendations for policy and planning at the end of the assessment report were as follows:

1 **Strengthen the provision of weather and climate information to fish farmers**. In particular, develop systems to improve the provision of information about emerging seasonal conditions, such as likelihood of water shortages or above normal rainfall; for instance, related to the El Nino – Southern Oscillation or monsoon development. Existing early warning systems for extreme weather events, such as floods, in a format appropriate to fish famers and hatcheries, should also be supported. This is a no-regrets strategy that would yield significant immediate benefits in terms of improving the management of climate-related risks under current climate, while the system improvements would also contribute to capacities to adapt to future changes in climate.

2 **Adjust existing aquaculture development policies, plans, and strategies to take into account climate**. This can be done in several ways. First, by including special provisions for dealing with extreme weather events, such floods or unusually dry periods causing serious drought. Second, by incorporating the notion of inter-annual climate variability, into the logic of targets and budgeting, so that there is some flexibility to take into account year-to-year differences; for instance, in the allocation of water for aquaculture. Third, by embracing long-term strategies which are capable of dealing with uncertainty and change, such as those which arise when considering future climate. Policies on standards, registration, and hatchery services, for example, could do more to mainstream concerns with climate change.[65]

3 **Increase awareness of the importance of the aquaculture stake in inland water resources management**. In particular, engage more closely in watershed, river, hydropower, irrigation, and flood protection deliberations at national, as well as local levels. Ensure aquaculture interests are represented in water user groups and other related water management organizations, especially those related to irrigation and river management. Involvement in these and broader integrated water resources management debates, should lead to more informed decisions on infrastructure and demand-side management.

4 **Enhance the sharing of good risk management practices among fish farmers.** In particular, document and acknowledge the role of local innovation and practice-based knowledge in extension services, fish farming cooperatives, and local networks. The sharing of knowledge is important in building adaptive capacities to deal with a range of risks, including those which are climate-related, but also for example, in the management of diseases. Improved management of fish stress and disease is one of the key ways to reduce climate-related risks as both are often part of the causal chain leading to slow growth and high mortality.

5 **Collaborate with private firms and fish farmers to provide new risk sharing options.** In particular, evaluate in detail the options for providing mutual or index-based insurance for aquaculture, and how these might interact with conventional compensation approaches. Risk sharing in contract farming relationships should be monitored, and perhaps also regulated by the government.

6 **Establish and implement a zoning policy for aquaculture**. Policies should take into account the local carrying capacities of the environment and seasonal differences in water flows or availability. In the case of river-based or reservoir-based cage aquaculture, it is important that overall stocking levels in a reach do not exceed local carrying capacities of surrounding aquatic ecosystems, especially during periods of low flows or volumes. In the case of earthen ponds on private land within irrigation schemes or drawing on and draining into natural water courses, similar considerations should hold. The zoning policy should include provisions for regular review of zones, to allow adjustment for changes in climate and water resource conditions.

7 **Promote and support the improved regulation and management of pollution that enters rivers used for aquaculture.** Pollution from urban and industrial uses is responsible for significant mass fish mortality events; on the other hand, the sustained presence of successful river cage aquaculture can be taken as an indicator of good river health and successful watershed management. High nutrient loading from human settlements, piggeries, and fertilizer run-off should also be monitored and regulated. In areas downstream from major water infrastructure support efforts should be made to maintain releases consistent with adequate environmental flows to protect natural ecosystems and aquaculture activities.

8 **Invest in research and development on climate-resilient aquaculture technologies and rearing practices**. In particular, to improve water productivity, increase resistance to stress and disease, and use technologies like aeration in ways that are economically efficient. Research is also needed on technical and economic aspects of alternative aquaculture practices and species aimed at niche markets and higher value products; for example, meeting pesticide-free, organic or sustainability-oriented standards.

9 **Make use of understanding of risk perception in communication.** Effective communication is important to the success of many policies related to improving the management of climate-related risks. Communication strategies need to become more sophisticated, acknowledging the importance of recent experience and situational factors to how fish farmers perceive risks. Appeals to analytical merits of particular measures may need to be complemented by recognizing the role emotions play in dealing with and taking risks.

10 **Draft a climate and water strategy for inland aquaculture.** The strategy should provide a clear pathway for strengthening capacities to deal with climate-related risks in the inland aquaculture sector. As most climate impacts are also related to water management activities, dealing with two issues in parallel seems particularly appropriate for this sector. Close links to a parallel strategy for the coastal aquaculture sub-sector would also be beneficial as many of the problems faced (apart from sea-level rise) are similar. The 5 to 10 year strategy document should provide a framework for the overall policy response to the climate and water challenges and be updated periodically.

6.8 Proposal for a Mekong Aquaculture Project

In the Interim Project Report at the end of 2015, one of the two key recommendations was to explore the potential for developing a multi-country, regional project focussed on adaptation to climate change in the aquaculture sector. After approval of the extension to end of 2016, this was actively pursued, and resulted in the development of a proposal. Working together with a consortium of partners in five countries, a proposal for a project on "*Climate Adaptation and Innovation in Mekong Aquaculture*" or AQUADAPT-Mekong, was developed for consideration by IDRC. The proposal was developed based on consultations in Canada and planning workshop in late 2016, but built on earlier events and field visits in 2015.

The proposed new project aims to assist fish farmers in five Mekong countries to be able to better manage climate-related risks, and thus capacities to adapt to climate change, through jointly evaluating and supporting the development or uptake of promising innovations. Innovations are novel practices or new applications of knowledge. While usually they are thought of as technologies (such as a pond aerator powered by wind, for example), they may also be institutions (as in weather index-based insurance, or information-communication systems). In this project *innovation facilitators* will work closely with farmers to develop solutions appropriate to local conditions and fish culture systems. This will involve deliberative communication with relevant stakeholders, undertaking targeted research, and coordinating efforts by *solution teams* to overcome performance limitations and barriers to adoption. The expected outcome is that fish farmers are better able to manage climate-related risks and adapt to climate change.

The proposed partners are:

- Inland Fisheries Research and Development Institute, Phnom Penh, Cambodia
- National University of Laos, Vientiane, Lao PDR
- World Fish Centre, Yangon, Myanmar
- Ubon Ratchathani University, Thailand
- Can Tho University, Can Tho, Vietnam
- Unit for Social and Environmental Research, Chiang Mai University, Chiang Mai, Thailand

7 Project Outcomes

Project outcomes were assessed by synthesizing observations made by project team members, and supplemented by evidence gathered by interviews done with a range of stakeholders in the last month of the project. Our evidence about impacts on fish farmers and other stakeholders thus remains primarily qualitative.

7.1 Understanding

The project substantially improved understanding of the risks of floods and droughts to fish farms, and how those risks could be managed under current climate. This improved understanding of risks was shared among researchers, fish farmers, public and private extension officers, and planning and policy officials. A pond fish farmer said "*I learned a lot about global warming*" from the project, and that he had shared information with others in his cooperative. Another argued that "*practitioners were direct beneficiaries*" of information provided by the project about climate-related risks; information that was otherwise hard to obtain from other sources. He also encouraged the project team to place a greater effort in any follow-up project, in sharing information much more widely among effected or at risk fish farmers. A senior advisor to the fisheries department concurred, arguing that while the project "*had many research outputs, many related to the impact of climate variability which are useful,*" there was still important work to turn the findings into more specific guidance on best practices for fish farmers.

The project improved understanding of risks under future climate and adaptation options. Qualitative analyses under a range of possible future climates were completed for all major culture systems, and a broad set of risks and impacts, as part of the assessment process. In addition, some quantitative model-based analyses have also been completed, for instance, for hatcheries. This new knowledge was shared with researchers via publications, and with other stakeholders (in particular, planners and policy-makers in the Department of Fisheries), through the assessment report and dialogue event. Through the series of advisory group meetings, along with other consultations with key stakeholders, the AQUADAPT project has created interest and increased awareness of climate and climate change as significant factors for aquaculture management and development. An agent from a private firm, for example, said he was interested in exploring further the implications of what he had learnt about climate change for the management of commercial fish farms, and his input supply firm; for example, whether adaptation required changes to the system of culture or new and improved business management practices. A senior DOF official told us that the AQUADAPT project was "*very useful in improving understanding and raising awareness about climate change; before this, we never gave much importance to the global warming issue. Now, and looking ahead, it seems likely that the impacts will increase. Thus, it is important for us to help farmers prepare and plan ways to reduce impacts.*"

The project improved understanding of the effects of aquaculture on adaptive capacity of fish farming households. The social consequences of the losses and damages to fish farms caused by extreme weather and climate vary with household characteristics, and community settings. Vulnerabilities depend on both physical (especially water resource conditions) and a wide range of socio-economic factors. Fish farms with capital, extensive social networks, and good access to knowledge were better able to cope and adapt than those without such a combination of resources; in particular, smaller-scale farms. These findings imply the on-going need for extension services to take into account the special disadvantages and challenges faced by small fish farms.

The project made a few significant and original contributions to scientific methods. First, was the use of a role-playing simulation game on hand-held tablets to experimentally explore factors influencing risk decisions [WP14]. This approach yielded nuanced insights into decision behavior, while still capturing many of the key features of decision context in real life. Second, was the development of a qualitative approach to robust decision-support analysis, as part of the assessment of long-term adaptation strategies in the assessment process [WP27]. This approach emerged out of the need for taking into account issues of uncertainty with respect to future climate and water use critical to evaluating adaptation options. It has potential to complement mathematical modelling and computer intensive approaches to robust decision making, especially in situations where the former are highly constrained by lack of appropriate long-term or spatially disaggregated datasets.

7.2 Capacities and relationships

The project improved the skills and capacities of researchers. Capacities and skills were built among students to analyze qualitative and quantitative data, and model climate-related risks. Fourteen individuals completed a degree or a post-graduate fellowship under the project (Table 7). Researchers were encouraged and supported to attend local and international conferences (Table 6), gaining valuable skills in communicating findings and building networks with researchers beyond the project.

The project strengthened collaboration among stakeholders. These new and improved relationships with other stakeholders arose through events where there was constructive interaction among stakeholders (farmers, officials, researchers); especially in the regular advisory group meetings, but also in project activities, local assessment meetings, and the final dialogue workshop. The participatory local assessment "*allowed the stakeholders (fish farmers, technical officers, scientists, researchers, local politicians, businessmen, and students) to jointly evaluate the root causes, direct and indirect impacts, and preferred solutions to some prioritize problems…the stakeholders learned and gained a lot from the process of two-way learning*." An official from irrigation department, while noting that aquaculture activities itself did not have much direct impact on his work, praised "the *multi-stakeholder dialogue approach used in the project is really important and significant,"* and argued that *"we need to develop these approaches much more, and not just for issues related to fish farming.*"

Boundary work done by the project team improved coproductive capacities or the capacities of policy actors and farmers to use scientific information [11]. Important forms of boundary work included engaging practitioners in the field, joint fact finding and evaluation, attention to alternative communication formats, and, most importantly, the interactions and relationships built through the iterative meetings of the research team with the multi-stakeholder advisory group. These relationships provided an important foundation of trust and mutual respect that could be taken into the deliberations at the AQUADAPT 2015 dialogue event.

The project built new regional cooperation leading to development of new proposals. The primary example was the preparation of the AQUADAPT-Mekong proposal on "*Climate Adaptation and Innovation in Mekong Aquaculture*" by a consortium of research, government, and international organizations in five countries: Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam (see Section 4.8*)*. The overall objective of the proposed project is to improve the capacity of fish farmers in the Mekong Region to manage climate-related risks and adapt to climate change through innovations that contribute to the sustainability of aquaculture value-chains. A second example was the preparation with collaborators in Singapore of a successful small grant proposal on the "*Governance of Water Use by Aquaculture*" to the Lee Kuan Yew School of Public Policy, National University of Singapore. This proposal directly follows-up the discovery made in the current project of low representation of aquaculture stakeholders in water governance, and how this a constraint to adaptation at scales above the individual farm.

7.3 Practices

The project improved capacities of fish farmers to manage climate-related risks as evidenced by adoption of better practices. Individual testimonies of fish farmers, as well as direct observations of some farms visited frequently during the project, suggest an influence on several key practices. First, farmers changed practices as a result of information about how to reduce the risks of exposing fish to low levels of DO. Specifically, they bought, made greater use of, or adjusted the times they used paddle-wheel or other forms of aerators. Some firms are now providing loans or discounts on feeds for farmers who set up aeration. Second, farmers with river cages shared and used information that the project helped facilitate with regards to techniques for reducing impacts of fast flow, by making frames for cages or adding empty cages or a triangular-shaped buffer at the front end of a series of cages. Third, farmers with river cages adjusted stocking decisions based on seasonal forecasts, for example, of likely river water levels in early 2016. Similarly, farmers with reservoir cages have shifted to stocking larger fish fry to reduce time in cages and avoid high risk periods. The AQUADAPT project helped sensitize fish farmers to information about climate and water conditions, as well as shared with them possible solutions, making it more likely they would act.

The project also influenced farmer's attitudes towards collaboration with each other in ways likely to increase resilience. This impact came primarily from arranging and facilitating exchange visits between groups of fish farmers. Another important technology-supported impact, was the use of mobile-phone based social media applications to share information, in particular, about high risk conditions in the Upper Ping Region. One river cage fish farmer said the project had helped "*improve relationships between fish farmers and key organizations with water management responsibilities, like the irrigation and fisheries department; so they help during crisis times when there is too much or not enough water.*" Another fish farmer also opined that the project helped him make new friends. In a context in which fish farmers have not always been recognized as stakeholders in water management, these strengthened relationships and recognition are significant for longer-term sustainability, and climate-risk management actions at larger spatial scales.

The project helped public and private actors with extension roles to do their work. A district fisheries officer said the project improved her understanding of climate, and other practical issues like use of aerators or monitoring temperatures, which was useful for her work when sharing information with fish farmers as part of extension work. In another area, a district fishery officer told us that "*the AQUADAPT project had brought a lot of benefits to fish farmers,*" for example, by providing useful knowledge on good practices like using aerators and other techniques or tactics used by successful fish farmers in other locations. Thus, he underlined, "*would like to see this project continue another 2-3 years, it would be great*. *My office and others in the province would welcome further collaboration.*"

7.4 Policy and planning influence

Impacts on sectoral policy and planning arising from the AQUADAPT project cannot be unambiguously demonstrated, though there are indirect indicators of potential influence from statements of individual officials. A senior advisor to the Department of Fisheries, for instance, argued "*for civil servants, there is no need to wait, the information provided by the project is already useful, and much can be used immediately*." At a regional fisheries conference in August 2016, two Department of Fisheries officials approached us and told us they found the "*Thai language assessment report extremely helpful for their work,*" and they hoped that we could make "*a second edition that covered the entire country*." Impacts on watershed planning were only at the level of dialogue, or interaction among stakeholders that otherwise "*do not usually meet,*" but these interactions did not yield new goals or membership structures of water or river management organizations. A modest level of media coverage highlighting senior officials participation in an AQUADAPT event may also have had some indirect influence (Appendix 2, Figure 6).

8 Overall assessment and Recommendations

8.1 Usefulness of partnerships to achieving project's objectives

The AQUADAPT project was largely a standalone project, but even so there were some valuable partnerships that contributed to helping achieve the project objectives.

First, was the on-going collaboration of the Project Leader with the Stockholm Environment Institute (SEI) Asia Office on several projects related to either climate change adaptation, or water resources management in mainland Southeast Asia. Apart from this general cross-sharing of technical knowledge and expertise, there was also a formal co-sponsorship of one SEI staff member as a post-doctoral fellow to the AQUADAPT project, for modelling work on the Nan Basin.

Second, was the expansion and deepening of collaboration with other IDRC funded projects in the region. Thus, the Project Leader of AQUADAPT was an advisor on experimental design and analysis to a climate risk communication project in Vietnam (Nos. 106707) led by NISFTA. He also led a co-authored review of theoretical and empirical literature on water governance under a changing climate for a book for a project (Nos. 107088) in Cambodia, led by the Cambodia Development Resource Institute (CDRI). He also helped review chapters for another book arising from a project (Nos. 106291) led by the Community Based Natural Resource Management Learning Institute (CBNRM LI), also in Cambodia. The AQUADAPT project also hosted a meeting where these three projects and others exchanged findings and lessons learned. Some of these initial, modest collaborations have substantial potential to be developed further in the future into collaboration on multi-country regional projects.

Third, was the close engagement with the Department of Fisheries, a key user of the research, at all levels: district, province, and national. One staff member joined the project as a post-doctoral fellow, carrying out research on the management of climate risks by hatcheries, and in a second study, reviewed the climate content and sensitivity of key Department policies. In 2016 the same individual also helped run the assessment dissemination workshops in 6 provinces around Thailand and contributed to research on communicating risks to fish farmers. Many other officials joined in local events, advisory group meetings, and the dialogue. Two students that graduated with support from the project went to work in the Department of Fisheries. Senior researchers were often peers of officials. These kinds of connections between civil servants and academics, while usually informal, made a significant contribution to the success of the project, and are likely to be important for longer-term collaboration and impact.

8.2 Contributions to development made by the project

The AQUADAPT project made several specific contributions to understanding the importance of improving risk management practices in inland aquaculture. Given the importance of extreme climate events and the aquaculture sector to livelihoods in Thailand, this represents a potentially significant contribution to development. The sustained engagement with planners and policy-makers in the Department of Fisheries also suggests that the project has a longer-term potential to inform or influence policies in the aquaculture sector, in ways that would make the sector more resilient or more easily adapt to a changing climate. At the same time, fish farmers, government officials, and firms urged the research team to continue to do more to bring this new knowledge to bear more widely on practices and policy; in particular, individuals who had not been engaged directly by the project.

8.3 Lessons learnt for improving future projects

The experiences in the AQUADAPT project raise a couple of lessons for multi-centre, inter-disciplinary, research projects on climate change adaptation that hope to create useable knowledge.

First, research users need to be involved in the conceptualization and elaboration of the project design; that is, from the start. Mechanisms are needed to build and maintain stakeholder collaboration; in this project, this was through an active Advisory Group. The Advisory Group also did useful boundary work in helping to identify and translate both research findings and policy needs, as well as manage expectations about the project.

Second, students doing a thesis are highly motivated to complete their research, and thus, with proper guidance, can contribute greatly to project outputs, as well as benefit from the training and experience opportunities provided by being part of a larger project. To maximize the mutual individual and project benefits, it is crucial that mentoring support be of high quality and that there is some scope for negotiating the focus and designs of individual contributing research studies, so they meet both academic and project requirements.

Third, mathematical model development invariably takes more time than anticipated, and this needs to be carefully factored into studies where such tools are expected to play an important role in analysis or assessment activities. One strategy is to do as much work as possible in parallel, and in a modular way, so that work in one sub-activity does not depend too much on having all the inputs of another sub-activity. Another strategy, developed in the AQUADAPT project, was to consider using simpler models and qualitative approaches when these were appropriate to the policy or practice questions being addressed.

Fourth, using appropriate communication formats, imagery, and language can greatly enhance the visibility and impact of a research project on multiple user groups. In preparing the final assessment report, on monitoring how the AQUADAPT Facebook page was used, for example, it became apparent that ‘infographics’ attract a lot of attention, and thus deserve more investment in preparation. The communication of uncertainties around climate change and strategic ways to adapt remains an important area for experimentation and learning.

8.4 The value and importance of this project

The AQUADAPT project is one of the few comprehensive analyses of the risks posed to the aquaculture sector by climate change for a country region that has also identified, and evaluated a range of short-term and longer-term adaptation options or pathways. Within Thailand, the research findings of the project provide a strong foundation for future research in this sector, as well as a starting point for adjusting or drafting new aquaculture-related policies. In particular, the findings affirm the importance of paying attention to climate risk management practices, even as other, longer-term and broader strategies for the sector need to be explored and evaluated.

The AQUADAPT project also made a significant contribution to building research capacity with respect to the analysis of climate and water impacts on the fisheries sector in Thailand. Many students were trained by the project; other stakeholders were sensitized to thinking about vulnerabilities, risks, and uncertainties associated with a changing climate. These enhanced capacities to produce and use scientific information about climate-related risks and climate change in the aquaculture sector, should be built upon in future work.

8.5 Recommendations

At the end of 2015, recommendations made were to: disseminate useable knowledge products to relevant stakeholders; assist completion and submission of working papers as journal articles; and develop a regional proposal. Following the approval of a no-cost extension of the project to end of 2016, these three recommendations were pursued. Dissemination was primarily done through workshops at the offices of the Department of Fisheries in six provinces outside Northern Thailand. Assistance to researchers and students resulted in 7 more manuscripts being submitted to peer review journals, and 5 new articles published in 2016. A regional proposal was developed with partners from 5 of the Mekong countries, and will be submitted to IDRC for their consideration.

At the end of 2016, the formal and final end of the project, we would like to offer 2 new recommendations on priority areas for use-inspired research. First, that more attention be directed towards the role of innovation and value-chain relationships in on-going adaptation to climate change. This will require much greater engagement with private sector beyond the farm than is typical in research projects. Second, that additional work be done on new and emerging water uses, like aquaculture, and how these interests can be incorporated into existing water governance institutions in the context of a changing climate. To date much of the research on water policy, allocation, and management has paid only limited attention to aquaculture as a stakeholder in water governance.

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10 Appendices

Appendix 1 Advisory Group members. Last column is number of meetings attended.

Name	Location (e.g. Province)	Att
Fish farmers		
Mr. Arkom Koonkong	Phayao	4
Mr. Thongchai Prayoonyad	Chiang Mai	4
Mr. Saming Oiwan	Phayao	3
Mr. Thongchai Kamnerdsap	Chiang Mai	3
Mr. Witsanu Jupanate	Uttaradit	3
Mr. Choksakul Mahakaroong	Chiang Mai	2
Mr. Charoen Yosmoon	Chiang Rai	2
Mr. Prapassorn Loto	Chiang Mai	1
DOF National Level		
Dr. Oopatham Pawaputanon Na Mahasarakham	Bangkok	6
Mr. Chirdsak Vongkamolchoon	Bangkok	3
Mr. Wongpathom Kamolrat	Bangkok	3
Ms. Juadee Pongmaneerat	Bangkok	2
Mr.Noppadol Poowapanich	Bangkok	1
Mr. Pongpat Boonchuwong	Bangkok	1
Mr. Boonsogn Sricharoaendham	Bangkok	1
Dr. Pholphisin Suvanchai	Bangkok	1
DOF Provincial Level		
Mr. Bunchong Chumnongsittatham	Chiang Mai	4
Mr. Thongyoo Outlert	Uttaradit	2
Mr. Witsanuporn Rattanatraiwong	Chiang Mai	2
Mr. Surapong Wiwatcharakoset	Chiang Rai	2
Mr. Prasan Pornsopin	Chiang Mai	1
Ms. Ausanee Eakpanithanpong	Lamphun	1
Ms. Supapun Booncharoen	Phayao	1
Mr.Wiwat Pralom	Phayao	1
DOF District Level		
Mr. Vilas Klomsoonthorn	Chiang Mai	6
Ms. Chayaporn Tiacharoenwong	Phayao	1
Office of Agricultural Economics		
Mr. Anusorn Pornchai	Chiang Mai	2
Ms. Sujaree Picha	Chiang Mai	1
Mr. Sakdham	Chiang Mai	1
Irrigation Department		
Mr. Phonchai Klinkhachon	Chiang Mai	4
Mr. Noppadol Kowsuwan	Chiang Mai	2
Ms. Watsamon Srikonk	Chiang Mai	1
Ms. Paimsiri Makssongkhla	Chiang Mai	1
Private Sector		
Mr. Pithak Thonkoksoong	Charoen Pokphand Foods	3
Mr. Tanomsak Sriboonruang	Charoen Pokphand Foods	3
Academic or Research Institute		
Professor Emeritus Dr. Anan Ganjanapan	Chiang Mai University	3
Professor Dr. Charit Tingsabadh	Chulalongkorn University	1
Dr. Chayanis Krittasudthacheewa	SEI	1
Local Government		

Name	Location (e.g. Province)	Att
Mr. Thavorn Chunjai	Chiang Mai	2
Mr. Ta Duangmano	Chiang Mai	1

Appendix 2 Weblinks for newspaper and television stories on AQUADAPT project

Source	Link
LC Cable TV News (in Thai)	https://www.youtube.com/watch?v=RGDiBUUqmdc
WE TV News (in Thai)	https://www.youtube.com/watch?v=7wnqgNjkRF0
NBT National TV News (in Thai)	https://www.youtube.com/watch?v=YKUmxi1dHac
North Public News (in Thai)	http://www.northpublicnews.com/?p=12008
Chiang Mai News Paper (in Thai)	http://www.chiangmainews.co.th/page/?P=438182
Naew Na Newspaper (in Thai)	http://www.naewna.com/local/190958
RYT9 News Feed (in Thai)	http://www.ryt9.com/s/nnd/2310817

Appendix 3 Division of labor among principle investigators in the project.

Individual	Responsibilities
Dr. Louis Lebel (USER, CMU)	Overall project A2.1 Climate change impacts A3.2 Adaptation policy All other activities
Dr. Chanagun Chitmanat (Fisheries, MJU)	A1.1 Climate risk management
Dr. Niwooti Whangchai (Fisheries, MJU)	A1.2 Climate sensitivities
Dr. Manoj Potapohn (Economics, CMU)	A2.2 Institutions & economics
Dr. Santita Ganjanapan (Geography, CMU)	A3.1 Livelihood resilience

Appendix 4 Broad timeline of project activities by six month periods. Design tasks includenegotiation with stakeholders. Implementation tasks include writing and the use of results. Writing tasks include analysis and writing.

<table>
<tr><th>Activity</th><th>0-6</th><th>7-12</th><th>13-18</th><th>19-24</th><th>25-30</th><th>31-36</th><th>37-42</th><th>43-48</th><th>49-54</th></tr>
<tr><td>A1.1 Impacts</td><td>Design</td><td colspan="5">Implementation</td><td>Writing</td><td colspan="2">Communications Study</td></tr>
<tr><td>A1.2 Sensitivities</td><td>Design</td><td colspan="5">Implementation</td><td>Writing</td><td colspan="2"></td></tr>
<tr><td>A2.1 Scenarios</td><td colspan="2"></td><td>Design</td><td colspan="3">Implementation</td><td>Writing</td><td colspan="2"></td></tr>
<tr><td>A2.2 Institutions</td><td>Design</td><td colspan="5">Implementation</td><td>Writing</td><td colspan="2"></td></tr>
<tr><td>A3.1 Livelihoods</td><td>Design</td><td colspan="5">Implementation</td><td>Writing</td><td colspan="2"></td></tr>
<tr><td>A3.2 Adaptation</td><td colspan="2"></td><td>Design</td><td colspan="3">Implementation</td><td>Writing</td><td colspan="2">Communications Study</td></tr>
<tr><td>A4.1 Dialogue meetings</td><td colspan="3"></td><td>Design</td><td colspan="3">Implementation</td><td colspan="2"></td></tr>
<tr><td>A4.2 Reviews</td><td colspan="3"></td><td>Design</td><td colspan="3">Implementation</td><td colspan="2">Writing support</td></tr>
<tr><td>A4.3 Assessment report</td><td colspan="4"></td><td colspan="2">Design</td><td>Writing</td><td colspan="2">Dissemination</td></tr>
<tr><td>A4.4 Local plan</td><td colspan="3"></td><td>Design</td><td colspan="3">Implementation</td><td colspan="2"></td></tr>
<tr><td>A5.1 Coordination</td><td colspan="7">Implementation</td><td colspan="2">Dissemination Workshops</td></tr>
<tr><td>A5.2 Meetings</td><td>Design</td><td colspan="6">Implementation</td><td colspan="2">Mekong Proposal</td></tr>
<tr><td>A5.3 Platforms</td><td>Design</td><td colspan="6">Implementation</td><td colspan="2">Dissemination</td></tr>
</table>