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ORIGINAL ARTICLE

Learning about climate-related risks: decisions of Northern Thailand fish farmers in a role-playing simulation game

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Abstract River-based cage aquaculture in Northern Thailand involves dealing with a number of climate- and weather-related risks. The purpose of this study was to improve understanding of how farmers make investment decisions in their fish farms when faced with risks from floods that are imperfectly known, and which may be changing. 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. In-depth interviews were conducted post-game to reflect on strategies used in the game as compared to in practice. 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 in games with large impacts when a flood occurred. Contrary to initial expectations, farmers were less likely to learn from experience—choose the optimal density and thus 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. Providing information about likelihoods prior to a game had no impact on performance or decisions. The methods and findings of this study underline the importance of understanding decision-making behaviour around risks for climate risk management. The novel combination of experimental, role-playing, and qualitative methods revealed limitations in common assumptions about the ease of learning about risks from previous experiences. The findings also suggest that decision-support systems for aquaculture need to take into account how recent experiences, understanding of information, and other factors influence risk perceptions and decisions.

Keywords Risk management · Decisions · Role-playing games · Aquaculture · Perception · Floods

Introduction

Farmers must often make decisions about their crops with only limited information about the probability and consequences of particular types of extreme weather events, seasonal patterns or change in climate (Wood et al. 2014; Crane et al. 2010). Under these conditions, farmers may learn about risks through experience or description; that is, information provided by others (Dutt and Gonzalez 2012a). Risk refers to uncertainty about the likelihood and consequences of an event with respect to something humans value (Aven and Renn 2009). Perceptions of climate-related risks are affected by personal experiences of weather and observations of impacts, and thus often differ regionally (Higginbotham et al. 2014; Manandhar et al. 2011).

In practice, learning from experience is a dynamic task as key decision conditions change as a result of both external factors and past decisions (Lejarraga et al. 2010). Learning from experience, individuals may be able to improve their decisions with time; for example, by getting a better understanding of likelihoods or outcomes (Erev et al. 2010). Many studies suggest that people are often more strongly influenced by what they learn from

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experience than from descriptions that require analysis and cognitive effort (Weber 2010; Dutt and Gonzalez 2012b). There are also important limitations from learning from experience; for instance, people tend to overestimate likelihoods of conspicuous and recent events, but also deny extremely negative outcomes (Ogurtsov et al. 2008). Uncertainty influences what can be known about risks. Farmers often are highly sensitive to ambiguity in risks, in addition to being generally risk-averse (Alpizar et al. 2011; Engle-Warnick et al. 2011).

Risk decisions are influenced by an individual's risk knowledge and the situation in which a decision is made (Fig. 1). Risk-taking may depend on whether or not a farmer is already in debt or they have just suffered a major loss, or have accumulated profits (Jakobsen 2013). For example, Italian apple growers who have experienced greater losses to weather events in past seasons, perceived risks for the current growing season to be higher (Menapace et al. 2013). Perceptions and subjective beliefs are also likely to influence evaluation of probabilities of adverse events, and more broadly, attitudes towards risk and thus decisions (Breakwell 2010). Gender and other traits are often associated with risk attitudes, perceptions, and decisions (Figner and Weber 2011). Women are typically found to be more concerned with risks, at least in part because they are also more vulnerable (Breakwell 2010). Emotions such as fear or dread have also been shown to play a significant role in decisions about risk (Sjöberg 2007; Slovic et al. 2004). Other contextual factors potentially important to the causal chain of risk decisions (shown in Fig. 1) include social relations, which amplify risks (Kasperson et al. 2003), and institutions, which influence risk information flows like early warning systems and markets (Chinh et al. 2014).

Only a few studies have looked closely at risk perceptions and decisions in aquaculture. Salmon farmers in Norway rated the most important sources of risk as future prices, diseases, and institutional changes (Bergfjord 2009). Similarly, mussel farmers in Denmark were most concerned about risks related to prices and government regulations (Ahsan and Roth 2010). Catfish farmers in Vietnam (Le and Cheong 2010) and the USA (Hanson et al. 2008) perceived price and production risks from diseases as more important than those related to weather. Tilapia farmers in the central region of Thailand rate risks of disease outbreaks and water pollution highest, and noted that these risks appeared to vary seasonally (Belton et al. 2009). A modelling study showed that profits from rearing shrimp in Mexico could be increased by adjusting stocking densities to match differences in risks related to uncertainty in temperatures in different seasons (Villanueva et al. 2013). Thus, while there is increasing understanding of which risks are perceived as important in aquaculture, less attention has been given to risk decisions.

The purpose of this study was to improve understanding of how fish farmers in Northern Thailand make cage stocking decisions when faced with risks that are imperfectly known, and which may be changing. River-based cage aquaculture involves dealing with a number of climate- and weather-related risks. Fish farmers, for example, make decisions about when to stock fish into cages and at what density. In making these decisions, they must take into consideration the likelihood of losses due to floods or low flows, as well as seasonal differences in temperature, all of which influence growth rates and likely prices at time of harvest. Information about future conditions is imperfect, and farmers vary in how much prior past experience which they can draw upon to evaluate likelihoods and consequences of adverse events like floods (Lebel et al. 2015c). Differences in location—both at regional and more local scales—influence exposure and contribute to differences in perceptions about the importance of various climate and non-climate-related risks (Lebel et al. 2015b). In this study, a role-playing simulation game was used to explore risk decisions.

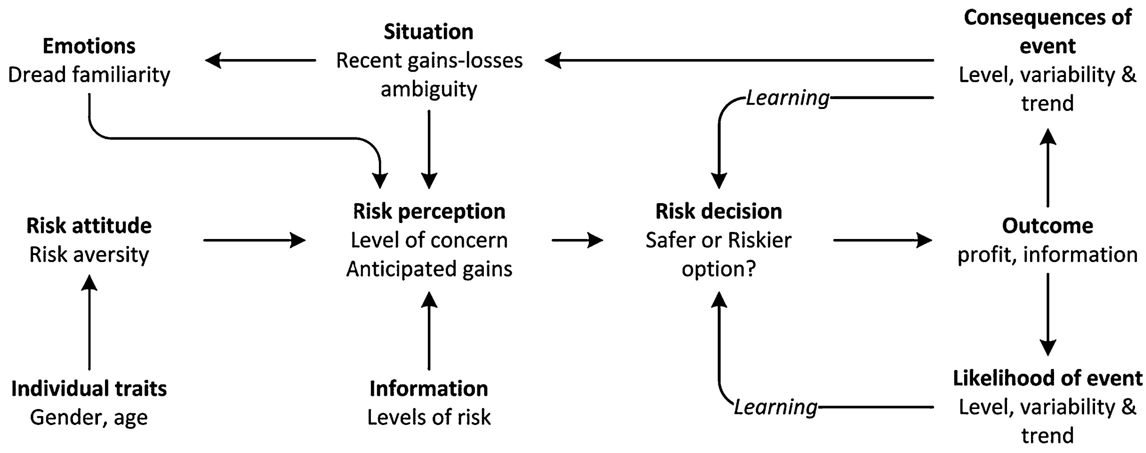


Fig. 1 Conceptual framework for learning about climate-related risks and making decisions

Role-playing games have been used to help stakeholders understand natural resource management challenges. Simulation modelling and role-playing games can support discussions and learning among stakeholders, for instance: about the collective impacts of harvesting in a subsistence fisheries in the Philippines (Cleland et al. 2012) and central Thailand (Worrapimphong et al. 2010); or, upland watershed land-use and management in Northern Thailand (Barnaud et al. 2007) and France (Souchère et al. 2010). In another application, role-playing games were used to help smallholder farmers in Morocco learn about options, and then with a supporting simulation, design a drip irrigation project (Dionnet et al. 2008). The condensing of time and space in simulation games is important as it allows exploration of alternative scenarios (Vieira Pak and Castillo Brieva 2010). Experiments with simulation games with water managers in the Netherlands, although not conclusive, suggested that such games can help communicate the uncertainties of climate change and the possibilities of adaptive water management (Van Pelt et al. 2015). Simpler games have been used to improve the understanding of risks by individuals (Ancker et al. 2011), and in the case of climate change, were shown to be more effective than just providing descriptive material (Dutt and Gonzalez 2012a). Role-playing games can also be used to understand how various contextual or situational factors influence decision behaviour (Vieira Pak and Castillo Brieva 2010).

The role-playing simulation game used in this study was created to capture some of the key features of the decision-making context in Northern Thailand aquaculture and explored with farmers in the field. So that key contextual factors could be systematically and experimentally investigated, the model and game were kept relatively simple. There was only one role: farming fish. The study focused on just one key decision—initial stocking density—which farmers widely reported was a factor which they manipulated to manage risks from floods, and is closely related to the level of investment in a particular crop. The specific research questions addressed in this study were as follows: (1) How do farmers evaluate levels of risk, including likelihoods and impacts, when these are fixed or varying, to make decisions? (2) How does information, investments in adaptation and insurance or compensation influence risk decisions? and (3) How do recent losses influence the next risk decision?

Methods

Study area

This study was carried out with fish farmers in Northern Thailand that reared Tilapia in open-top mesh cages suspended on floating platforms in major rivers (Lebel et al. 2013). In this culture system, fish fingerlings aged 2–3 months are released into river cages at densities of around 20–100 fish m^{-3} and reared for a further 3–5 months using commercial pellet feeds. Four growing regions are distinguished (Supplement 1). The climate in all regions is highly seasonal with most rain fall between May and October. The river flow regimes of these four regions differ: peak flows in the Upper Ping are strongly associated with tropical storms or monsoon anomalies, especially towards end of wet season (Lim et al. 2012). In the Upper Nan, in particular, the seasonality of peak flows is substantially modified by the operations of Sirikit Dam (Lebel et al. 2015c).

Flood risk pay-off matrix model

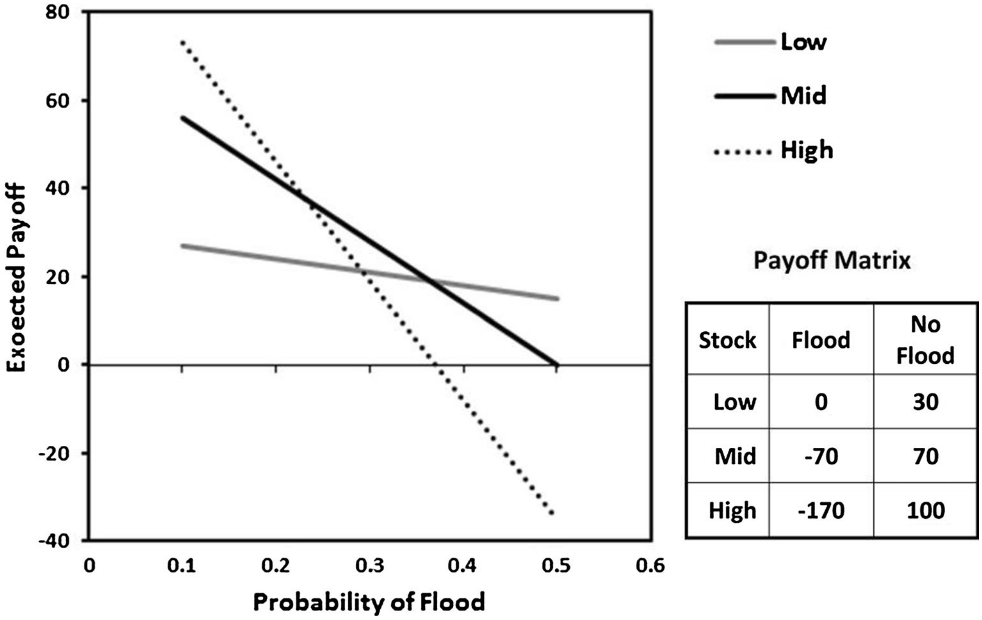
A simple model for flood-related losses from fish farms was constructed based on empirical survey findings (Supplement 2). Nevertheless, there were several important differences between the model and the decision context in real world (Table 1). The model, for instance, simplifies reality: treating stocking level or density as a proxy variable for level of investment, and thus the riskiness of a cropping decision. In addition, only flood risks were considered; whereas in reality, farmers in some locations must also consider the risks from extreme low flows in the dry season. We considered a more complicated, two-risk version of the model with an explicit calendar, but decided against it, because we did not yet have a good enough understanding of risk decision-making in simpler contexts, to be able to design more complex mixtures of slower-onset (low flow) and more uncertain (high flow) risks. Another difference was that, in the model, the impact of a flood on the value of a harvest was amplified (Table 1), to sharpen the contrast in pay-offs between less and more risky options farmers were asked to make in the game. The graph in Fig. 2 shows the expected pay-offs for each fixed level stocking strategy across a range of flood probabilities. From the graph, it is clear that with this pay-off structure, the optimal stocking density varies from high density at low probabilities of floods (0.1), through middle density at intermediate probabilities (0.3), to low density at high probabilities (0.5).

The simulation game

The flood risk model was turned into a simulation game as an Android application. In the role-playing game, farmers play a person like themselves, that is, a fish farmer. The game is played on a touch screen hand-held tablet. The main idea of the game is to maximize cumulative profit by choosing among three options: low, medium, or high

Table 1 Summary of key similarities and differences between real world and role-playing simulation game

Feature	Real world observed range (10th–90th percentile)	Simulation game value(s) or range	Key differences between game and reality
Likelihood of a flood or high flows with negative impacts	0.0–0.67	0.1–0.5	Similar likelihoods of flood
Likelihood of low flows with negative impacts	0.0–0.50	Not included	Did not consider slow flow risk in dry season
Time between stocking cage(s) decisions	1–9 months	3–10 s	Compresses time between decisions
Harvest value: input costs	1.04–1.39	2	Harvest, and thus profits, relatively high if no flood impact
Fraction of harvest value lost if flood impacted	0.01–0.30	0.15, 0.65, 1.0	Loss of harvest relatively high if floods for riskier decisions
Ratio of non-harvested loss to input costs if flood	0.01–0.4	1.7	Non-harvested loss relatively high if floods
Profit last crop	0–80,000 baht	−10 to 55 thousand baht	Similar range. Gains and losses in game in units of thousands of Baht
Sources of information about flood impacts, climate and likely river flows	Multiple, including other fish farmers	Limited to experience in game and from game screen	Limited sources of information in game



Stock	Flood	No Flood
Low	0	30
Mid	-70	70
High	-170	100

Fig. 2 Expected pay-offs from adopting single stocking strategy

stocking density. After selecting an option, the game responds with a harvest graphic, pay-off value and cumulative total (Supplement 3). In the event of a flood, a corresponding animation appeared.

A session with a farmer started with a very brief explanation on how to use the hand-held tablet device to make stocking decisions in each round. Farmers were told that that if there was no flood, then a higher stocking density means more profit, but if a flood occurs, then lower stocking density means less loss. Farmers were not told the level of risk of a flood or specific pay-offs, except in specific treatments (T12–T14, Supplements 4 and 5) used to test the effects of information. Each game lasted 20 rounds or crops, that is, 20 stocking decisions.

Farmers played seven games corresponding to different treatments. In pretests with students and farmers, we learnt that attention begins to fade after around ten games, whereas with seven, players maintained concentration. On average, each game took about 3.5 min to play. This compression of time between stocking decisions, it should be acknowledged, is another important way in which the decision context in the game differs from reality (Table 1).

The order in which games were played was randomized to minimize order effects. Each time they began a new game, farmers were told to imagine starting farming in a new location where risks and consequences may be different from earlier games. In nine cases, problems with tablets meant the farmer played only six recorded games rather than seven. All decisions made by farmers and the pay-offs were recorded automatically in a database in the tablet for later analysis. Across all crop decisions, farmers chose: low (27.1 %), mid (40.2 %), and high (37.7 %).

We considered rewarding players depending on how high they scored in the game, but because of the different treatments they played, this would have been unfair. Moreover, additional discussions with farm leaders suggested that they would take the task seriously even without such an incentive, and that they would prefer that all players received the same small allowance intended to cover local travel costs and their time, which is what we did.

In the end, a total of 224 fish farmers played the risk game: 54 % men and 46 % women. The distribution of player ages was as follows: <30 (7 %), 30–39 (17 %), 40–49 (29 %), 50–59 (29 %), and 60+ (18 %). Approximately equal numbers were drawn from four growing regions: Upper Ping, Lower Ping, Upper Nan, and Lower Nan. All fish farmers included had recently reared tilapia, but in seven cases were currently rearing only other species.

Experimental treatments

Each game was an experimental treatment which in various combinations would allow comparisons that could address the specific hypotheses posed. The set of all treatments used is summarized in Supplements 4 and 5. As a consequence of a programming error, treatment 8 was the same as 1 and treatment 9 the same as 5, so findings for these were pooled. A priori, planned contrasts used to test each hypothesis are given in the tables in the results section of the paper.

Measurement of risk decision variables

Six indicator variables were derived from the simulation game runs to describe different aspects of decisions made by players: first were two measures of overall performance: cumulative profit (CP) and random standardized profit (RSP, Table 2); second was a measure of the level of risky decisions taken: the mean density level (MDL); and third were three measures of risk learning: the proportion of crops for which the optimal level for that type of game was chosen (ODI), the improvement in profit in second-half compared to first-half of the game (RLR), and that improvement standardized with respect to actual number of flood events experienced (RSRLR). In this paper, learning about risks was thus inferred either from the ability to perform better in one game than another (ODI), or from improved performance within a game (RLR, RSRLR).

Qualitative information

Most participants were interviewed in-depth after they had completed the game. The short (15-min) discussions covered: strategies used in the game to increase profits; similarities and differences between game and reality; and what games they liked and how they felt about making risk decisions. Interviews were carried out in the Thai language, taped, transcribed, and coded using the NVIVO software. Translations of illustrative quotes to English were done only in the final stage of preparation of the manuscript.

Data analysis

Specific hypothesis about the effects of various game factors on decision measures was tested by using a priori

Table 2 Measurement of key risk decision indicator variables

Variable	Definition
Cumulative profit	Sum of pay-offs from 20 rounds of a game CP $= \sum_{i=1}^{20} P_i$
Random standardized profit	Difference between sum of pay-offs and expected score if chose randomly RSP $= \sum_{i=1}^{20}(P_i - P_{\text{rand}}) = \text{CP} - (\sum_{i=1}^{20} P_{\text{rand}})$
Mean density level	Mean density level chosen MDL $= (\sum_{i=1}^{20}(d_i))/20$ where $d_i = 1$ if low, 2 if mid and 3 if high
Optimum decision intensity	Proportion of times chose optimum density for that game. ODI $= (\sum_{i=1}^{20}(P_i = P_{\max}))/20$
Risk learning rate	Difference in pay-off in second 10 crops compared to first 10 crops. RLR $= (\sum_{i=11}^{20} P_i - \sum_{i=1}^{10} P_i)/10$
Random standardized risk learning rate	Risk learning rate standardized against expected if played randomly RSRLR $= (\sum_{i=11}^{20} (P_i - P_{\text{rand}}) - \sum_{i=1}^{10} (P_i - P_{\text{rand}}))/10$ where $P_{\text{rand}}$is based on number of flood events in that time period

contrasts of treatment means within an analysis of variance (ANOVA) framework. Making specific comparisons among means in line with the logical structure of the hypothesis was preferred over indiscriminate comparisons of all means, because it reflects that logic and is statistically much more powerful. In preliminary analysis, game number was included as a predictor to adjust for possible learning across games, but as it was not significant, this was dropped. In the analysis, games were treated as independent and the blocking with respect to farmers ignored. The primary purpose of using incomplete, partial blocks was to ensure reasonable interspersion of treatments among farmers.

To explore in more detail decision-making from crop to crop within a game, associations between recent flood events and other variables with decisions to stock low, medium, or high were analysed. Nominal or polytomous regression was chosen as an appropriate tool for analysing such associations, because the outcome variable of interest, stocking density, was categorical and had three levels.

Results

Likelihood of event

The first set of hypotheses explored how the likelihood of flood events influences risk decisions, specifically:

H1a The greater the likelihood of a flood, the lower the profit.

H1b The greater the likelihood of a flood, the lower the density chosen.

H1c Farmers find it harder to learn the likelihood of rare than common risks.

The first two hypotheses follow directly from game goal of maximizing profits and general information provided on the structure of pay-offs at the start. The third hypothesis is based on the logic that when events happen, more often it is easier to get information about likelihoods and outcomes than if the event rarely happens.

When floods were more frequent, farmers' raw profit (CP) declined (Table 3), as would be expected from pay-offs in treatments. After adjustment for expected pay-offs however, there was no significant difference (RSP); implying that increased flood risk and thus losses, did not affect decision-making performance once taken into account differences in expected pay-offs. Hypothesis H1a was thus only supported in the obvious case.

Farmers on average reduced their stocking densities (MDL) when faced with higher flood risks as predicted under hypothesis H1b, but the difference was primarily between the first two lower levels of risk, and the latter three treatments. There was a significant trend towards fewer optimal decisions with higher level of flood risks (ODI, Table 3). Again, contrary to initial hypothesis (H1c), farmers appeared to learn better when flood risks were low than when they were high (RLR); but after adjustment for actual flood events experienced in each half of the game (RSRLR), the difference was no longer significant.

The qualitative interviews suggest that the key features of the game were understood and reflected important dimensions of decision-making about risks. The difficulty of frequent floods was recognized: "when it floods frequently it is awful. I shifted to the middle option. Scared of high risks. Choose high scared will lose a lot; choose low worried make too little." Post-game, many farmers identified low probability of flood games as the most enjoyable, as they could make a lot of profit: "I liked the game where it only flooded two times; it was easy to adapt to the conditions and invest a lot in each round." In recalling the last game played, however, farmers tended to overestimate the number of floods when rare ($P = 0.1$) and underestimate them otherwise (Supplement 6).

With a few exceptions, most farmers found the game to reflect key elements in their real-life decisions: "It is like the real-life situation. You can make a profit or a loss. It depends on natural disasters. Rearing fish is risky: There

Table 3 Effects of likelihood of flood event

Treatment	Flood risk	CP	RSP	MDL	ODI	RLR	RSRLR
T1	0.1	1090	50.2	2.11	0.36	56.7	3.30
T2	0.2	806	59.7	2.10	0.35	45.8	1.63
T3	0.3	452	−2.2	1.99	0.38	16.9	−0.70
T4	0.4	131	−28.5	2.04	0.27	10.7	−1.33
T5	0.5	−104	29	1.99	0.30	−8.2	−1.56
Test	Conclusion linear	+H1a .01	−H1a ns	+H1b .01	#H1c .01	#H1c .001	−H1c ns

Treatment means for six decision and outcome measures and result of hypothesis tests using a priori planned contrasts

Abbreviations are as in Table 2

+ Hypothesis supported; − hypothesis rejected; # support for opposite relation are risks every crop if we rear fish.” There is a risk of losses due to water conditions. If invest too little, take too small a risk, then gains on investment are not worth the time spent. “It is about investing, investing in fish farming. If you stock a lot the risk is high, if encounter bad conditions you lose a lot; if you stock a little and encounter bad conditions you lose a little.” When water and climate conditions look good, farmers invest fully, but when conditions are poor, then they are more cautious: “It is very similar to rearing fish in reality, because in reality when rear fish it is like this. When it rains a lot, if it is me I will not increase investments, not stock high. I won’t stock much, will reduce densities.” Another explained how in the dry season they stocked 20 cages, whereas in the wet season only ten, because there were fewer safe sites and exposure to high flows results in injuries to fish. The results of the interviews suggest that the pay-off matrix was, at least in general terms, understood and similar to real world with respect to stocking decisions and flood risks.

Magnitude of consequences

The second set of hypotheses explored how the magnitude of flood impacts influences risk decisions, specifically:

H2a The larger the magnitude of flood impacts, the lower the profit.
H2b The larger the magnitude of flood impacts, the lower the density chosen.
H2c Farmers find it harder to learn about consequences from small than large magnitude events.

When floods had larger impacts, farmers’ raw profit (CP) declined (Table 4), as would be expected from pay-offs in treatments. After adjustment for expected pay-offs, a similar trend was present; however, there were only some significant differences (RSP) when floods were unlikely. Hypothesis H2a was partly supported.

Farmers did not reduce their stocking densities (MDL) when faced with higher impacts from floods as predicted under hypothesis H2b (Table 4). Again, as above, and contrary to initial hypothesis (H2c), farmers appeared to learn better when flood impacts were low than when they were high (RLR). Similarly, they were more likely to select optimal densities when impacts were low (ODI); although means were not as easy to separate as in the case of the RLR measure.

In interviews, fish farmers explained their responses to large and normal flood impacts. In case of very large losses, one explained: “if we lose a lot like this then invest a little then we change strategy and carefully build back up from the losses. With big losses, start low, have a bit of savings then shift to middle.” Some farmers said they liked the latter games more than the earlier ones, because by then they felt they could understand how to play and make better decisions based on understanding of the magnitude of flood impacts: “The last game, I made a profit. At the start did not know what effect floods would have. After playing a while I felt I knew how to play.”

Variable likelihood

The third set of hypotheses explored how changes in the likelihood of flood events influence risk decisions, specifically:

H3a When likelihood of a flood changes profits are lower.
H3b When likelihood of a flood changes more likely to choose lower densities.
H3c Farmers find it harder to learn the likelihood of a risk when they are changing.

Table 4 Effects of magnitude of flood impact

Treatment	Likelihood of flood	Magnitude of impact	CP	RSP	MDL	ODI	RLR	RSRLR
T7	0.3	0.5	715a	20.8	2.09	.348a	35.2a	0.37
T3	0.3	1	452b	−2.2	1.99	.381a	16.9b	−0.70
T6	0.3	2.1	−108c	−28.3	2.10	.240b	−13.8c	−2.84
Hypothesis tests			+H2a	−H2a	−H2b	#H2c	#H2c	−H2c
T1	0.1	1	1090a	50.3a	2.12	.357a	56.7a	3.30a
T19	0.1	2.4	820b	5.9ab	2.05	.329a	37.9b	−3.27b
T20	0.1	8	−129c	−48.7b	2.12	.217b	−32.4c	−12.8c
Hypothesis tests			+H2a	+H2a	−H2b	#H2c	#H2c	#H2C

Treatment means for six decision and outcome measures and result of hypothesis tests using a priori planned contrasts

Magnitude of impact is ratio of pay-off loss in event of flood for the treatment related to standard pay-off (see: Supplement 5)

Abbreviations are as in Table 2

\+ Hypothesis supported; − hypothesis rejected; # support for opposite relation

The idea behind these three hypothesis is that uncertainty makes evaluating risks more difficult (H3c), thus making it harder to succeed (H3a), and in response, farmers become more cautious (H3b). To explore these three hypotheses, we classified games into three types, based on a difference of 2 or more floods in first versus second ten crops: increasing, unchanged, and decreasing. There was no support for any of the three hypotheses, and in some cases, support for opposite or other patterns (Supplement 7). Farmers chose riskier options (MDL) when likelihoods varied in either direction. When likelihoods were changing, raw profits (CP) were higher; but analysis of standardized scores (RSP) suggests that this just reflected differences in pay-offs. The pattern for RLR was what would be expected given classification of games. Even after standardization for expected pay-offs, however, rates of learning (RSRLR) were highest in games with decreasing risks and lowest with increasing risks.

The key point is that in the game, as in real life, the risks are imperfectly known: “It is like rearing fish for real. When we rear fish we don’t know future risks or what will happen in the future. This year: will there be a shortage of water? Will it flood? Will the river be dry? When we invest we know there will be risks, but not how big they will be.” Fish farmers understood the game as being about making decisions in situations where you do not know in advance what will happen: “a situation in which cannot predict when fish will die, when it will flood.”

Variable consequences

The fourth, and final set of hypotheses under research question 1, explored how variability in the magnitude of flood impacts influences risk decisions, specifically:

H4a The more variable the magnitude of flood impacts, the lower the profit.
H4b The more variable the magnitude of flood impacts, the lower the density chosen.
H4c Farmers find it harder to learn when consequences are more variable.

All planned contrasts were not significant (T10, T11 in Supplement 5), implying that there was no support for the three hypotheses. As there were no significant differences, a detailed table of averages for each of the measures is not shown.

Information

The fifth set of hypotheses, under research question 2, explored how prior information on the likelihood of floods influences risk decisions, specifically:

H5a Knowing likelihood of floods beforehand increases the profit.
H5b Knowing likelihood of floods is high beforehand lowers the density chosen, and if low then raises the density chosen.
H5c Farmers find it easier to learn when likelihoods of floods are known beforehand than when they are not known.

The third hypothesis reflects the idea that when the likelihoods of a flood are already known, a farmer needs only to estimate the impact, which is easier then when must estimate both. With better understanding, one would expect better choices (H5b) and thus, overall performance (H5a). All planned contrasts in this set of hypotheses were not significant, so no support for any of these hypotheses. Again, as there were no significant differences, a table of summary means for each treatment is not shown.

Although on average, farmers did not do better with information, when asked what game they liked to play most, some farmers identified these treatments. Several said they liked it when they were given information about the number of floods to expect, as this allowed them to make more strategic decisions: “I liked the game that told us it would flood once in 10 times. I could decide to invest a lot and only lose once in ten times.” At the same time, it is clear not all farmers were able to make use of the information provided, in part, because of a tendency to play quickly: The game “is good, but I cannot think fast enough. I don’t know what to do. I was muddled.” Similarly, other farmers argued that if they concentrated as much as they do in the real world, then they could figure out what to do each round, but they did not have the time to do so.

Adaptation

The sixth set of hypotheses, under research question 2, explored how investment in adaptation influences risk decisions, specifically:

H6a If there is investment in adaptation or insurance, then farmers are more likely to gain higher profit when floods are frequent than when they are rare.
H6b If there is investment in adaptation or insurance, then farmers are more likely to choose a higher density.
H6c Farmers find it easier to learn when have invested in adaptation.

The first hypothesis follows directly from the reduced impact of floods. The second is more speculative but is based on the idea that these investments reduce perceived risks. The last hypothesis is based on the argument that farmers would learn that having invested in adaptation, losses when it floods will be reduced and thus pay-offs less variable.

The first hypothesis, H6a, was supported for raw pay-offs (CP), but not standardized pay-offs (RSP, Table 5). There was no evidence that adaptation investments led to higher risk-taking (MDL, H6b, Table 5). Farmers appear to learn more easily when investing in adaptation, and there is reduced variability in pay-offs only when flood risks are high (RLR, ODI, H6c); but after standardization (RSRLR), the effect disappears. One difference farmers noted was that in the game there was no warning or opportunity to prepare for individual flood events, as there is in real life; this particular set of treatments only helped understand the effects of that option when it was used.

Investing in a fixed-compensation insurance—like index-based schemes rather than one that depends on actual losses—led to better decisions (ODI) than one which reduces flood impacts by 50 %, for which expected pay-offs (Supplement 2) were identical (ODI: T16 versus T18, Table 5). Post-game some farmers noted they liked the games with "insurance as even though there was a risk, when it flooded there was some help."

Fish farmers, however, also complained that the game provided no information or opportunities for making adjustments to decisions or reducing risks in other ways during a crop. They argued: "in the real world can get news and information," and that they can "look at weather conditions, note that this year is dry, stock less and check information about water levels on the web".

One final result at the level of individual fish farmer should be underlined. The average random standardized profit (RSP) of 40 % of individual fish farmers who each played six or seven games each, was less than zero. This implies that a substantial fraction of fish farmers did not do better, overall, than would expect from random choices.

Learning strategies within a game

We next looked more closely at decisions within a game, and what learning strategies farmers might be using by analysing sequences of decisions within a game, in particular, following floods. To investigate the effects of a flood event on subsequent stocking density decisions, separate nominal (or polytomous) regression models were estimated for situations in which the last stocking decision was low, medium, or high (Supplement 8). In each model, the outcome variable was 'stocking density' chosen this crop (which also has three possible values). The reference category was set to no change in density for each model. Overall, the tendency was to repeat the last decision and increasingly so as density increased: low (46 %), mid (49 %), and high (54 %). In each model, the candidate predictors were as follows: flood last crop, gender, age group, late round (crop number >15), and region. The findings with respect to floods will be discussed first and in most detail.

The effects of a flood in previous crop on the next stocking decision depended on the density, and thus pay-off outcome from the previous crop (Fig. 3). If the last stocking density was high and a flood occurred, farmers were more likely to reduce stocking densities in the next round (rightmost panel, Fig. 3). If density chosen in the last crop was low, however, farmers were more likely to make the riskiest choice if they had just experienced a flood (leftmost panel). At low densities, it should be noted, flood effects were modest. If the density chosen for the last crop was intermediate, farmers responded to a flood by changing density: taking both lower and higher densities more often than continuing to choose the mid-option, though generally reduce more than increase (central panel).

The key findings for other predictors apart from floods in Supplement 8 will now be briefly considered. It should

Table 5 Effects of investments in adaptation and insurance

Contrast	Prob. flood	CP	RSP	MDL	ODI	RLR	RSRLR
T1 versus T15	0.1	+***	Ns	Ns	ns	+**	ns
T3 versus T16	0.3	ns	Ns	Ns	+**	Ns	ns
T5 versus T17	0.5	−***	Ns	Ns	−**	−***	ns
Hypothesis tests		+H6a	−H6a	−H6b	+H6c if P hi	+H6c if p hi	
T16 versus T18	0.3	ns	Ns	Ns	−**	Ns	ns
T3 versus T18	0.3	ns	ns	Ns	ns	ns	ns
Hypothesis tests							

Treatment means for six decision and outcome measures and result of hypothesis tests using a priori planned contrasts

Abbreviations are as in Table 2

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

+ Hypothesis supported; − hypothesis rejected; # support for opposite relation

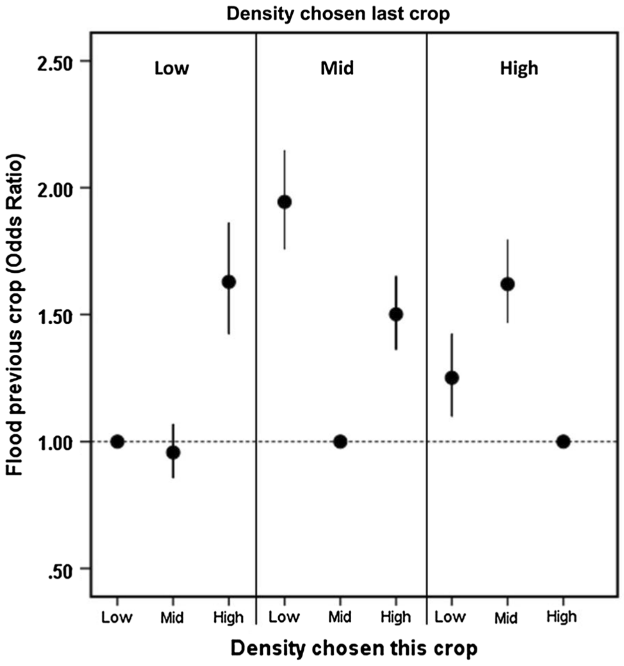


Fig. 3 Effects of a flood in previous crop on subsequent stocking decisions. Odds ratios and 95 % confidence intervals from nominal regression model with multiple predictors

be underlined that these associations are after mutual adjustments for other factors in the model. Women responded to floods more cautiously than men. Women were more likely than men to reduce densities by one step (H → M) following a flood; they were also less likely to increase densities from a low level following a flood (L → M or L → H, odds ratios < 1.0). Young and old farmers tended to maintain the same density more than middle-aged farmers, and being less likely to make a big reduction (H → L) or increase (L → H). In later rounds, farmers were less likely to move to intermediate densities following a flood (H → M or L → M), suggesting that by then they were clear on the appropriate level of risk to take. Regional differences in response to floods were strong and consistent. Farmers from the Upper Nan region were more likely to change density after a flood event than those in the other three regions (odds ratios < 1.0).

Fish farmers understood that "each time you stock fish it is like an experiment. You cannot predict what will happen. It is practice in analysing investments: which option would be good to choose next?" They also acknowledged that different places have different risks, so when starting in a new place they initially began with small investments, that is, less risky decisions. The game "makes us think when we invest: In this new situation should we invest a little or a lot? Do we dare to take a risk? In a new place who would take the high risk? In a new place you need to take less risk."

Discussion

In this game, selecting low stocking was a relatively certain bet compared to high stocking where differences in pay-offs if it flooded or not were large. As would be expected, more frequent or larger impact floods reduced cumulative profits (Tables 3, 4). Farmers slightly reduced their stocking densities when playing in games with high likelihood of floods, but did not do so as expected when impacts were larger. Farmers found it harder to choose the optimal density when floods were common or had large impacts. Most laboratory studies on learning from experience suggest participants underweight rare events (Erev et al. 2010). In the context of climate-related risks and a role-playing game situation, the findings suggest that there may also be an emotional component, rather than purely an analytical response to losses (Slovic et al. 2004). Players, for instance, may sometimes seek to recover as quickly as possible from a recent major loss and take more risks, or, alternatively, feel overwhelmed by a large impact event or repeated losses, thereby losing sense of control over risks, and as a result, become overly risk-averse.

Apart from evidence about effects of likelihood and consequence, we also explored several other situational factors which might influence risk decisions following the conceptual framework presented earlier (Fig. 1). Uncertainty in risks as variation in likelihoods produced some unexpected effects. Raw profits were higher in games with change than those with unchanging risks (Supplement 7). Again, contrary to initial hypothesis, farmers appeared to learn about risks better when they were decreasing, and do worst when they were increasing. This latter finding has particular significance when considering potential adverse impacts of climate change, for which many key risks are increasing, but perceptions of policy or planners lack urgency (Runhaar et al. 2012; Moser 2010). In this study, however, uncertainty in risks—as greater variation in outcomes—did not significantly reduce profits, result in lower densities being chosen or reduce rates at which learning takes place, as might be expected. One explanation is that learning from experience in the role-playing game was already challenging under conditions of fixed risks.

Farmers concentrated hard when they played the game, but it was not easy to play. Many did not do much better than would expect with random choices. This is a telling finding, because the game was designed to reflect the series of decisions a fish farmer must make based on accumulation of experience. Moreover, farmers validated that the game matched reality in key features around investment decisions. Against a background of variation in pay-offs, the likelihood and consequences of adverse events like floods are hard to estimate with much precision, and thus are not much use as a guide for subsequent decisions. The technology interface of the game—hand-held tablets—was itself not an obvious barrier to engagement in this population as most fish farmers already had their own mobile phones, and the game interface was simple. Rather, the challenge seemed to be more one of detail in recalling past impacts and capacities to estimate pay-offs and risks.

Providing information about likelihoods prior to a game had no impact on performance or decisions. One explanation for these findings is that many farmers did not understand or translate a statement like chance of “1 in 10 times” or “1 in 2 times” into meaningful information to use in their choices. At the same time, some farmers did perform well in these types of games and, in interviews, stated that knowing likelihoods was very helpful in making decisions in those games. Many studies have shown that people have difficulty in understanding and using ratios, proportions and probabilities (Reyna and Brainerd 2008). Another possible explanation for lack of hypothesized effect of information might be probability matching, where decision-makers focus on matching choice probabilities with their selections rather than making selections based on the most likely outcome—a strategy that would maximize their cumulative pay-offs (James and Koehler 2011).

In games with compulsory insurance, farmers did better when floods were more frequent as would expect based on pay-offs, but not better than that. There was no evidence that adaptation investments led to higher risk-taking (Table 5). Farmers play significantly improved within a game when they had invested in adaptation, but only when flood risks were high. This may relate to feelings of confidence when losses are reduced (Weber 2010). Investing in a fixed amount compensation insurance—like an index-based scheme rather than one that depends on actual losses—led to better decisions than one which reduces flood impacts by 50 %, for which expected pay-offs were identical. This suggests that farmers appreciate reduced ambiguity with respect to outcomes. A study of coffee farmers in Costa Rica (Alpizar et al. 2011) and another of mixed field crop farmers in Peru (Engle-Warnick et al. 2011), both found that ambiguity made it even less likely for farmers to change practices, for instance, invest in new adaptation options.

Place-related factors—like region of origin—were significant for some of the associations with learning about risks. Regional differences in immediate responses to floods (Supplement 8), for example, might be explained by differences in experiences, as in the case of the Upper Nan River flow modification; whereby dam operations have large consequences for seasonal risks of extreme flows (Lebel et al. 2015c). We suggest that farmers entered the role-playing game with a set of expectations about likelihoods and consequences based on their own personal experiences, and then updated these or their mental model when playing the game. Different groups of expert stakeholders appear to have distinct mental models for adaptation to climate change (Otto-Banaszak et al. 2011). Further in-depth investigations of farmers’ perceptions and attitudes towards climate-related risks are needed, to more completely understand how beliefs and concepts influence risk management decisions and support for various adaptation actions.

The above findings help, in several ways, improve understanding of how fish farmers make stocking decisions in the face of risks that are imperfectly known, and may be changing (Fig. 1). The findings caution against placing unrealistically, optimistic assumptions about how fast individuals can learn about risks from monitoring and experience. Learning from experience is not easy as there is often a tendency to repeat last decisions despite poor outcomes or a problem of inertia (Dutt and Gonzalez 2012b). Farmers who switch densities frequently, on the other hand, especially after negative events, may be searching for information that could inform alternative strategies (Weber and Johnson 2009). Switching was observed in this study: farmers were more likely to reduce stocking densities in the next round if they had just chosen high and it flooded, and to do the reverse if they had chosen low and it flooded (Fig. 3). At the same time, the findings of this study also caution against assuming information about likelihoods of extreme events has high values: such information may be difficult to communicate in a way that is easily understood and related to decisions which must be taken.

The findings suggest that decision-support systems (DSSs) for aquaculture need to take into account, how recent experiences and other factors influence risk perceptions and decisions. An extensive review of experiences with DSS for farmers in Australia, however, noted that DSS should not aim to optimize recommendations, but rather help farmers explore options and understand their own intuitions about problems and solutions (Hochman and Carberry 2011). An example of such an approach is the prototype decision-support system developed for catfish farmers in Vietnam (Le et al. 2012). To develop a useful system for inland tilapia aquaculture, it would be important to also consider key non-climate-related risks, such as costs of fish fry and feed, and risks of disease (Lebel et al. 2015a; Belton et al. 2009).

This study also had some important limitations, mostly related to the simplifications of reality made in the game, which implies a need to treat some of the findings with care and suggest potential areas for further research. First, the sequence of stocking decisions made and outcomes experienced in the simulation game were seconds apart, whereas those in the real world are separated by several months. Second, as no cash transactions were involved, it is likely that the emotional elements of the decision—including things like fear of losing investment—dread of extreme floods and their impacts on farmer's households, would not be fully replicated in the role-playing game. Third, the games were played by individuals, whereas in the real world, farmers talk to each other and learn about risk levels from others, and not just their own experiences. Finally, in the game farmers had to make only one decision—how much to stock—whereas decision-making in the real world involves considering multiple risks and trade-offs or interactions among them.

The latter limitations are perhaps the easiest to address. Future versions of the role-playing games could consider multiple risks by explicitly considering a cropping calendar with risks of floods, low flows, and disease that vary monthly and, in the case of low flows, are relatively more knowable in advance. Opportunity costs of delaying stocking, and income losses from harvesting early or late, could also be incorporated. Players might be given the option to invest in adaptation or risk reduction measures before stocking each crop. With more complex criteria to consider, it will be important to put additional effort into the communication of information about game conditions—for example, using visualizations and interactive sliders to specify choices—so that this information is well understood by fish farmers playing the game. Experimental treatments could compare the effects of providing and not providing different sorts of risk-related information. An experiment might also be set up to compare performance when playing in groups against playing alone, to help understand effects of communication and interaction on learning about risks. This would require slowing down the game so people can discuss between decisions if they wish to. The problem of virtual compression of time in a simulation game is difficult to address methodologically, but potentially important as the time between decisions is likely to influence recall from memory and opportunities for reflection on experiences. Including delays between decisions so farmers feel they have time to review information and reflect may be a practical way to reduce the artificiality arising from compressed time. One way this might be done that would also help with understanding of information, would be to use more animations or visualizations to show magnitudes of gains and losses rather than just reporting numbers and simple profit or loss graphic as was done in the current version of the game. The findings about decision behaviour from these more complex and realistic role-playing games, could then be explored using decision models. Relatively simple and stylized models based on instance-based learning theory, for instance, are known to perform reasonably well on a wide range of tasks, including probability learning and making repeated choices (Lejarraga et al. 2010; Erev et al. 2010).

Conclusion

Taken together, the methods and findings of this study have significant implications for future work on climate risk management, especially in aquaculture; but maybe also beneficial in some other agricultural decision-making settings. The combination of experimental, role-playing and qualitative methods was novel and proved helpful to obtaining a deeper understanding of decision behaviour in a specific context. The experimental tests imply that some common or otherwise reasonable assumptions about how farmers evaluate risks based on experience, need to be revisited. In particular, it is difficult to learn with much precision from a relatively short series of decisions about the likelihoods or consequences of an adverse climate event, especially if those risks are increasing. This novel finding is likely to be robust as it was made in a relatively simple decision context; with multiple risks and more contextual factors to consider, learning about levels of risks from individual experience is likely to be even more difficult. In the real world, however, information about risks and impacts are shared and there is more time to reflect upon experiences. The importance of learning in groups and other sources, as well as having enough time for reflection, deserves further study. Past experiences in different locations and from recent flood events were shown to influence risk-taking behaviour, implying the need to adjust risk information by site and recent history of impact when providing decision support. An outstanding challenge is to effectively communicate risk-related information in a way that is widely understood, and can be acted upon. Insights from experiments with role-playing games, combined with other work on risk perceptions and experience of impacts in the field, should be useful for the design of future risk communication activities and decision support to improve climate risk management in aquaculture; and, ultimately, developing realistic strategies for enabling climate change adaptation.

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