Harnessing the opportunities and overcoming constraints to widespread adoption of cage aquaculture in Ghana

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Abstract

Understanding cage aquaculture adoption decisions and factors affecting adoption is necessary to ensure that fish production from cage aquaculture in Ghana is both significant and sustainable. The goal of this study was to provide a framework for understanding cage aquaculture adoption decisions and to identify factors affecting adoption, to inform decision makers as they formulate policies aimed at promoting cage aquaculture adoption in Ghana. I surveyed 122 respondents comprising current cage fish farmers, farmers who have abandoned cage aquaculture, and potential adopters of cage aquaculture such as, fish traders, fishermen and land-based fish farmers. Respondents answered questions related to knowledge, interest, constraints in cage aquaculture, and demographics. I used non-metric multidimensional scaling and discriminant function analysis to identify unique groups within the respondents, classify respondents according to their position in the innovation-decision continuum, and identify factors affecting cage aquaculture adoption. Based on their differences in knowledge and interests, I placed respondents into one of three stages of the cage aquaculture innovation-decision process model I developed: (1) Unawareness, (2) Knowledge, Persuasion, and Decision (KPD), and (3) Implementation (Confirmation and Abandonment). Respondents in the KPD and Implementation stages had knowledge, were more interested in cage aquaculture, and were aware of constraints in cage aquaculture, whereas respondents in the Unawareness stage lacked knowledge and interest in cage aquaculture, and did not clearly understand the constraints. Respondents who were males, belonged to the tribes Ewe and Akan, and who had fishing experience tended to be more interested in cage aquaculture. The lack of capital, high input costs, inability to adequately market fish, theft, lack of information sources, conflict over water use, and cage destruction by storms, were identified as the main constraints to cage aquaculture adoption in Ghana. The results of the study suggest that programs aimed at encouraging new entrants into cage aquaculture should focus on demographic characteristics such as gender, and tribe. Some recommendation to address the major constraints in cage aquaculture include: the Fisheries Directorate should (1) develop an efficient extension program that farmers can access regularly, especially, for farmers with no other information sources, (2) provide feed subsidy to enable farmers produce fish at competitive prices, (3) facilitate the formation of fish farmers' cooperative groups that would purchase large quantities of feed, (4) encourage local production of high quality fish feed, and (5) develop credit facilities that can be accessed by individuals interested in cage aquaculture to assist potential farmers who would, otherwise, not be able to adopt cage aquaculture . In addition, fish farmers should (6) be proactive in marketing their fish by identifying potential niche markets prior to production, and (7) join cooperative groups to ease the burden of accessing loans to increase production.

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Attribution

Emmanuel Frimpong co-authored both Chapters 1 and 2. The manuscripts for Chapters 1 and 2 are in preparation to be submitted to Technological Forecasting and Social Change, and Aquaculture Research respectively. Emmanuel's contributions to the papers include assistance in developing the conceptual framework, evaluation of the statistical analysis, and editing the manuscripts for publication.

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General Introduction

Sub-Saharan Africa has abundant water resources, but these have not been tapped to increase aquaculture production significantly in the region (Machena and Moehl 2001). Water resources such as the Volta Lake and Lake Victoria are among the world's largest freshwater lakes but are also very much underutilized. As a result, the Word Bank and its partners have sharpened focus on commercial aquaculture development in the region (World Bank 2007). Cage aquaculture has been widely cited as an astute way of exploiting inland water resources to achieve development (Petr 1994; Blow and Leonard 2007).

Since its inception, aquaculture in Ghana has been predominantly land-based. The Fisheries Directorate estimated in 2006 that the aquaculture industry had more than 2,800 fish farmers in the Ashanti, Brong Ahafo, Central and Western Regions of Ghana operating about 4,500 ponds (Lionel Awity, Fisheries Directorate, unpublished data). Despite these numbers the contribution of aquaculture to local fish production is still insignificant. Available data suggests that the output from aquaculture in 2006 was estimated to be less than 1% of the total fish produced locally for human consumption (Abban *et al*. 2006). Increasing aquaculture production will be a major step towards food security in Ghana and a further step in achieving 20% of the fish produced locally for human consumption, similar to the global mean, which the government seeks (Abban *et al*. 2006). In order to achieve this goal, cage aquaculture must be given serious consideration since most land-based fish farmers in Ghana practice extensive system (fish are not fed high quality diet and fish production is low), and the land is finite.

Cage aquaculture although relatively new in Africa, dates back to the late 1800s in Southeast Asia (Gopakumar 2009). The technology involves keeping fish in netted enclosures usually floated in rafts, and secured to the water bottom by an anchor or connected to the shore by wooden walkways (Beveridge 1984). Cage aquaculture was introduced on a trial basis in the 1980s in sub-Saharan Africa when momentum for aquaculture development grew and the need for aquaculture research received government recognition as part of national development plans (Masser 1988). Ghana offers considerable opportunities for commercial-scale development of freshwater cage aquaculture, especially on the Volta Lake. Apart from the many advantages it shares with pond aquaculture, cage aquaculture has an added advantage of exploiting existing water bodies, especially in areas where land and ground water are scarce, as well as enabling stocking of higher densities of fish. When well developed, cage aquaculture also has the potential to produce seed for stocking inland waters, enhancing those fisheries also (Beveridge and Stewart 1997).

Currently, cage aquaculture farmers in Ghana raise the traditional Nile tilapia *Oreochromis niloticus* since people are familiar with this fish (FAO 2009). However, other species not extensively used in aquaculture could also be considered. Fish such as Chrysichthys spp. that occur naturally in the Volta Lake have recorded high performance under captive conditions. Additionally, the Chrysichthys have a good consumer base across Ghana and should be well accepted in markets if they were cultured intensively. Two other species that have also been recommended for aquaculture are African bonytongue *Heterotis niloticus,* and African snakehead *Parachanna obscura*. Farmers have observed these species to breed in captivity, and their growth rates are reported to be good, characteristics that enhance their potential species for cage aquaculture. A recent study in Ghana suggests that these non-traditional aquaculture species give potential cage aquaculturists a wider range of species to consider for culturing, especially since they are popular among fish consumers (Frimpong *et al.* 2011).

Concerns about the negative environmental impacts of cage aquaculture have been expressed (Tacon and Halwart 2007). Increasing levels of nutrients such as nitrogen and phosphorous, in the surrounding water body is an example of the potential impact of cage aquaculture (Comel and Whoriskey 1993; Xu 2004; Sarà *et al.* 2011). However, Wu (1995) reported that most impacts can be avoided if appropriate policies, such as operating cage aquaculture below the carrying capacity of the water body, are implemented to limit the extent of water allocated for cage aquaculture. A study to assess the carrying capacity of the Volta Lake for cage aquaculture had been planned (Lionel Awity, Fisheries Directorate, pers. comm.), and should help address the environmental concerns associated with open water cage aquaculture in Ghana. Current policy requires potential cage farmers to provide environmental impact assessments as part of the permitting process. Cage aquaculture in Ghana can be environmentally sustainable if impacts are well monitored.

Existing irrigation reservoirs are also potential systems for cage aquaculture development. Asmah (2008) identified irrigation reservoirs suitable for cage aquaculture in Ghana. However, integrating cage aquaculture with irrigation programs has its environmental and socioeconomic challenges such as minimizing pollution, and satisfying all stakeholders (Brugere 2006), which should be taken into consideration when developing programs that integrate cage aquaculture with irrigation agriculture.

For many years, the fisheries sector of Ghana existed as a Fisheries Directorate under the Ministry of Food and Agriculture. This created the perception that the sector was under performing due to lack of autonomy. Therefore, the government created an independent Ministry of Fisheries to develop and advance fisheries and aquaculture in Ghana in 2005 (Awity 2005). Shortly thereafter, a new fisheries and aquaculture policy was drafted. Since 2009, the Ministry of Fisheries has been placed under the Ministry of Food and Agriculture by a new government, assuming its old name, the Fisheries Directorate. Despite the transition, efforts to promote aquaculture development have continued. In order to encourage more people to participate in fish farming and provide alternative livelihoods in the face of dwindling capture fisheries, the Ministry of Food and Agriculture has introduced a new policy, The Youth in Agriculture (MoFA 2009). The policy has development of aquaculture as one of its key programs (MoFA 2009). Frimpong *et al*. (2009) found a high interest in fish farming as evidenced by the number of fish farmers that had entered the business in the past 10 years. Asmah (2008) also reported that fish farming in Ghana increased by 16% between 2000 and 2005, with new entrants into cage aquaculture observed.

The interest in fish farming is important for cage aquaculture adoption, and the fact that the government has policies promoting aquaculture suggests that cage aquaculture could develop rapidly in Ghana in the next few years. However, policies and programs promoting aquaculture in Ghana, and for that matter cage aquaculture, would benefit from research that provide information about where to focus attention and resources to ensure that substantial results in terms of fish production are obtained on a sustainable basis.

Asmah (2008) provided insightful information about areas suitable for cage aquaculture development in Ghana. Even though physicochemical data and siting information were unavailable, an assessment based on factors such as market potential, infrastructure, availability of inputs and technical support showed that the southern and middle portions of the country were suitable for cage aquaculture (Asmah 2008). Research identifying individuals and their characteristics, that make them suitable candidates for programs encouraging cage aquaculture adoption, would complement her findings. Moreover, some studies have cited feed and fingerling availability as major constraints to aquaculture development in Sub-Saharan Africa (Ridler and Hishamunda 2001; FAO 2004; Moehl *et al.* 2006; Blow and Leonard 2007; Asmah 2008). However, it is not certain if or which of these is primary constraint to cage aquaculture adoption in Ghana. Observations and interviews during the 2008 National Best Fish Farmers survey in Ghana suggested that lack of knowledge and training in cage aquaculture, and lack of high quality floating feeds might be important constraints facing cage farmers (Steve Amisah, KNUST, Ghana, pers. comm.). Hence, understanding the decision processes in cage aquaculture adoption, and identifying the factors that affect adoption would inform policy makers about areas to concentrate effort to ensure sustainable adoption of cage aquaculture, ultimately leading to significant fish production by using the technology.

The purpose of this study was to identify the opportunities yet to be exploited to promote cage aquaculture in Ghana, and to identify constraints that need to be overcome to ensure sustainable cage aquaculture adoption in Ghana. In the first chapter of this thesis, I developed a framework for understanding the innovation-decision process of cage aquaculture and identified characteristics of individuals that make them suitable or otherwise for cage aquaculture adoption programs. This decision framework can be used by policy makers and other institutions interested in promoting cage aquaculture to focus efforts and resources on individuals interested in cage aquaculture. In the second chapter, I identified factors affecting cage aquaculture adoption using the innovation-decision framework developed. The results should assist policy makers in developing policy strategies and solutions targeting specific factors affecting different stages of adoption in Ghana, which would ensure sustainable cage aquaculture adoption.

Chapter 1: The cage aquaculture innovation-decision process in Ghana

Abstract

Innovation-decision frameworks have been used to understand how individuals make decisions about a new technology and to identify the characteristics of individuals, which makes them adopt the innovation, as well of characteristics of the innovation that encourages adoption. However, this approach has not been used to study cage aquaculture adoption in Ghana, even though the technology is being promoted. Hence, in this study, I sought to provide a framework for understanding cage aquaculture adoption decisions to aid in sustainable adoption of cage aquaculture in Ghana. In summer 2010 and 2011, I surveyed current cage fish farmers (Adopters), farmers who have abandoned cage aquaculture (Abandoned), and Potential Adopters of cage aquaculture, such as fishermen and fish traders. I asked respondents questions related to knowledge, interest, constraints in cage aquaculture, and demographics. I found that some Potential Adopters, as well as the Abandoned, had knowledge and interest in cage aquaculture and were willing to start or resume cage aquaculture. I used non-metric multidimensional scaling and discriminant function analysis to develop a cage aquaculture innovation-decision process model, which had the following stages: Unawareness, Knowledge, Persuasion and Decision (KPD), and Implementation (Confirmation and Abandonment). Respondents at the various stages differed in their rankings of constraints in cage aquaculture as well as demographic variables. Respondents in the KPD and Implementation stages had knowledge, were more interested in cage aquaculture, and were aware of the constraints in cage aquaculture whereas respondents in the Unawareness stage lacked knowledge and interest in cage aquaculture and did not clearly

understand the constraints. Additionally, the respondents in the Unawareness stage tended to be female, fish traders, and belonged to the tribe Ga-Dangme, whereas respondents in the KPD and Implementation stages tended to be males, fishermen, and belonged to the tribe Ewe. My model can be used to guide programs promoting cage aquaculture adoption about who needs to be encouraged to ensure that the output from cage aquaculture is significant.

Introduction

Interest in cage aquaculture in Ghana has increased in the last two decades, growing from only two recognized cage aquaculture companies in the 1990s (Blow and Leonard 2007), over 60 cage aquaculture enterprises established between 2000 and 2010 (Anane-Taabeah, unpublished data). Most cage aquaculture companies in Ghana are small in scale. Cage aquaculture is expected to develop rapidly if the government concentrates efforts into promoting its adoption. A previous government effort resulted in a massive rush into aquaculture in the 1980s (MaCpherson and Agyenim-Boateng 1990). In order to encourage aquaculture adoption in Ghana, a recent policy known as the Youth in Aquaculture Program has been introduced (MoFA 2009). The Youth in Aquaculture Program has a target of creating employment through the training of about 1,000 youth in various aspects of pond aquaculture (MoFA 2009). The program also seeks to promote cage aquaculture by supplying fingerlings for cage farmers (MoFA 2009). With the greater media presence existing now in Ghana, as a result of increased private media compared to pre-constitutional days (Kwansah-Aidoo 2003), coupled with non-governmental organizations' involvement in aquaculture (Blow and Leonard 2007; Asmah 2008), programs to promote cage aquaculture could rapidly spread before the necessary institutional structures required to ensure sustainable adoption develop.

Aquaculture has been practiced in Ghana for over 50 years, however, without significant results (Ministry of Fisheries 2008). The low production may be attributed to the rush to adopt aquaculture without the appropriate technical knowledge. Ofori (2000) found that over 50% of pond-based fish farmers in Ghana had abandoned their ponds. Abandonment has already been observed among cage farmers (personal observation).

Even though cage aquaculture has the potential to significantly increase local fish production, as has been achieved elsewhere (Baotong and Yeping 1998), without a good understanding of the adoption decision processes and constraints, promotion of the technology may result in rapid adoption but no significant output will be realized.

Some studies on aquaculture adoption decisions in Ghana have been done with potential adopters (Lightfoot *et al.* 1996; Anning *et al.* 2012), however, research focused on cage aquaculture adoption decisions is lacking. From an information technology perspective, Karahanna (2009) found that potential adopters differed from users in terms of their attitudes towards the use of information technology (IT). For example, whereas potential adopters' attitudes were influenced by the perceived usefulness, ease of use, demonstrability, visibility, and trialability (the degree to which an innovation may be experimented with, on a limited basis) of the technology, adopters were only influenced by perceived usefulness and image (Karahanna 2009). Efforts aimed at increasing cage aquaculture adoption, especially on the Volta Lake, will benefit from a good understanding of the adoption decision processes involving current adopters, those who have abandoned cage aquaculture, and potential adopters of cage aquaculture. With adequate regulatory measures and comprehensive understanding of the decision processes involved in adopting cage aquaculture, we could begin to see significant results from promoting aquaculture in general and cage aquaculture in particular.

In this study, I sought to understand the decision process of cage aquaculture adoption in Ghana. I used the innovation-decision process model by Rogers (2003) as a guide to assess the decisions and stages that individuals go through before fully adopting the cage aquaculture innovation. As Guerin and Guerin (1994) argued, it is better to conceive adoption of an innovation as a decision process rather than as an event that occurs at a specific time. Since cage aquaculture can be considered new in Ghana, and indeed Africa, studying the innovation-decision process can inform programs designed to promote adoption.

The innovation-decision process model developed by Rogers (2003) has five stages, each of which must necessarily be transited before complete adoption (or rejection) can be said to have occurred (Figure 1.1). "Knowledge" is the first stage in the model and it indicates the awareness of an innovation. At this stage individuals come into contact with information about the innovation and learn about how it works (Rogers 2003). "Persuasion*,"* the next stage, involves attitude formation about the innovation. The perceived attributes of an innovation, including relative advantage, compatibility, complexity, observability and trialability have been shown to influence the Persuasion stage (Guerin and Guerin 1994; Rogers 2003). Once the individual considers the innovation as relatively advantageous, compatible with current beliefs or practices, less complex, observable and trialable, an initial decision is made to accept the technology. If the contrary is true, the innovation will be rejected. Thus the third stage, "Decision," has two possible outcomes: acceptance (adoption) and rejection. After an adoption decision has been made, the next stage is "Implementation" where the individual puts the innovation into practice. The final stage, "Confirmation" is where the decision to implement the innovation is reinforced through accumulation of evidence that the innovation works (Rogers 2003). Diffusion researchers acknowledge discontinuance, a decision to reject an innovation after it has previously been adopted (Rogers 2003). Discontinuance has been observed as a frequent occurrence with innovation adoption

(Leuthold 1967). Ultimately, the innovation-decision process is facilitated by effective communication by diffusion agents and is a function of time. In the case of cage aquaculture, fisheries officers, non-governmental organizations and current adopters or farmers who have abandoned cage aquaculture are potential diffusion agents.

The specific objectives of this study were: (1) To describe the cage aquaculture innovation-decision process in Ghana, and (2) to investigate the differences among individuals in the different stages in the innovation-decision process model.

Methods

Study area

The study was conducted in communities surrounding the Volta Lake, with present or past cage aquaculture activities (Figure 1.2). The Volta Lake is currently the main inland water body used for cage aquaculture in Ghana. The 8502 km^2 lake, (ILEC 1999), presents enormous opportunities for aquaculture expansion. Communities around the lake have mostly engaged in farming, and fishing, with the men mostly involved in active fishing and the women focusing on fish processing and trading. The Volta Lake and its tributaries drain 70% of the entire area of Ghana (FAO 2005), covering portions of the Northern, Volta, Eastern, and Brong-Ahafo Regions. The Eastern and Volta Regions were the focus of this study. I selected the respondent groups from Asuogyaman, Upper and Lower Manya Krobo, Kwahu North Districts (all located in the Eastern Region), and South and North Tongu Districts (Volta Region), based on recommendations from the Fisheries Directorate. The districts selected for this study contained the largest number of current cage aquaculture operations in Ghana as well as cage aquaculture operations that had been abandoned. The Eastern region has four major ethnic groups (tribes): Akan (52.1%), Ga-Dangme (18.9%), Ewe (15.9%), and Guan (7.2%), with Ewe being the only non-indigenous tribe (Ghana Statistical Service 2005a). The Volta Region also has four major tribes: Ewe (68.5%), Guan (9.2%), Akan (8.5), and Gurma (6.5%; Ghana Statistical Service 2005b).

Survey methodology

I conducted the study through a survey in summer 2010 and 2011 with three respondents groups: current cage fish farmers (Adopters), cage fish farmers who have abandoned the trade (Abandoned), and Potential Adopters. Based on my prior hypothesis that people with fish-related livelihoods were more likely to adopt cage aquaculture, I originally defined Potential Adopters as individuals already employed in fish-related activities, including fishermen and land-based fish farmers and fish traders. This made sampling easier for Potential Adopters since I had no sampling frame for this group otherwise. However, during the field surveys, I encountered individuals who did not have fish-related livelihoods but had received training in cage aquaculture through government promotion programs and were awaiting cages promised them by the government in order to commence operations. I therefore, included these individuals in my Potential Adopters' group.

With the exception of Potential Adopters, all respondent groups identified for this study had small populations. I surveyed the Potential Adopters group by approaching individuals and administering the surveys to those willing to participate in the study after the purpose of the study had been explained to them. For the Adopters and Abandoned, I obtained a list of names from officers at the Fisheries Directorate, Ghana, and key informants. I contacted individuals with active phone numbers before visiting their farms or other work places to conduct the surveys. Where I could not contact farmers directly, I employed opinion leaders such as leaders of fish farmers' associations, and other cage farmers to help access them. With the help of a field assistant, I administered the questionnaires in person to ensure answers provided were directed to exact questions asked. However, some Adopters filled out their own questionnaires because they requested to send them home with them after I had encountered them at a fish farmers' meeting, and they had time constraints. Accordingly, using a follow-up member check, which I conducted by calling Adopters who filled out their own questionnaires, I clarified all their responses to ensure consistency in the data.

Survey instrument

I designed three questionnaires, one each for Adopters, Abandoned, and Potential Adopters (Appendices A-C). However, to compare responses across the three groups, I included similar questions in all questionnaires but modified the wording to suit the particular group. I assessed four main dimensions: knowledge, interest, constraints, and demographics, all measured with multiple variables. The literature on innovation decisions suggests that social, behavioral and economic variables encompassing both adopter (or potential adopter) and innovation characteristics are important in explaining adoption decisions (Guerin and Guerin 1994; Adesina and Seidi 1995; Batz *et al*. 1999; Enyong *et al*. 1999; Roger 2003; He *et al.* 2007; Karahanna 2009). Thus, I selected these four dimensions because they could be used to understand the cage aquaculture innovation-decision process in the context of the individual and the innovation itself.

To assess knowledge, I asked Adopters and Abandoned to indicate whether or not they had had specific training in cage aquaculture. Potential Adopters were asked to indicate whether or not they had knowledge in cage aquaculture. Since respondents were providing self-reported knowledge or training, as a follow-up, I asked them to state the type of training in order to verify the responses.

As part of assessing knowledge, I also asked respondents' questions about cage aquaculture policies, since knowledge of policies could potentially influence adoption decisions. I asked three questions related to knowledge of cage aquaculture policies. Respondents were asked whether, 1) a policy promoting cage aquaculture existed in Ghana, 2) a policy limiting cage aquaculture existed in Ghana, and 3) a government permit was required to start cage aquaculture on the Volta Lake. Respondents who answered "yes" to either "policy promoting cage aquaculture" or "policy limiting cage aquaculture" were asked to describe the policy. In assessing knowledge about "policy promoting cage aquaculture," I expected respondents to answer "yes" and be able to mention policies such as Youth in Aquaculture and national fisheries and aquaculture policies that relate to cage aquaculture development. Anecdotal information suggested that a policy on cage aquaculture existed such that a limited area of the Volta Lake had been allocated for cage aquaculture. However, the Fisheries Directorate revealed that no such policy existed, even though a study to assess the carrying capacity of the Lake for cage aquaculture had been planned. Also, a government permit was required to start cage aquaculture on the Volta Lake. Thus, I expected respondents to answer "no" on the question about policy limiting cage aquaculture and "yes" on the question asking about permit requirement for cage aquaculture.

To evaluate interest, I asked Potential Adopters to indicate whether or not they had interest in starting cage aquaculture on the Volta Lake. I further asked both

Abandoned and Potential Adopters to indicate if they would resume or start cage aquaculture if constraints were removed, and to provide reasons for their responses. I also asked Potential Adopters and Abandoned to provide reasons for their interest or lack of interest in cage aquaculture, to understand factors influencing adoption decisions. I assumed interest in cage aquaculture on the part of Adopters since they still practiced cage aquaculture during the survey. However, to assess practitioners' motivation, I also asked Adopters to provide reasons for their decision to start cage aquaculture. I also asked Adopters to rank how profitable they perceive cage aquaculture to be, and whether or not they would recommend cage aquaculture. Both Adopters and Abandoned were asked if they had other fish farming experience apart from cage aquaculture.

I included 9 items representing constraints in the questionnaires to be ranked by the all respondent groups. I selected the items based on the information available in the literature about constraints in aquaculture in general and cage aquaculture in particular. I presented the 9 items to be scored on a four-point interval scale ranging from 1 to 4 where 1 is "not important" and 4 is "very important," modified from Vagias' (2006) level of problem type-scale. I asked respondents to rank the constraints according to how important they were to them, and with respect to their group (Appendices A-C). The constraints were "lack of funds (capital)," "lack of feed," "lack of good quality feed," "lack of fingerlings," "lack of extension services/information," "conflict over water use," "lack of market," "theft," and "cage destruction by storms."

I asked questions related to education, gender, occupation, age, tribe, and residence location, to assess how demographic characteristics affected individuals' cage aquaculture adoption decisions.

Data analysis

I coded both quantitative and qualitative responses and entered them into an Excel 2007 spreadsheet for analyses. I summarized qualitative results and used them in discussing my quantitative results. Respondents' residences were reported as towns or cities, so I used maps to calculate the distance between respondents' residence and the closest area on the Volta Lake where cage aquaculture is practiced. The resulting variable became Distance. Age was measured in years and I used the raw ages reported in my analyses. I subdivided occupation into four categories for Potential Adopters; Fishtrader, Fisherman, Fishfarmer, and Other. Occupation was also coded as 1 if cage aquaculture was a full-time occupation or 0 if part-time for Adopters and Abandoned.

To model the cage aquaculture innovation-decision process*,* I selected six variables from the Potential Adopters' questionnaire, which were good indicators of their stage in the innovation- decision process, and which could easily be applied to the Adopters and Abandoned. The variables selected were, " knowledge or training in cage aquaculture," response to "policy promoting cage aquaculture," response to "policy limiting cage aquaculture," response to "permit required for cage aquaculture," response to "interested in starting cage aquaculture," and response to "interest to start/continue if constraints are removed."

All six variables were measured across the three respondent groups except "interested in starting cage aquaculture," which was not measured for the Adopters and Abandoned, and "interest to start/continue if constraints are removed," which was not measured for the Adopters. Since the Adopters still practiced cage aquaculture, I assigned "yes" to all Adopters for "interested in starting cage aquaculture" and "interest to start/continue if constraints are removed." Also, all Abandoned responded "yes" to "interest to start/continue if constraints are removed." therefore, I inferred interest in starting and assigned "yes" to all the Abandoned for "interested in starting cage aquaculture."

I used nonmetric multi-dimensional scaling (MDS) to ordinate all respondents based on their responses to the six questions and plotted the results in two dimensions to identify underlying patterns in their responses. I further explored the relationship between the dimensions and responses on the six items among the Adopters, Abandoned and Potential Adopters with box-plots. The nonmetric MDS showed that respondents could be grouped into two clusters. Using the results from the nonmetric MDS, I developed a linear discriminant function to separate the two clusters.

I tested for significant differences, if any, in the responses obtained from the respondents located on the two sides of the discriminant function across the six variables with Fisher's exact test and α set at 0.05. I combined "yes" and "no" as one response (i.e., assertion of knowledge) for "policy promoting cage aquaculture," "policy limiting cage aquaculture" and "permit required for cage aquaculture" because the two responses showed similar patterns and contrasted the response of "don't know." I also combined "no" and "not sure" as one response for the variables "interested in starting cage aquaculture" and "interest to start/continue if constraints are removed." In this case, "no" and "not sure" more clearly contrasted "yes" with respect to disposition of respondents to start cage aquaculture.

I used bar charts, nonmetric MDS, and box-plots, to explore how the respondent groups ranked the constraints presented. I used multivariate analysis of variance

(MANOVA) and the Tukey procedure post-hoc for contrasting differences among group rankings of the 9 constraints presented at $\alpha = 0.05$. Apart from the bar charts (Excel 2007) and box-plots (Minitab®16 statistical analysis package), I conducted all analyses with SAS software version 9.2.

Results

Nonresponse bias

I interviewed 122 respondents comprising 45 Adopters, 20 Abandoned, and 57 Potential Adopters. The 45 Adopters represented 73% of the total population (62) of cage farmers during the surveys. The remaining 27% of cage farmers represent farmers who did not return questionnaires or were not available. I found no difference between respondents and nonrespondents in terms of demographics and farm size, thus, the results from this study are representative of the entire population of cage farmers in Ghana. Of the 20 Abandoned (100% of the population), 10 had abandoned pen aquaculture. I included the pen farmers in my study because of the similarities between the two culture systems, with the expectation that their responses could help understand abandonment of water-based aquaculture. Even though Potential Adopters were not randomly sampled, their representation in this study approximates a representative sample of the potential adopters in the population of interest for this study.

Demographics

Overall, males dominated the respondents (72%). Among the three groups, males dominated the Adopters (100%), and Abandoned (90%). However, the Adopters surveyed consisted of owners and caretakers. Even so, only one caretaker mentioned the owner was a female. In contrast, females formed the majority of Potential Adopters

(56%). The groups differed significantly by gender (Table 1.1). The distribution of the primary occupation types among the Potential Adopters was: fish traders (46%, including fish processing), fishermen (27%), fish farmers (8%), and others (19%). Several Abandoned had multiple primary occupations so I did not compute the statistics for this group though crop-based farmers and fishermen dominated the group. Sixty percent of Adopters operated cage aquaculture on a full-time basis, compared to only 10% among the Abandoned (1 out of the 10 farmers who had abandoned cage aquaculture). More than half of Adopters (51%) indicated that they had experience in other fish activities such as pond-based fish farming.

I categorized all the tribes respondents identified themselves with into four groups: "Ewe," "Akan," "Ga-Dangme," and "Other." Ewe was the major tribe represented in the study: 57%, Adopters, 85%, Abandoned, and 54%, Potential Adopters. Akan was the next major tribe (31%) among Adopters, whereas Ga-Dangme was the second major tribe (42%) among Potential Adopters. The differences observed for tribe among Adopters, Abandoned and Potential Adopters was significant (Table 1.1). According to the 2000 census, Ewes are non-indigenous in the Eastern region and the second minority group, forming 15% of the population. However, they are heavily represented in districts surrounding the Volta Lake: Asuogyaman (39.1%) and Kwahu North (50.8%; Ghana Statistical Service 2005a). In this study, I found that about 92% of the Ewe Adopters were located in the Eastern region, with over 73% located in the Asuogyaman district alone. The percentage of Ewes among the Abandoned (cage abandoned) and Potential Adopters located in the Eastern region were 100% and 70% respectively.

Adopters had the most education, and were between the ages of 26 to 35 years, followed by Abandoned who were between the ages of 36 to 45 years (Table 1.1). Potential Adopters were also between the ages of 36 to 45, and had the least education (Table 1.1). The majority (76% and above) of Adopters, Abandoned and Potential Adopters lived less than 6 km away from cage aquaculture hotspots on the Volta Lake. However, 11% of Adopters lived more than 81 km away from the lake (Table 1.1).

Stages of respondents in the cage aquaculture innovation-decision process

The nonmetric MDS showed that respondents could be grouped into two clusters in two-dimensional space (Figure 1.3). Cluster 1 comprised Adopters and Abandoned and some Potential Adopters placed toward the positive end of Dimension 1. Cluster 2 comprised only Potential Adopters placed toward the negative end of Dimension1 (Figure 1.3). The presence of Potential Adopters in Cluster 1 suggested that those respondents had characteristics similar to Adopters and Abandoned. Specifically, the characteristics that could indicate their positions on the innovation-decision process such as knowledge, persuasion, and decision. Dimension 2 did not show a clear respondent-axis relationship with most respondents clustering around the center of the axis (Figure 1.3). However, some Potential Adopters separated toward the negative end of Dimension 2 (Figure 1.3). The difference in respondent locations on the axes suggested that the two dimensions, especially Dimension 1, could be used to understand respondent-stage relationships.

Exploring the patterns of responses among Adopters, Abandoned and Potential Adopters using box-plots revealed that, in general, a "yes" response moved respondents toward the positive end of the axes, while "no" moved them toward the negative end for “training in cage aquaculture” across groups (Figures 1.4 and 1.5). For “policy promoting cage aquaculture,” “policy limiting cage aquaculture,” and “permit required for cage aquaculture,” the general trend showed that the more definitive answers, yes and no, moved respondents toward the positive end whereas the less definitive answers “don’t know,” moved them toward the negative end (Figures 1.6 to 1.11). However, for “interested in starting cage aquaculture” and “interest to start/continue if constraints are removed,” only “yes” moved respondents toward the positive end while “no” and “not sure” moved them toward the negative end (Figures 1.12 to 1.15). These trends were observed clearly for Potential Adopters especially on Dimension1, supporting my conclusion that Dimension 1 could be used exclusively to explain respondent-stage relationships. I provided no box-plots for “interested in starting cage aquaculture” and “interest to start/continue if constraints are removed” for the Adopters, and “interested in starting cage aquaculture” for the Abandoned since I imputed “yes” response for these variables.

The results from the MDS provided support for grouping respondents into two clusters. Since the Adopters and Abandoned were already distinct groups higher up the innovation-decision continuum, the ordination and box-plots also provided a basis to separate Potential Adopters into two groups, those with knowledge about cage aquaculture, have been persuaded about the innovation, and have made a decision, on the one hand, and the unaware of cage aquaculture, on the other hand. Only one Potential Adopter clearly rejected cage aquaculture, therefore, I collapsed “Accept” and “Reject” in the innovation-decision continuum into one stage, “Decision.”

I calculated the discriminant function to be the equation of the line such that $y + 1.8x = -2.4$, where y is Dimension 2 and x is Dimension 1 (Figure 1.16). Potential Adopters located above the line ($y + 1.8x \geq -2.4$) formed the "KPD" (Knowledge, Persuasion, and Decision) group. Conversely, Potential Adopters located below the line ($y + 1.8x < -2.4$) formed the "Unaware" group. The Fisher's exact test indicated that apart from "permit required for cage aquaculture," KPD and Unaware show significant differences in their response to all the variables used for determining stage (Table 1.2; Figures 1.17 to 1.24). Box-plots are not provided for the variables "training in cage aquaculture" for Unaware because the entire group responded "no." Similarly, all KPD responded "yes" to "interest to start/continue if constraints are removed," explaining the lack of box-plots for that variable. The Fisher's exact test and the box-plots give weight to the discriminant function analysis and provide a basis for grouping Potential Adopters into KPD and Unaware (Figure 1.25).

For the purposes of the stage classification, since the Adopters were still involved in cage aquaculture at the time of the survey, I assumed confirmation of the innovation by this group, thus, will refer to them as a distinct group known as "Confirmed." Similarly, the "Abandoned" will be a distinct group for the purposes of modeling the innovation-decision process. However, when combined, Confirmed and Abandoned represent the "Implementation" stage because both groups have practiced cage aquaculture (assuming all Abandoned previously practiced cage aquaculture) and will also be treated as a distinct stage in the decision continuum.

The four new respondents groups, created according to their stages in the decision continuum: Confirmed, Abandoned, KPD, and Unaware differed significantly by gender and tribe (Fisher's exact test; $p < 0.000$). The groups also differed in their rankings of the constraints presented. The Confirmed, Abandoned, and KPD ranked lack of capital as an important constraint, whereas Unaware ranked lack of capital as slightly unimportant. Mean ranking of lack of capital, on a 1 to 4 scale, where 1 is not important and 4 is very important, was 3.5, 3.3, 3.8, and 2.0 for Confirmed, Abandoned, KPD, and Unaware respectively (Figure 1.26). Lack of extension was ranked as the second most important constraint by the Confirmed with a mean of 3.0 (Figure 1.26). However, both the Abandoned and KPD ranked lack of extension or lack of information (in the case of KPD and Unaware) as a slightly unimportant constraint. Apart from lack of capital and lack of extension or information, The Confirmed, Abandoned and KPD ranked all other constraints as slightly unimportant (mean rank of 2.3 or lower). The only exception was "cage destruction by storms," which the Abandoned ranked higher (mean rank of 2.7). In contrast, the Unaware consistently ranked the remaining eight constraints as not important (mean rank of 1.7 or lower). The MANOVA test revealed significant differences in the rankings of the 9 constraints among the groups ($p < 0.0001$).The Tukey post-hoc analysis showed that Confirmed and Abandoned did not differ significantly in their mean rankings of all constraints except for conflict over water use (Figure 1.26). On the other hand, KPD and Unaware differed significantly in their rankings of lack of capital, lack of feed, and lack of quality feed (Figure 1.26). Both the Confirmed and Abandoned ranked lack of capital significantly higher than the Unaware (Figure 1.26). Additionally, the Confirmed ranked conflict over water use, and lack of market significantly higher than KPD and Unaware (Figure 1.26). The Confirmed also ranked lack of extension services significantly higher than Unaware (Figure 1.26). Finally, the

Abandoned ranked lack of feed, lack of quality feed, and lack of market significantly higher than KPD, and also ranked cage destruction by storms significantly higher than Unaware (Figure 1.26).

Discussion

The cage aquaculture innovation-decision process model

I designed this study to understand the decision process of cage aquaculture adoption in Ghana. I refined Rogers' model, as it applies to the cage aquaculture situation in Ghana, to create a model of the cage aquaculture innovation-decision process to guide efforts aimed at encouraging cage aquaculture in Ghana. The refined model has the following stages: (1) Unawareness (2) "Knowledge," "Persuasion," and "Decision," as defined in Rogers (2003) but combined as one stage: "KPD," and (3) Implementation, split into Confirmation, and Abandonment (Figure 1.27).

The stages in the decision process model developed from this study and the characteristics of individuals at each stage warrant some discussion, particularly Unawareness and KPD, because potential adopters tend to be the focus of communication efforts aimed at increasing adoption. Understanding the characteristics of respondents at the different stages identified offers a way of reaching individuals to encourage sustainable adoption of cage aquaculture in Ghana. I begin the discussion of the stages with an explanation of Unawareness and Implementation stages because Rogers' model does not include Unawareness and my interpretation of Implementation differs slightly from how Rogers (2003) conceptualized this stage in his model.

Unawareness stage

The Unawareness stage I identified is a departure from the traditional adoption-decision process and presents an interesting way of conceptualizing cage aquaculture adoption decisions. Being unaware of an innovation means more than just being ignorant about it. In this study, respondents referred to as Unaware can also be termed “Disinterested.” As argued by Hassinger (1959) and discussed by Rogers (2003), being exposed to an innovation does not necessarily mean an individual will actively seek out information about the innovation and implement it. The need for an innovation may be important for an individual to adopt the innovation. Selective exposure and selective perception could explain the Unawareness stage in the cage aquaculture innovation-decision process. In selective exposure, “individuals attend to communication messages that are consistent with their existing attitudes and beliefs” (Rogers 2003). They consciously or unconsciously avoid messages that conflict with their existing values (Rogers 2003). On the other hand, selective perception involves “the tendency to interpret communication messages in terms of the individual’s existing attitudes and beliefs” (Rogers 2003). Since the individual does not see a need for the technology when selective exposure and selective perception are acting, it is possible for that person to come into contact with the innovation and not regard it. Thus, an individual influenced by selective exposure and selective perception may “see” cage aquaculture and still be disinterested. The roles of selective exposure and perception on the decision process at the Unawareness stage will be explained further during the discussion of the differences among the innovation-decision stages identified in this study.

Implementation stage: Confirmation and Abandonment

In my model, Confirmation and Abandonment are two stages which branch off the Implementation stage. Similar to the “Decision” stage where “Reject” or “Accept” are considered as the possible outcomes for decision, my model recognizes Confirmation and Abandonment as possible outcomes of Implementation (Figure 1.27). Rogers (2003) discussed “Discontinuance” much like I conceptualize Abandonment. However, he does not consider it as a stage by itself in the innovation-decision process. Abandonment or Discontinuance deserves much more attention in diffusion of innovations research. Abraham and Hayward (1984) noted that we may obtain misleading results if discontinuance is not considered in measuring the overall impact of an innovation. Especially, for potential adopters, observing discontinuance may affect their adoption decisions more than continuance (confirmation). Chamala (1987) suggested a model that integrates stages of discontinuance by potential adopters in the original model by Rogers and Shoemaker (1971) and Rogers (1983).

In fact, both Abandonment and Confirmation can be considered as transient zones between which adopters can be expected to move, depending on the existing conditions of using the innovation. As I have observed in cage aquaculture in Ghana, abandonment often occurs anytime between a few months to a number of years depending on the cause of abandonment. Some farmers who fold up activities briefly may not even consider themselves as having abandoned the innovation. Hence, it is imperative to understand factors that may influence both confirmation and abandonment. Once these factors are identified, strategies can then be developed to eliminate the causes of abandonment while promoting those that encourage confirmation. The apparent success of the Confirmed in this study is probably due to the fact that majority of them spend more time in the day-to-day operations of their cage aquaculture business. About 60% of the Confirmed operated cage aquaculture on a full-time basis, compared to only 10% of the Abandoned. Additionally, the Confirmed had diverse previous experience compared to the Abandoned. Even though almost all the Abandoned had a history of fishing and many went back to fish after abandoning cage aquaculture, only 20% had experience in fish farming related activities. In contrast, over 50% of the Confirmed had previous fish farming experience. Thus, having previous fish farming experience, and being more involved in the daily operations of cage aquaculture, could ensure that farmers remain in the business.

Differences among stages in the cage aquaculture-innovation decision process model

Individuals in the different stages differed significantly with regard to knowledge and interest in cage aquaculture. It appeared that communication of aquaculture policies influenced the differences in the innovation-decision process identified. Individuals at the different stages also differed in their rankings of constraints in cage aquaculture and in demographics.

Knowledge and training in cage aquaculture

I expected the Confirmed, Abandoned, and KPD to have knowledge (training) in cage aquaculture compared to the Unaware. As expected, all Unaware lacked knowledge about cage aquaculture. However, some Confirmed, Abandoned and KPD also lacked knowledge. Still, since for the Confirmed and Abandoned lack of knowledge or training actually represents "no formal training," I can ascribe both knowledge and training for them because of hands-on activities on the job. However, for Potential Adopters, lack of knowledge in cage aquaculture means one of two things. Either the respondent knew about the innovation but did not have specific training in cage aquaculture or the respondent had no knowledge and training in cage aquaculture all together. Both cases could have happened because of the mode of questionnaire administration to Potential Adopters. The wording for the question that assessed knowledge in cage aquaculture was "do you have knowledge in how to operate a cage aquaculture farm?" Since I administered the questionnaires in a local language, I first asked respondents whether they knew what cage aquaculture was and followed it with whether they had training in cage aquaculture. Consequently, the response recorded for an individual who had knowledge about cage aquaculture but lacked training was "no." Thus, it appears that individuals who lacked complete knowledge in cage aquaculture and who should be considered Unaware were grouped with KPD. However, since multiple variables were used in the non-metric MDS and discriminant function analysis, this discrepancy was remedied. Apparently, Potential Adopters who had knowledge about cage aquaculture also knew about current policies promoting cage aquaculture in Ghana and were interested in starting cage aquaculture.

Knowledge of cage aquaculture policies

Generally, respondents lacked knowledge about cage aquaculture policies suggesting that communication of aquaculture policies to adopters and potential adopters of cage aquaculture has not been effective. I found that some respondents who answered "yes" to "policy promoting cage aquaculture" could not describe the policy. Also, even though no policy currently exists that limits the extent of cage aquaculture on the Volta Lake as rumor has it, a few of the respondents cited demarcation of areas suitable for cage aquaculture, and recommended spacing between cage farms, as policies limiting cage aquaculture. Regarding knowledge about cage aquaculture permits, Confirmed and Abandoned were relatively more aware of the requirement than KPD and Unaware. However, many Confirmed (40%) either said no government permit was required for cage aquaculture or they did not know about the requirement. The presence of "no" and "don't know" responses even among Confirmed and Abandoned reveals the lack of connection between policy makers and the target population.

Interest in cage aquaculture

The Abandoned showed a surprisingly high interest in cage aquaculture (100% interest to resume, or start in the case of the pen farmers), and cited profitability as the major reason for their interest. The apparent high interest suggests that this group could be a focus of efforts to encourage adoption. KPD also showed a high interest to start cage aquaculture (97%). The fishermen in the group, as well as the individuals with non-fish related livelihoods, who had already received government-sponsored training in cage aquaculture, expressed the most interest. Apparently, the individuals who had received government-sponsored training were also promised free cages to start cage aquaculture. It is important for the promise of cages to be fulfilled if the interest is to be sustained, especially for individuals who may lack the initial starting capital. The finding that fishermen have a high interest in cage aquaculture is consistent with the results obtained by Anning *et al.* (2012) who assessed the willingness of marine fishermen to adopt aquaculture and recommended focusing training and capacity building on marine fishers in aquaculture.

While I expected only the Confirmed, Abandoned and KPD to have interest in cage aquaculture, the results indicated that some Unaware also had interest in cage aquaculture adoption. As previously shown, the Unaware clearly lacked knowledge about cage aquaculture; therefore, they cannot possibly have interest in cage aquaculture, at least prior to the survey. The possible explanation for this observation is that in the process of interacting with respondents, especially for the Unaware, I acted as a communication channel through which they learned about cage aquaculture. Diffusion studies recognize two communication channels, mass media and interpersonal interactions, through which innovations diffuse to target groups (Rogers 2003). Both channels have been shown to influence the adoption of innovations differently (Valente 1993). However, mass media has been suggested to be more efficient in creating awareness of the innovation, whereas interpersonal channels appear to be effective in persuasion to adopt (Rogers 2003). Hence, in this study, my interpersonal communication with respondents could likely have moved some Unaware past the knowledge stage to the decision stage in the innovation-decision process.

It is entirely possible that the Unaware who showed interest were not really interested in adopting cage aquaculture but responded in the affirmative, reasoning that perhaps, they could gain immediate benefit by expressing interest. Nonetheless, the finding that this study possibly mediated the decision process in cage aquaculture shows the potential of communication efforts in influencing adoption. For the uninterested in cage aquaculture, some reasons provided for lack of interest included 1) “it is a male job,” 2) wild-caught fish tastes better than farmed fish, 3) preference for fish trading and inability to combine trading with cage aquaculture, 4) fear of working on the water, and 5) complexity of cage aquaculture.

The influence of communication agents

Communication of aquaculture policies may play a significant role in defining the Unawareness and KPD stages. Rahman (2003) stated that education and extension play important roles in awareness creation, which I also observed. Apparently, both governmental and non-governmental institutions contributed to providing training for most individuals in KPD who reported training in cage aquaculture. Through training workshops, KPD individuals likely learned about government policies promoting cage aquaculture and improving livelihoods of, especially, communities surrounding the Volta Lake. With the majority of KPD individuals who had training being fishermen (with seasonal jobs), it appears that minimal challenges will be encountered when attempting to reach this group through cage aquaculture promotion programs. In contrast, the Unaware may represent the most difficult group to reach. Since most of the Unaware traded in fish, mass media methods such as radio and television suggested to efficiently create awareness of an innovation may not be efficient for them because their trade happens mostly in noisy market settings. Additionally, fish traders may be too busy to pay attention to these media even at home, since they spend a great deal of time preparing their products for the market. Therefore, communication efforts would have to be carefully planned to efficiently reach this group. Perhaps interpersonal communication, as I observed through the survey, may be an option to consider.

Perceived attributes of cage aquaculture and the influence of demographics on adoption

Many researchers have discussed the role of perceived attributes of innovations on adoption decisions (Byerlee and de Polanco 1986; Adesina and Zinnah 1993; Guerin and Guerin 1994; Adesina and Baidu-Forson 1995; Adesina and Seidu 1995; Rogers 2003). In this study, all the five attributes; relative advantage, compatibility, complexity, trialability, and observability, appeared to significantly influence the innovation-decision process. However, relative advantage is probably the most important attribute that determined the likelihood for adoption among the innovation-decision stages identified. Enyong *et al.* (1999) reported perceived profitability as one of the rationales behind farmers' adoption of soil-fertility enhancing technologies. Sixty percent of all Adopters reported that cage aquaculture was either very profitable or moderately profitable. Additionally, 91% of Adopters said they would recommend cage aquaculture to potential farmers, with more than half of them (57%, n = 44) recommending cage aquaculture on the basis of its profitability.

The dominant reasons provided by the Confirmed for adopting cage aquaculture (16 out of 21 qualitative responses) directly indicated a perception of relative advantage of cage aquaculture.

Many individuals in the both the Abandoned and KPD groups also cited profitability and easy management of cages as reasons for interest in cage aquaculture suggesting a relative advantage of cage aquaculture over their current occupation . In contrast, the Unaware may have judged cage aquaculture as less advantageous in terms of profitability. Fish trading, apparently, is very profitable (Robertson 1974). Fish farmers have frequently complained that fish traders make most of the profit in the aquaculture industry which goes to support why fish traders may typically not be interested in cage aquaculture or any fish farming for that matter. Whereas fishing is seasonal, fish traders have the flexibility of dealing with different fish suppliers. Some women revealed that they bought fish directly from their husbands, the fishermen, maximizing their profit. Thus, it could take a severe decline in capture fisheries for fish traders to look for alternatives. Even though in this study, the fish traders surveyed mostly traded in wild-caught fish, the presence of fish farmers in the fishing industry could potentially broaden the customer base of fish traders ensuring "constant" supply. Unlike fishermen who will readily embrace the innovation due to their seasonal jobs, fish traders may not see a clear need for cage aquaculture adoption.

Gillespie *et al.* (2008) reported unfamiliarity and non-applicability as the two most cited reasons for non-adoption of best management practices by cattle farmers. Awareness of an innovation through direct observation and possibly hands-on trials also contributes to willingness to adopt. Matata *et al.* (2008) found that farmers' lack of awareness was a major constraint to planting improved fallows. Due to having knowledge in cage aquaculture, and in some cases, training, the Confirmed, Abandoned, and KPD would be more interested in cage aquaculture than Unaware. Conceivably, some Unaware may have seen or heard about cage aquaculture. However, because they may perceive cage aquaculture as unprofitable or non-applicable to them, they are likely to interpret any information regarding cage aquaculture inconsistent with the lifestyles, a condition facilitated by selective exposure and selective perception. Consequently, even if the Unaware observed cage aquaculture, they mostly likely would be oblivious to it (Rogers 2003).

Existing attitudes and beliefs more likely caused the Unaware to consider cage aquaculture as complex and incompatible. Batz *et al.* (1999) reported that relative complexity strongly influenced the adoption of 17 dairy technologies in Kenya. Understandably, cage aquaculture may be considered a complex innovation on the part of women who also formed the majority of the Unaware. The sheer fact that cage aquaculture involved working on a vast expanse of water similar to open water fishing, can be particularly daunting for aquaphobic individuals. In this study, it was evident that the Confirmed and Abandoned found cage aquaculture compatible with their current lifestyle or occupation. For the Confirmed, whether the individual practiced cage aquaculture on a full time or part time basis, it was obvious that they felt comfortable using the technology. However, together with the Confirmed, the Abandoned cited lack of complexity of cage aquaculture and easy management of cages as a reason for their interest in adoption. More than half of the Confirmed (51%) had experience in other fish related activities including fishing and pond aquaculture, and almost all the Abandoned had a history of fishing. A past experience with fishing or fish farming may explain why some Confirmed and Abandoned cited easy management of cages as a reason for interest to adopt cage aquaculture. Similarly, since KPD had a good representation of fishermen, they more likely will find cage aquaculture compatible and will be comfortable with routine work such as cage maintenance.

Differences in demographics: the role of gender and tribe in cage aquaculture adoption

The significant lack of women among the Confirmed supports the notion that cage aquaculture is perceived as a male-dominated occupation. The role of women in sub-Saharan Africa and beyond in the fisheries industry has been well documented. Women have primarily been involved in the post-harvest sector, concentrating on processing and marketing (Walker 2001, 2002; Browne 2002; Bennett 2005; Heck *et al.* 2007; Weeratunge *et al.* 2010). However, aquaculture, like fisheries need not be regarded as a "male-dominant" occupation. Nandeesha (2009) suggested that women need to be involved in the mainstream aquaculture production. A women-led aquaculture initiative is possible and has many advantages (Bhujel *et al.* 2008). Lebel *et al*. (2009) found that women active in cage aquaculture have been as successful as their male counterparts.

The Confirmed, Abandoned, KPD and Unaware differed significantly with respect to tribe. Cage farmers and KPD tended to be Ewe whereas Unaware tended to be Ga-Dangme. The fact that Ewes are among the minorities in the Eastern Region (Ghana Statistical Service 2005a), but formed the majority of Adopters, Abandoned and KPD adopters in the region suggests that they are more inclined to relocate for the purposes of cage aquaculture. Anning *et al.* (2012) also found that Ewes, though not originally from the Effutu area in the Western region made up a good number of the fishermen studied, supporting the results that Ewes could be more inclined to adopt cage aquaculture than other tribes.

Differences in rankings of constraints

Having implemented cage aquaculture, the Confirmed and Abandoned were more in the position to say which constraints mattered so I expected that implementers would rank constraints differently than non-implementers. Consequently, the differences observed in the ranking of the constraints by the individuals at the different stages in the innovation-decision process seem intuitive. The Confirmed and Abandoned had similar rankings of constraints compared to KPD and Unaware. As implementers of cage aquaculture, Confirmed and Abandoned have been exposed to what constraints exist with using the innovation, and they can best provide credible information about constraints practitioners face. On the other hand, potential adopters are a good source of understanding the constraints preventing individuals interested in cage aquaculture from implementation. KPD rankings provide insight into what prevents potential adopters from implementing cage aquaculture. Meanwhile, since the Unaware lacked knowledge and interest in cage aquaculture I expected them not to be concerned about constraints in cage aquaculture, which is exactly what I found.

Conclusions

In this study, I developed a cage aquaculture innovation-decision process model to understand cage aquaculture adoption decisions in Ghana. I found that respondents differed in terms of knowledge and interest, and could be placed in different stages of the cage aquaculture innovation-decision process model: (1) Unawareness, (2) Knowledge, Persuasion, and Decision (KPD), and (3) Implementation (Confirmation and Abandonment). Respondents in the KPD and Implementation stages had knowledge, were more interested in cage aquaculture, and were aware of constraints in cage aquaculture, whereas respondents in the Unawareness stage lacked knowledge and interest in cage aquaculture, and did not clearly understand the constraints. Respondents also differed in demographic variables. Whereas respondents in the KPD and Implementation stages tended to be male, fishermen and mostly in the tribe Ewe, respondents in Unawareness tended to be female, fish traders and belonged to the tribe Ga-Dangme.

The results from this study have implications for efforts promoting cage aquaculture adoption;

1. Efficient communication between policy makers and cage fish farmers is needed to improve the knowledge of cage aquaculture policies and to ensure sustainable adoption.
2. It may be necessary to intensify communication efforts to encourage adoption among potential adopters but the effort should be focused on creating a need for cage aquaculture.
3. Meanwhile, the Abandoned who are willing to re-adopt, and KPD who are willing to start cage aquaculture could be the focus of future programs aimed at increasing adoption.

Table 1.1 - Comparison of demographic variables among Adopters, Abandoned and Potential Adopters.

	Adopters	Abandoned	Potential Adopters
Gender [a]			
Female	-	10%	56%
Male	100%	90%	44%
Tribe [a]			
Ewe	57.8%	85.0%	54.4%
Akan	31.1%	-	1.8%
Ga-Dangme	6.7%	15.0%	42.0%
Other	4.4%	-	1.8%
Education (high school and above)	64%	30%	14%
Age (years):			
25 or under	4%	5%	12%
26 – 35	40%	10%	23%
36 – 45	31%	40%	32%
46 – 55	11%	25%	23%
56 – 65	7%	10%	9%
66 – 75	7%	5%	-
76 or under	-	5%	2%
Distance (km)			
Under 1	67%	60%	46%
1.0 – 5.9	9%	35%	37%
6.0 – 10.9	11%	5%	18%
11.0 – 15.9	-	-	-
16.0 – 20.9	2%	-	-
.			
.			
.			
81.0 and above	11%	-	-

[a] Fisher's exact test of the distribution of gender and tribe of Adopters, Abandoned and Potential Adopters shows significant differences (p < 0.000). Sample size (n) for Adopters, Abandoned, and Potential Adopters are 45, 20 and 57 respectively.

Table 1.2 - Comparison of variable responses between Knowledge, Persuasion, and Decision (KPD), and Unaware among Potential Adopters.

Variable	Unaware	KPD
Do you have knowledge and training in cage aquaculture? [a]		
Yes	17	0
No	20	20
Is there a government policy promoting cage aquaculture in Ghana? [a]		
Yes or No	24	1
Don't know	13	19
Is there a government policy limiting cage aquaculture in Ghana? [b]		
Yes or No	16	3
Don't know	21	17
Is a farmer required to have a government permit to start cage aquaculture? [c]		
Yes or No	17	4
Don't know	20	16
Are you interested in starting cage aquaculture on the Volta Lake? [a]		
Yes or No	36	3
Not sure	1	17
Are you interested in practicing cage aquaculture if constraints are removed? [a]		
Yes or No	37	6
Not sure	0	14

[a] Fisher's exact test of the distribution of responses between KPD and Unaware showed significant differences (p = 0.000). Sample size (n) is 57.

[b] Fisher's exact test of the distribution of responses between KPD and Unaware showed significant differences (p = 0.041). Sample size (n) is 57.

[c] Fisher's exact test of the distribution of responses between KPD and Unaware showed no significant differences (p = 0.0847). Sample size (n) is 57.

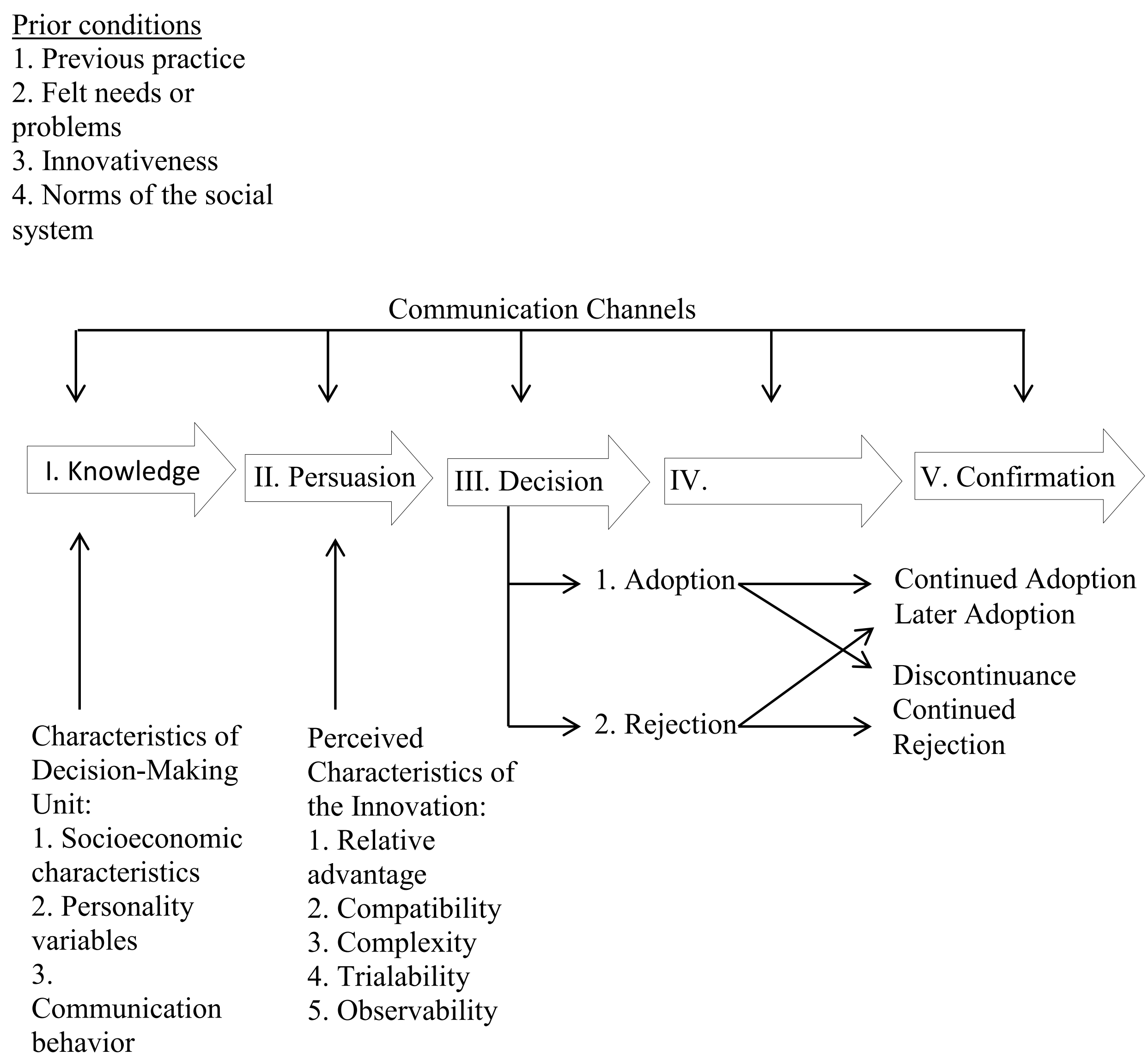

Figure 1.1 - The five stages of the innovation-decision process model (Rogers 2003).

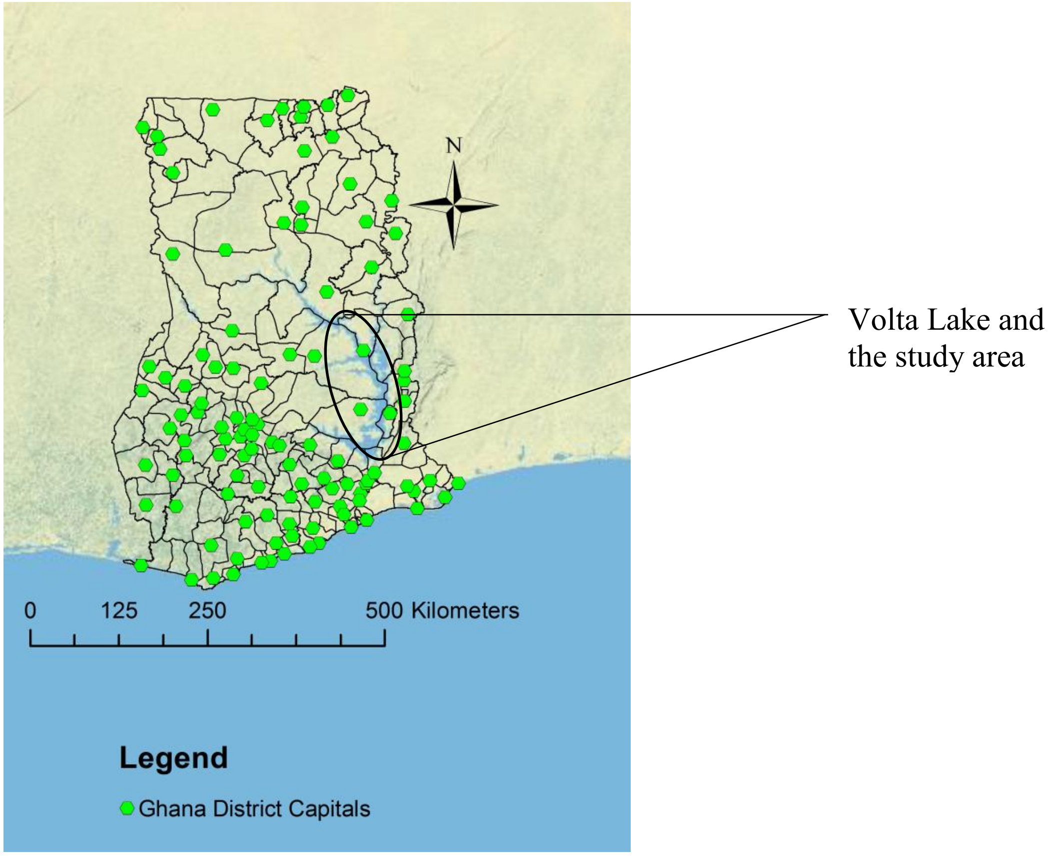

Figure 1.2 - Map of Ghana showing the Volta Lake and the study area.

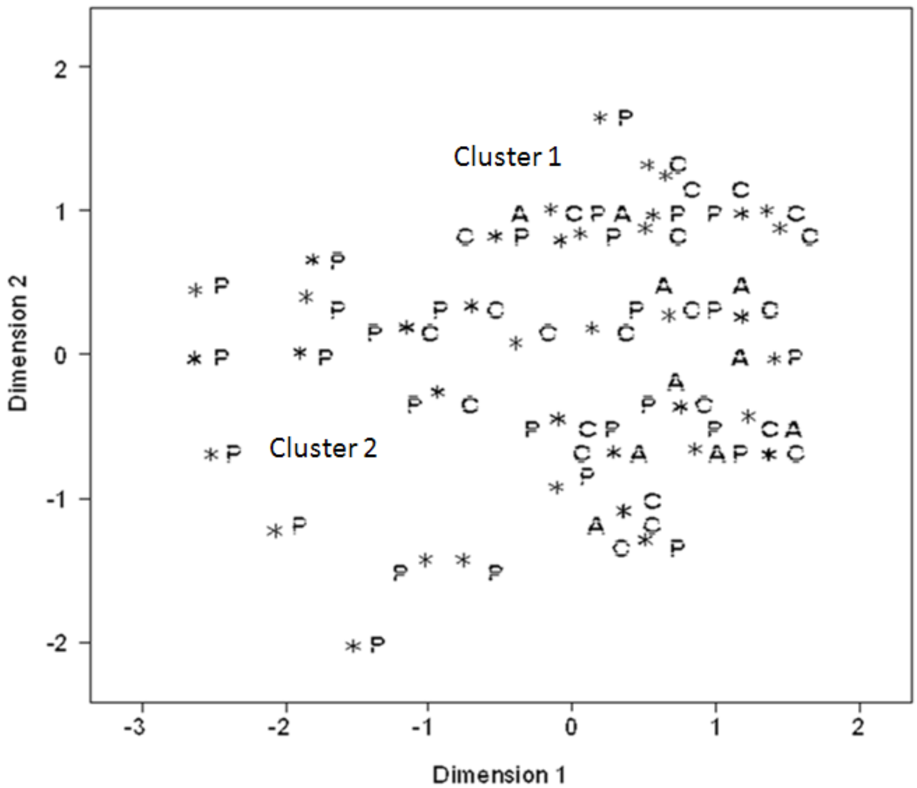

Figure 1.3 - Relationship of C (Adopters), A (Abandoned), and P (Potential Adopters) in two-dimensional space according to their responses to knowledge and interest questions in cage aquaculture showing Clusters 1 and 2. Total sample size (n) is 122.

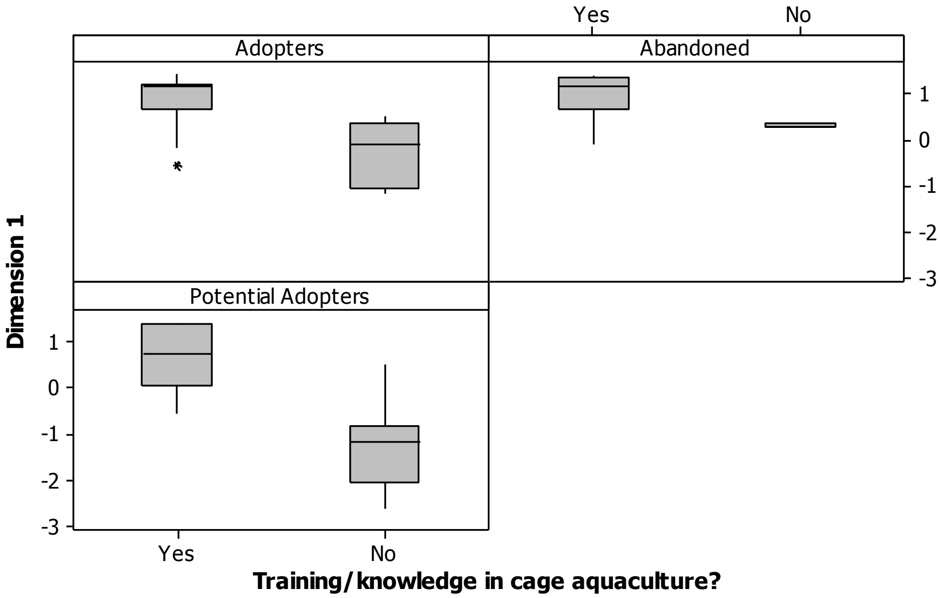

Figure 1.4 - Distribution of responses to "training/knowledge in cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

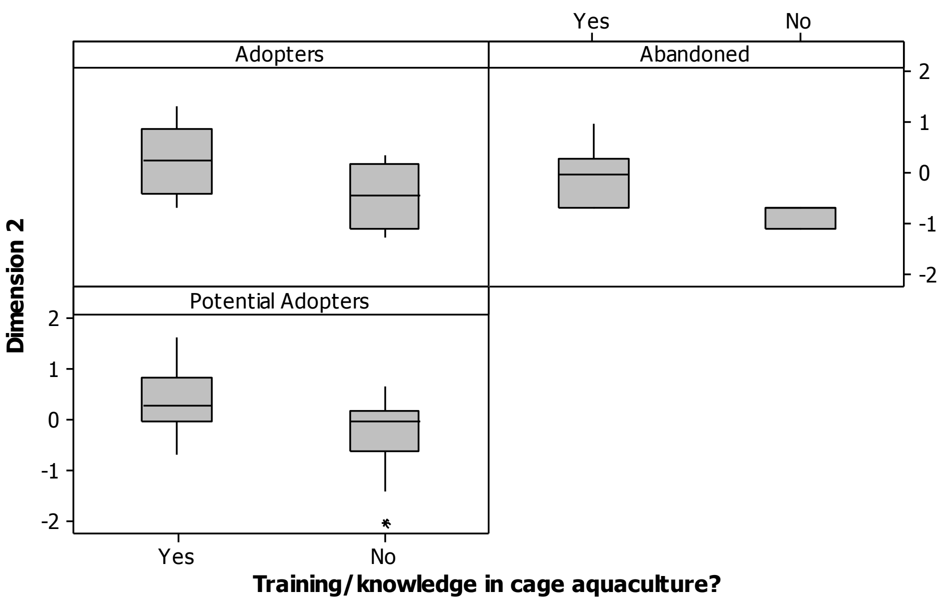

Figure 1.5 - Distribution of responses to "training/knowledge in cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 2, the axis of the non-metric multidimensional scaling plot which, together with Dimension 1, helped in explaining respondent-stage relationships. Outliers are marked with asterisks. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

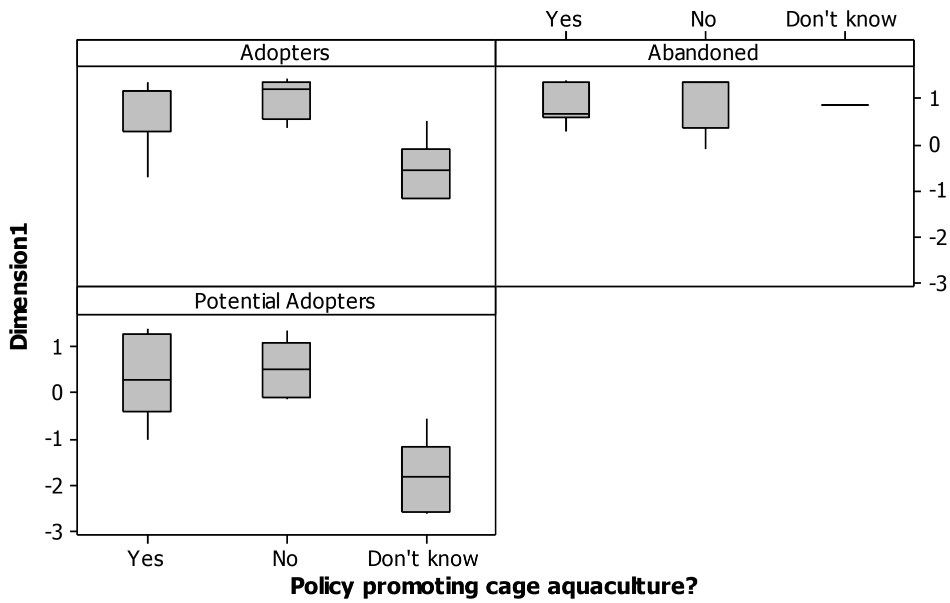

Figure 1.6 - Distribution of responses to "policy promoting cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

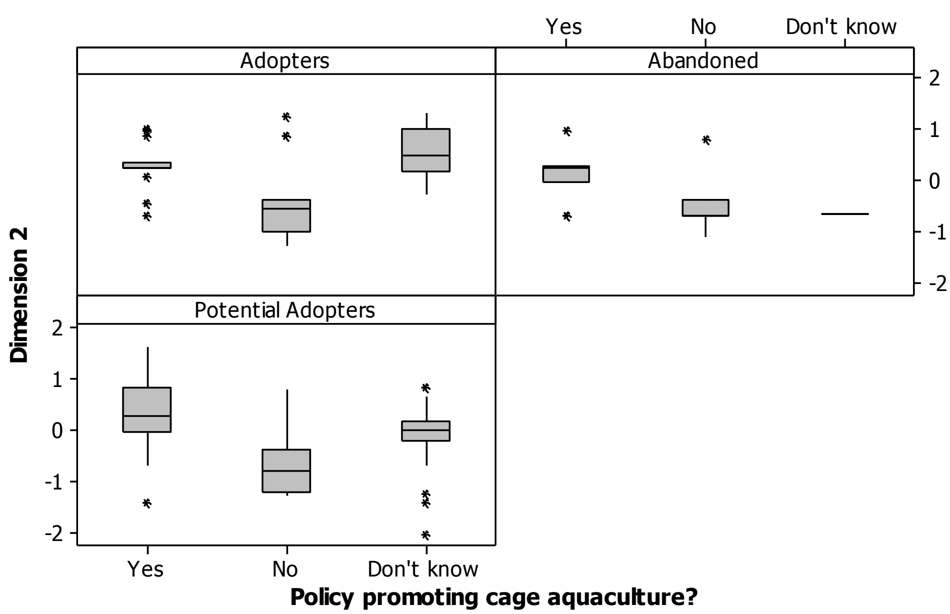

Figure 1.7 - Distribution of responses to "policy promoting cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 2, the axis of the non-metric multidimensional scaling plot which, together with Dimension 1, helped in explaining respondent-stage relationships. Outliers are marked with asterisks. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

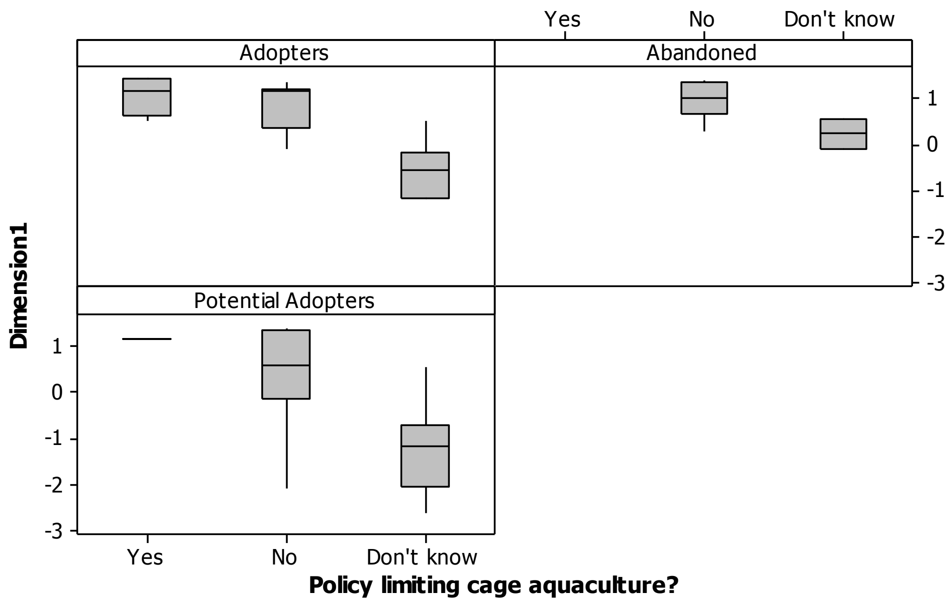

Figure 1.8 - Distribution of responses to "policy limiting cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

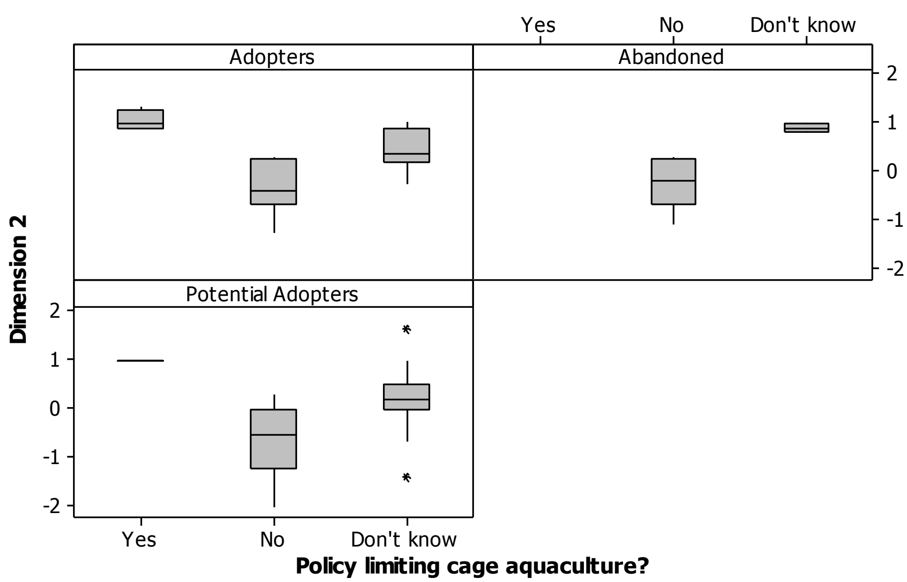

Figure 1.9 - Distribution of responses to "policy limiting cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 2, the axis of the non-metric multidimensional scaling plot which, together with Dimension 1, helped in explaining respondent-stage relationships. Outliers are marked with asterisks. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

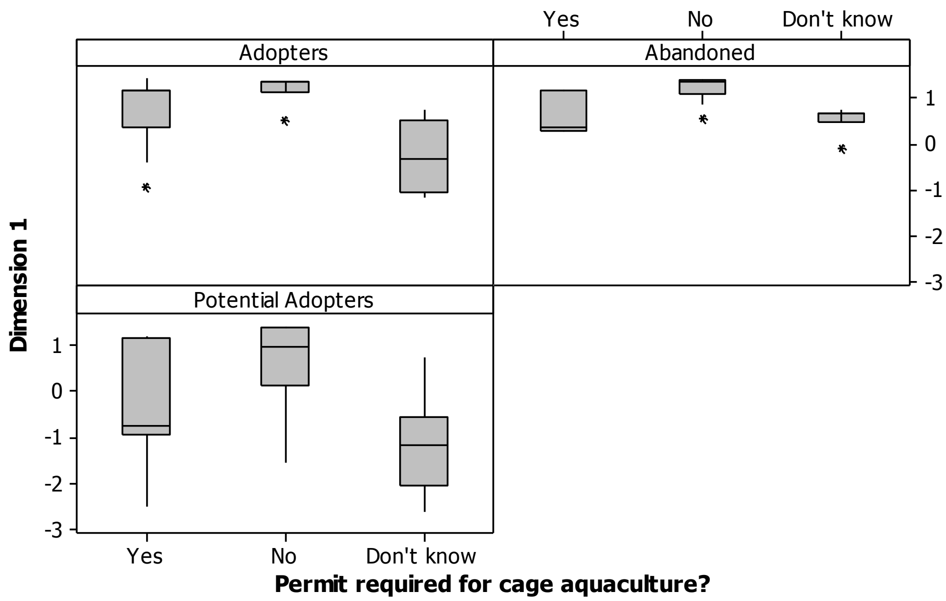

Figure 1.10 - Distribution of responses to "permit required for cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

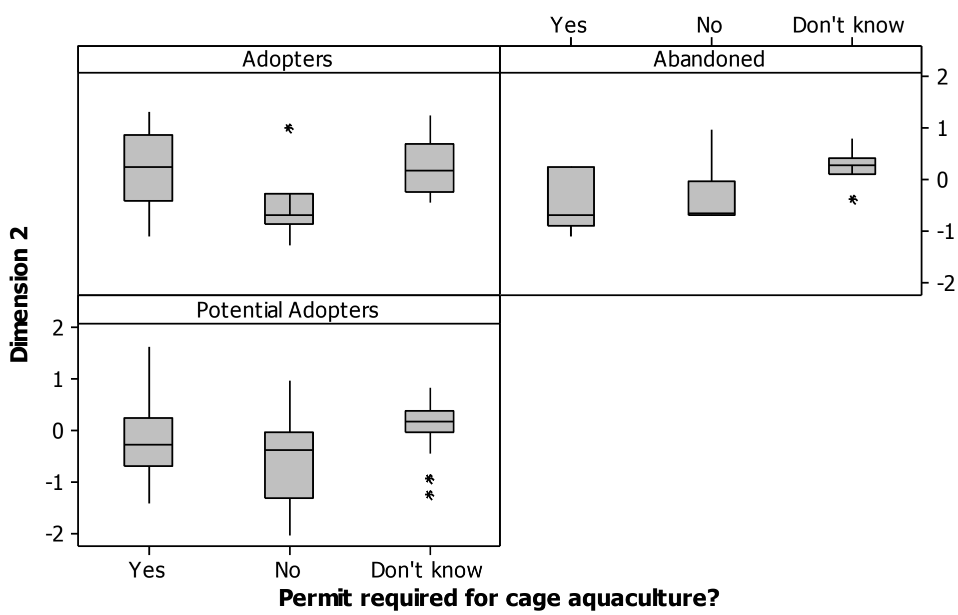

Figure 1.11 - Distribution of responses to "permit required for cage aquaculture" for Adopters, Abandoned and Potential Adopters on Dimension 2, the axis of the non-metric multidimensional scaling plot which, together with Dimension 1, helped in explaining respondent-stage relationships. Outliers are marked with asterisks. Total sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20 and 57 respectively.

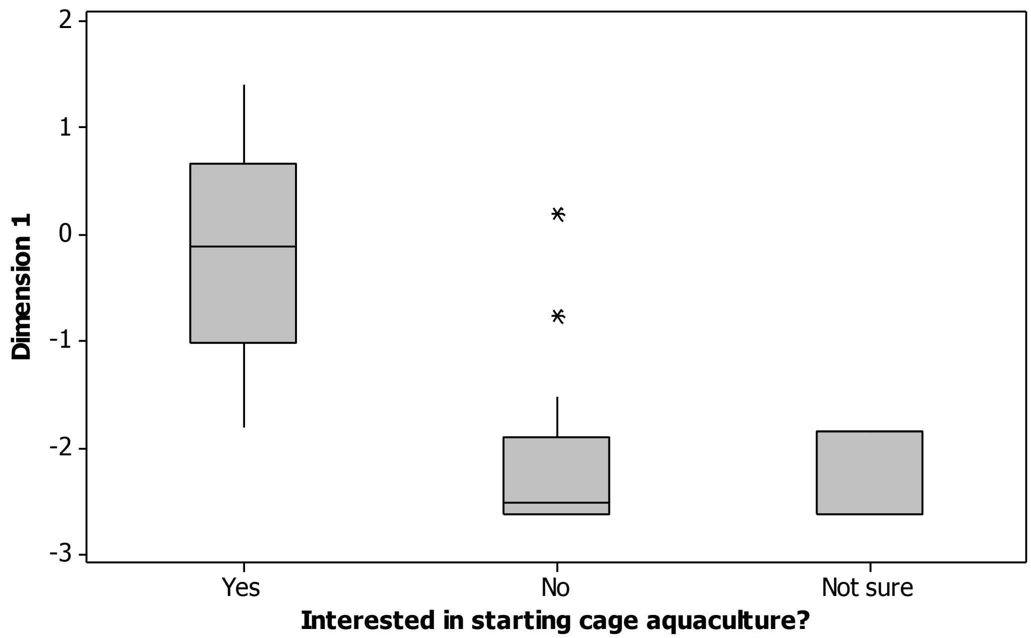

Figure 1.12 - Distribution of responses to "interested in starting cage aquaculture" for Potential Adopters on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 57.

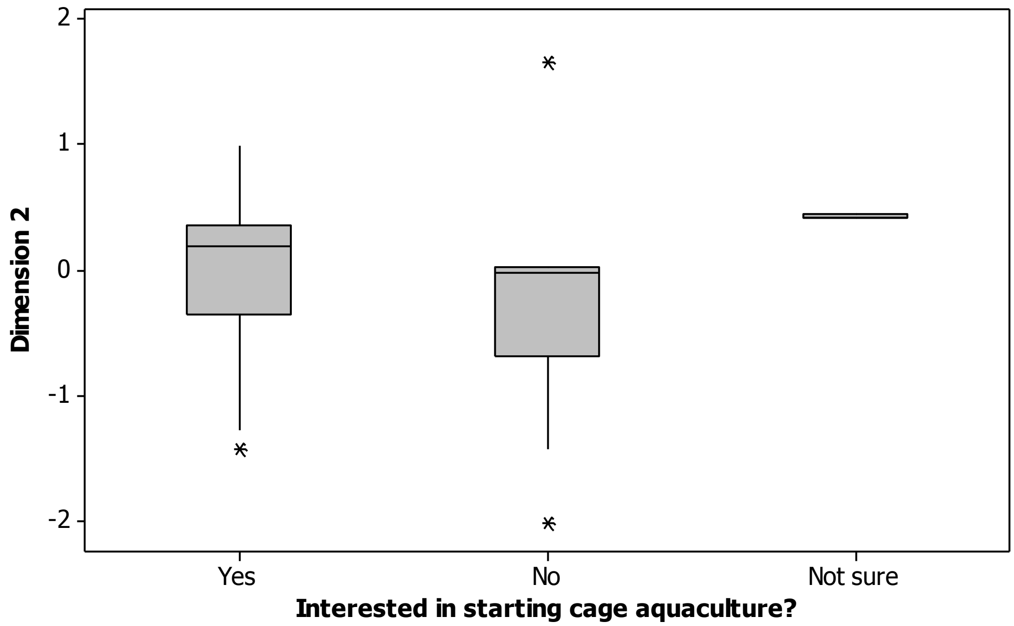

Figure 1.13 - Distribution of responses to “interested in starting cage aquaculture” for Potential Adopters on Dimension 2, the axis of the non-metric multidimensional scaling plot which, together with Dimension 1, helped in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 57.

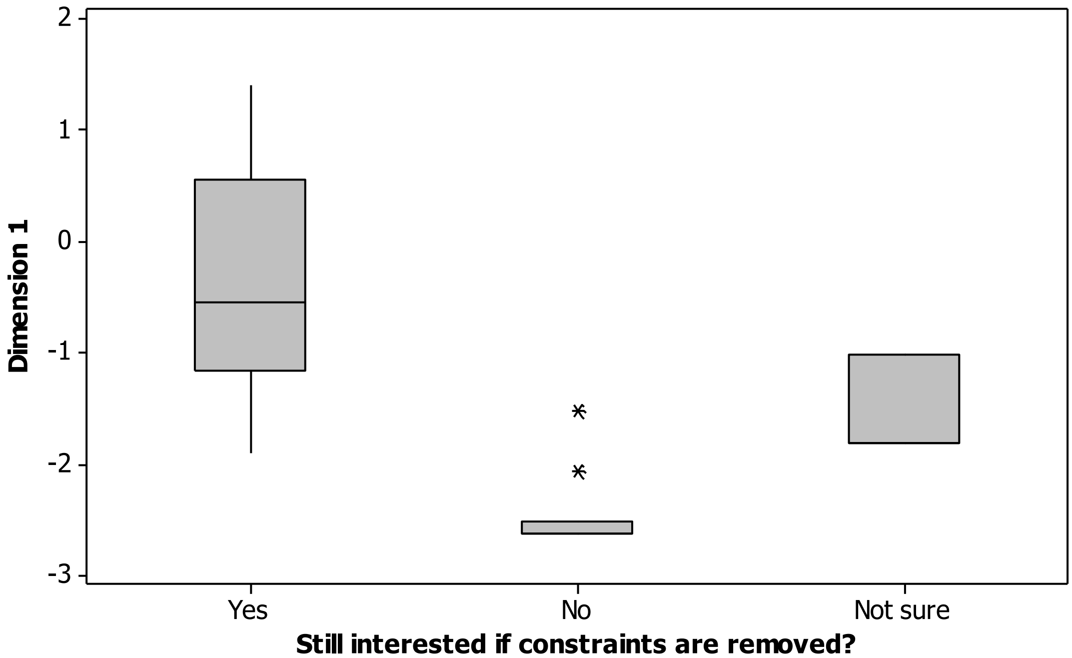

Figure 1.14 - Distribution of responses to "interest to start/continue if constraints are removed" for Potential Adopters on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 57.

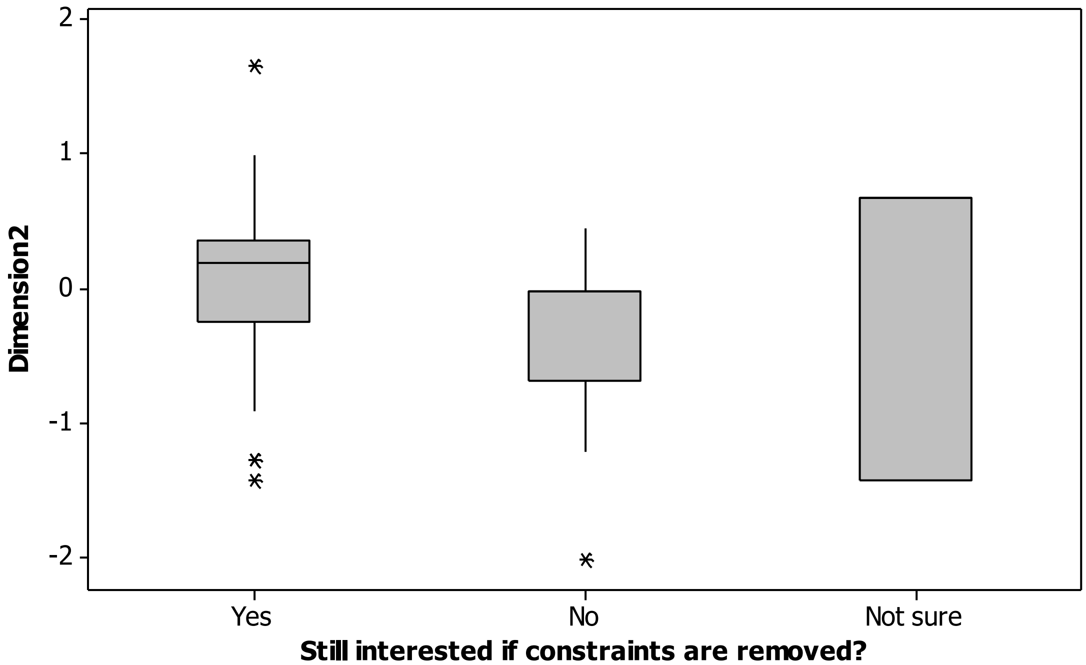

Figure 1.15 - Distribution of responses to "interest to start/continue if constraints are removed" for Potential Adopters on Dimension 2, the axis of the non-metric multidimensional scaling plot which, together with Dimension 1, helped in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 57.

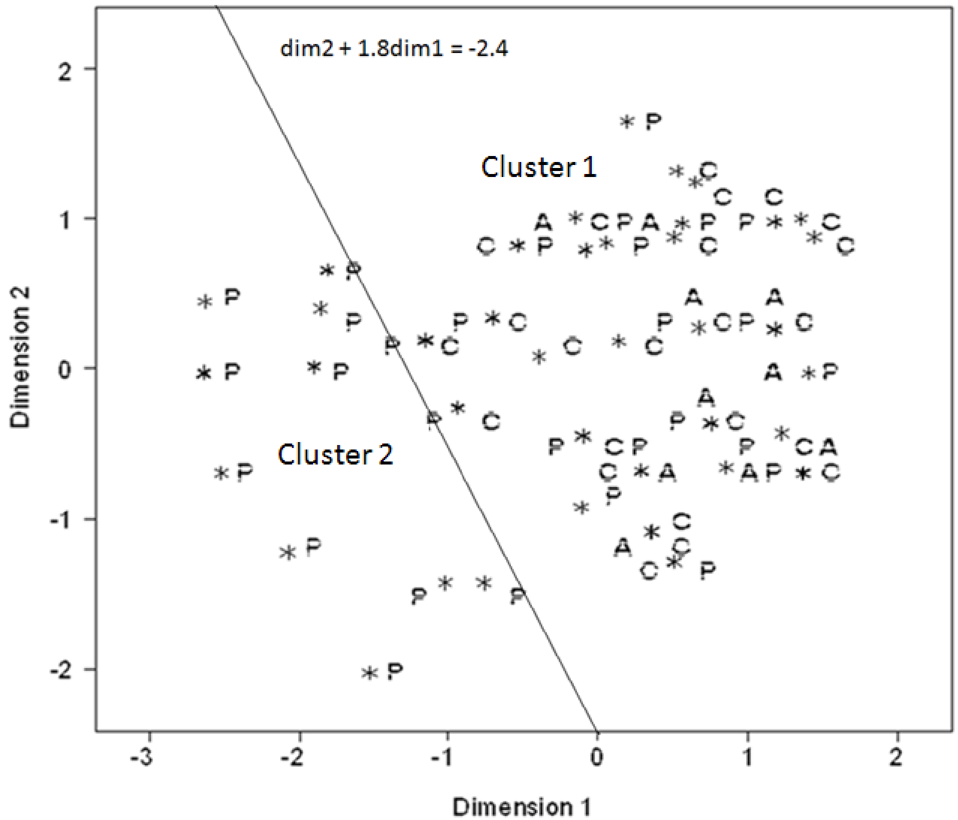

Figure 1.16 - Relationship of C (Adopters), A (Abandoned), and P (Potential Adopters) in two-dimensional space according to their responses to knowledge and interest questions in cage aquaculture showing a discriminant function separating Cluster 1 from Cluster 2. Total sample size (n) is 122.

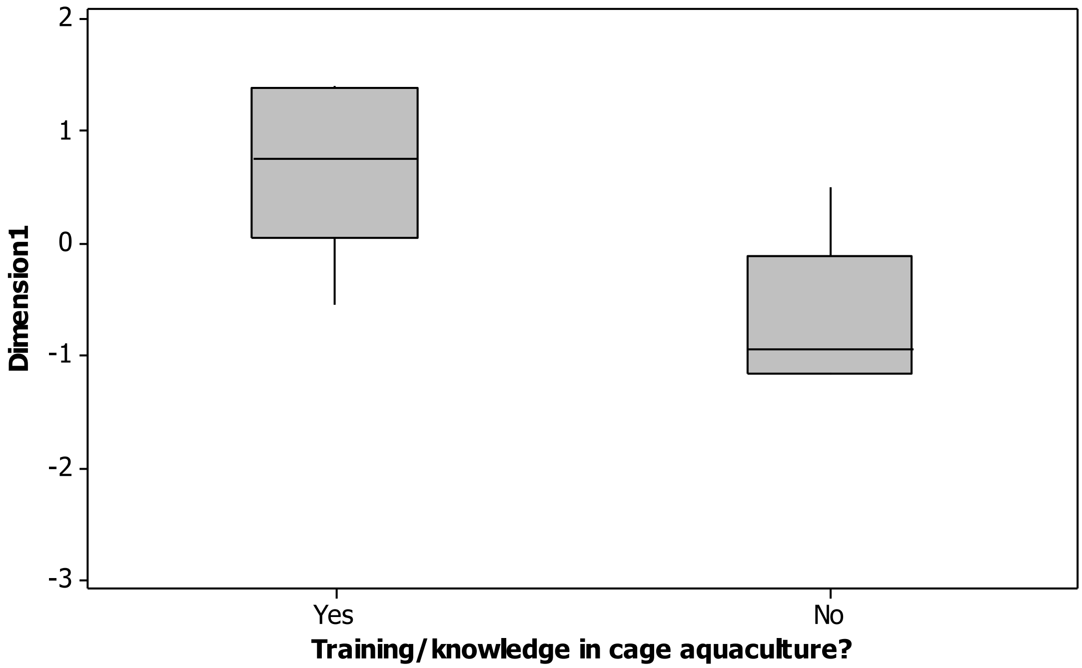

Figure 1.17 - Distribution of responses to “training in cage aquaculture” for KPD on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Sample size (n) is 37.

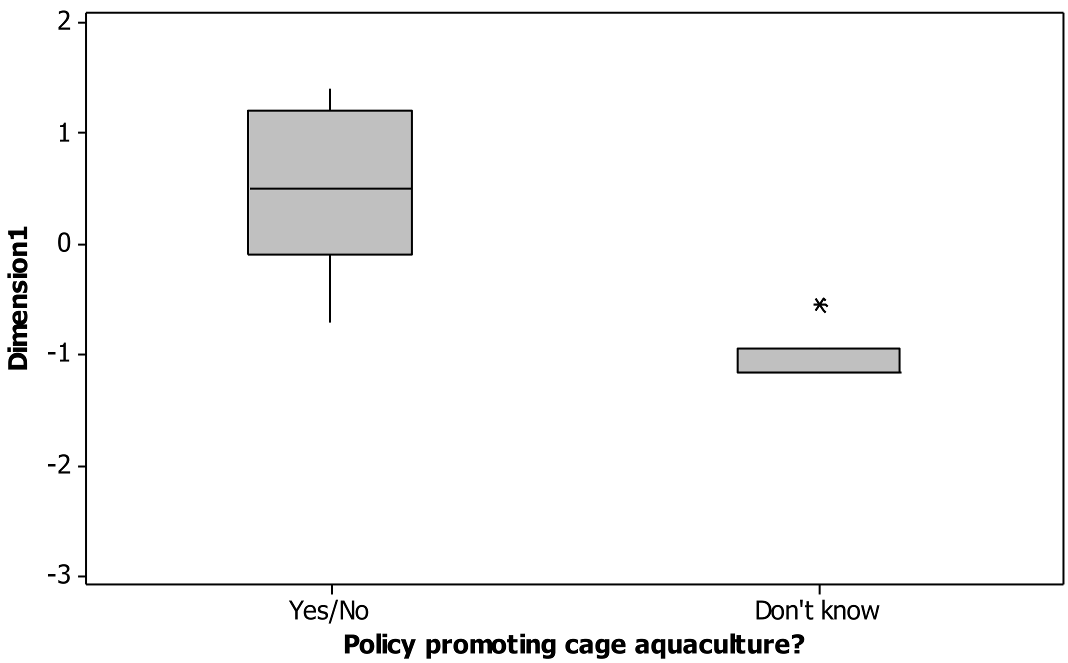

Figure 1.18 - Distribution of responses to "policy promoting cage aquaculture" for KPD on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 37.

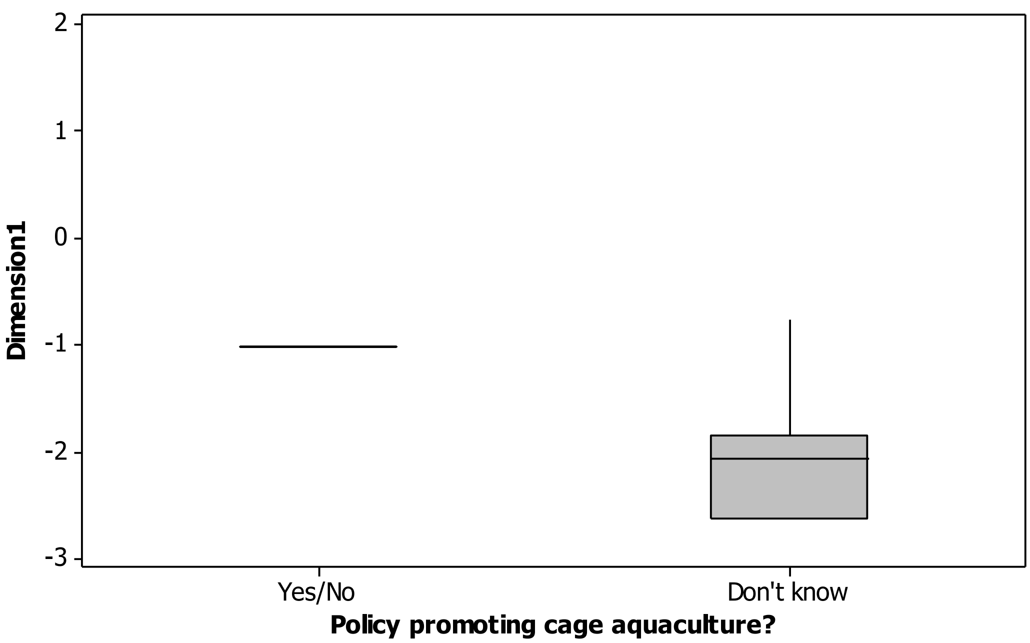

Figure 1.19 - Distribution of responses to "policy promoting cage aquaculture" for Unaware on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 20.

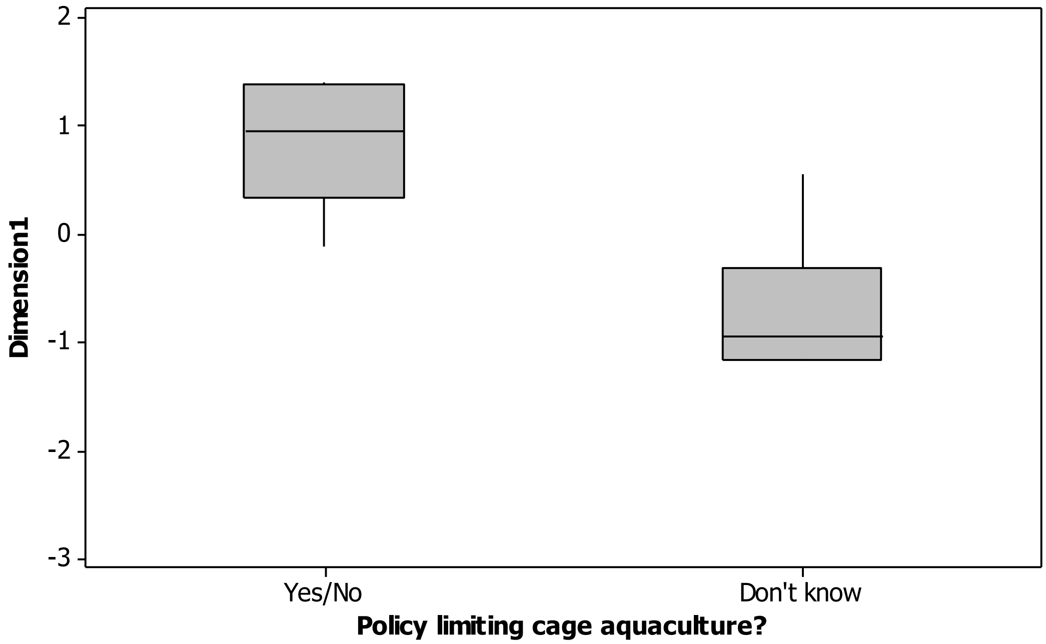

Figure 1.20 - Distribution of responses to “policy limiting cage aquaculture” for KPD on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 37.

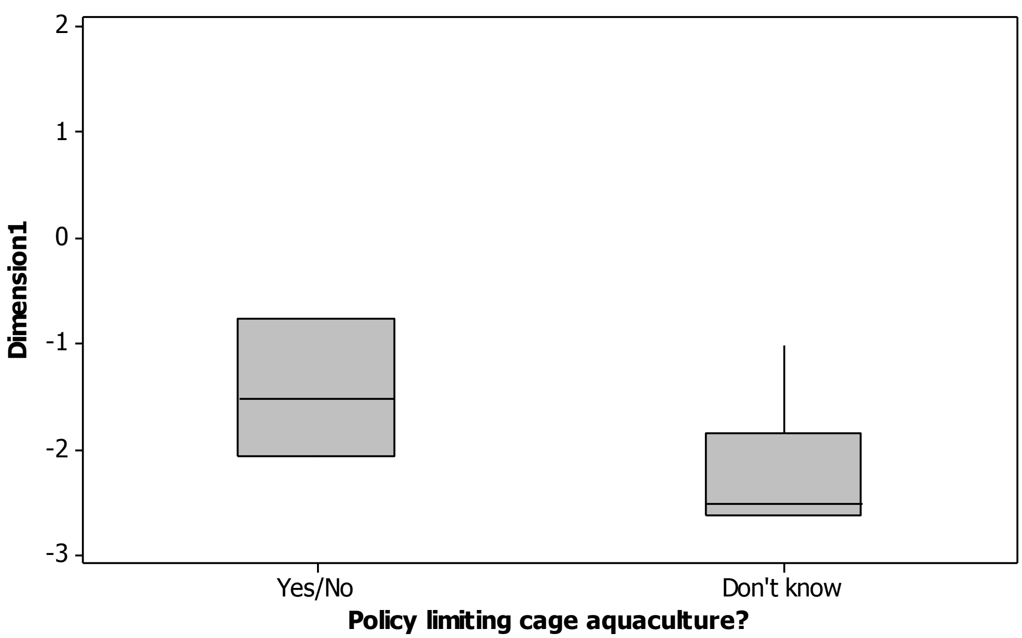

Figure 1.21 - Distribution of responses to “policy limiting cage aquaculture” for Unaware on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 20.

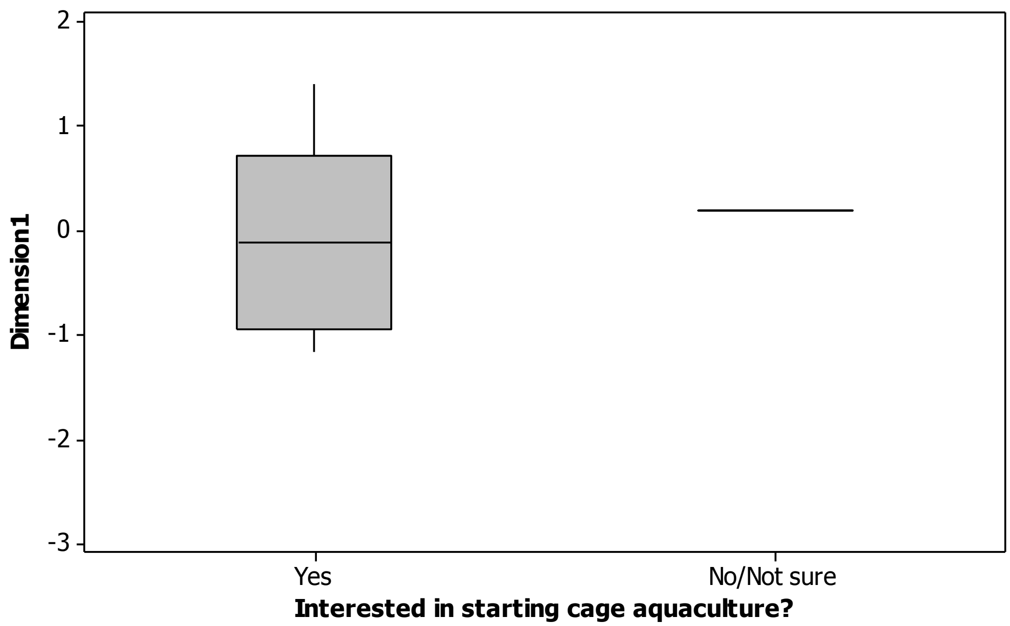

Figure 1.22 - Distribution of responses to "interested in starting cage aquaculture" for KPD on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 37.

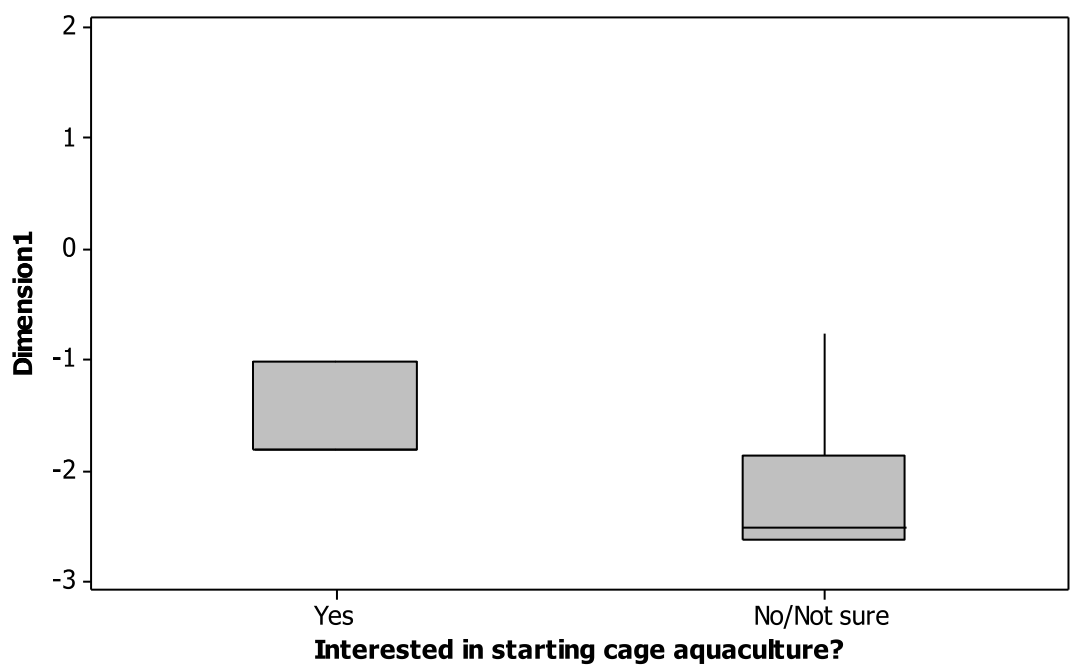

Figure 1.23 - Distribution of responses to "interested in starting cage aquaculture" for Unaware on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 20.

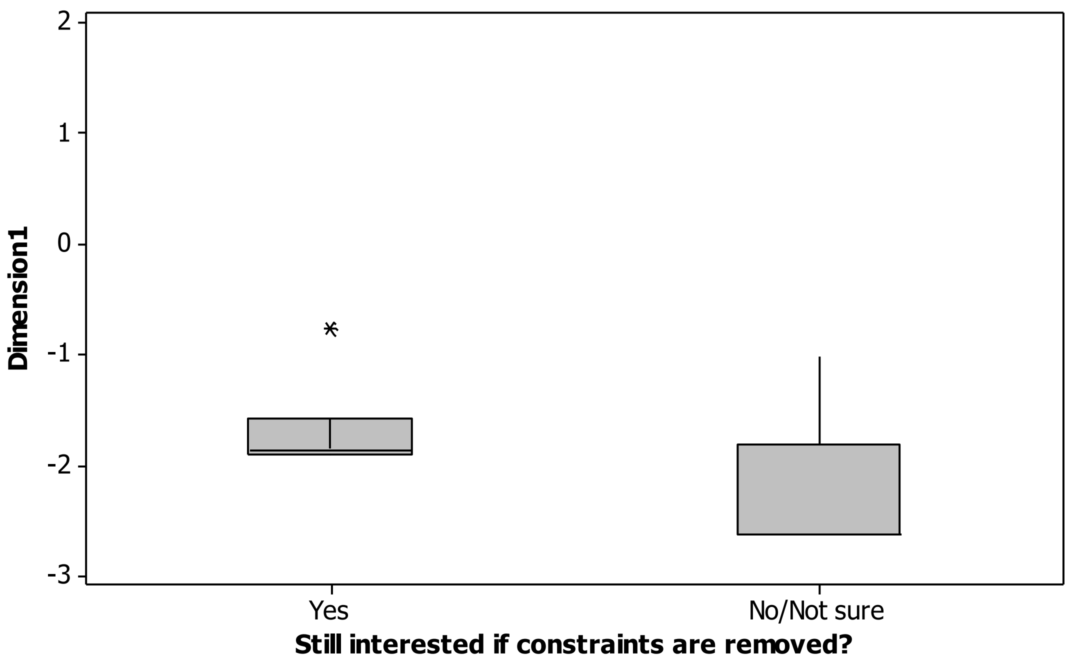

Figure 1.24 - Distribution of responses to "interest to start/continue if constraints are removed" for Unaware on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Outliers are marked with asterisks. Sample size (n) is 20.

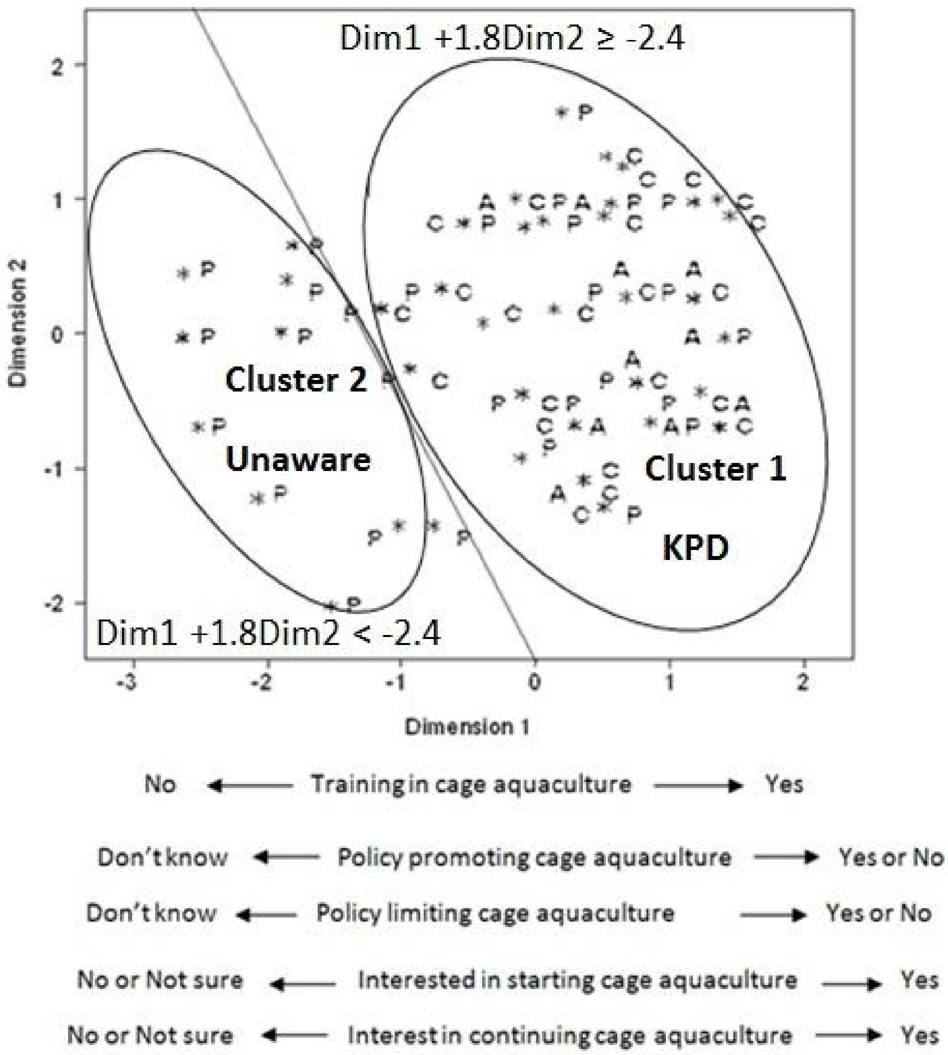

Figure 1.25 - Respondent-stage relationships for two groups of Potential Adopters: KPD (Knowledge, Persuasion and Decision), and Unaware, on Dimension 1, the axis of the non-metric multidimensional scaling plot which was particularly useful in explaining respondent-stage relationships. Sample size (n) for KPD and Unaware are 37 and 20 respectively.

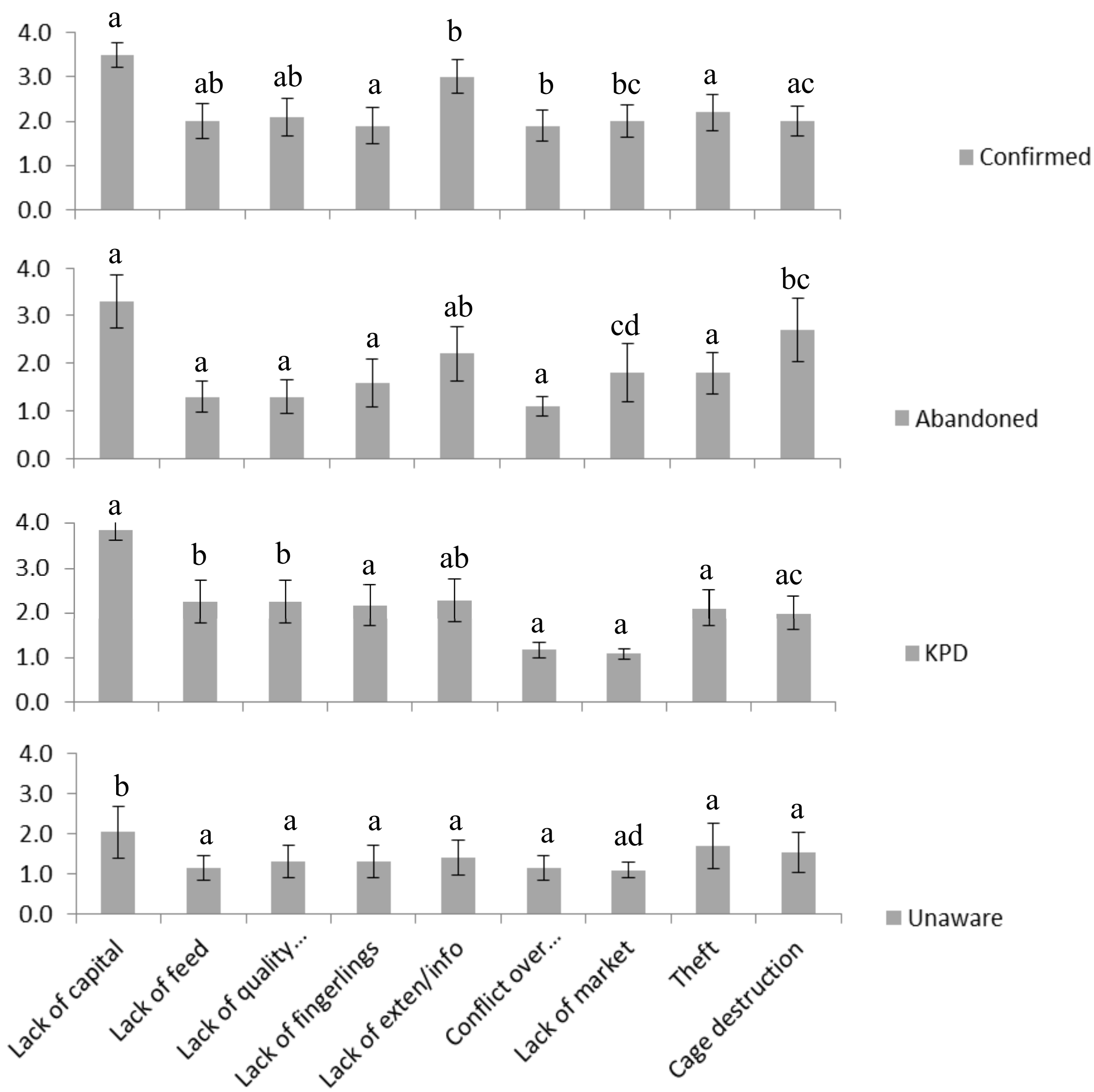

Figure 1.26 - Mean rankings of 9 constraints for Confirmed, Abandoned, KPD (Knowledge, Persuasion and Decision), and Unaware. The ranking is based on a 4-point scale, where 1 is not-important and 4 is very-important. Total sample size (n) for Confirmed, Abandoned, KPD, and Unaware are 45, 20, 37, and 20 respectively. Error bars are 95% confidence intervals. Comparison among groups is vertical across constraints. Constraints with similar letters means that rankings are not significantly different at α = 0.05 among groups.

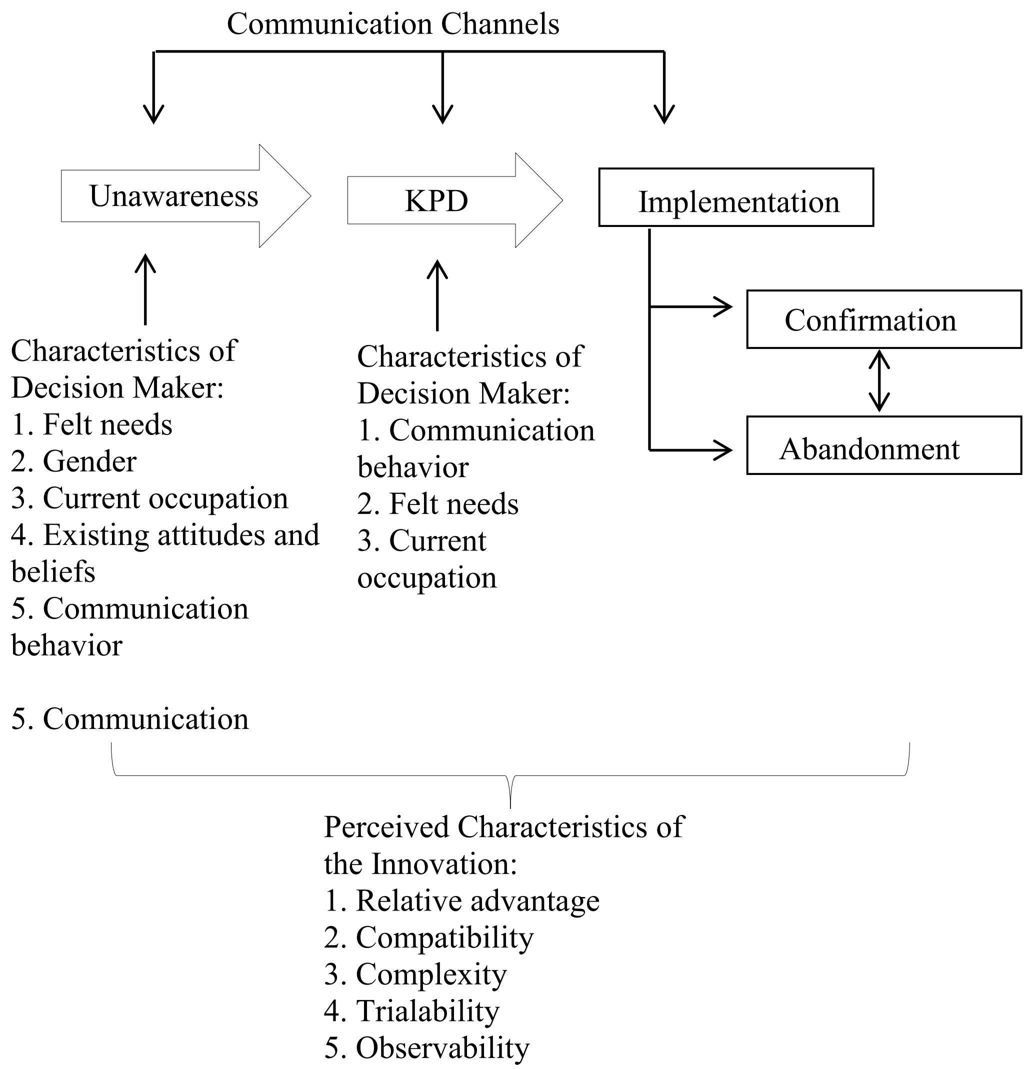

Figure 1.27 - A modification of Roger's model to describe cage aquaculture innovation-decision stages in Ghana. KPD represents Knowledge, Persuasion, and Decision. Adapted from Rogers (2003).

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Chapter 2: Factors affecting the adoption of cage aquaculture in Ghana

Abstract

Interest in freshwater cage aquaculture in Ghana has increased in the last decade, but the potential of cage aquaculture to significantly increase local fish production has not been realized. This study was conducted to identify the factors affecting cage aquaculture adoption and to provide recommendation to help policy makers develop appropriate strategies for promoting cage aquaculture adoption. In summer 2010 and 2011, I surveyed current cage fish farmers (Adopters), farmers who have abandoned cage aquaculture (Abandoned), and potential adopters of cage aquaculture, such as fishermen and fish traders. Respondents answered questions related to constraints in cage aquaculture, and demographics. I used the cage aquaculture innovation-decision model previously developed and stepwise discriminant function analysis to identify factors affecting cage aquaculture adoption in Ghana. I found that the demographic factors, gender, tribe and occupation, influenced adoption decisions prior to the implementation of cage aquaculture. Respondents who were males, belonged to the tribes Ewe and Akan, and who had fishing experience tended to be more interested in cage aquaculture. I also found that the lack of capital, high input costs, inability to adequately market fish, theft, lack of information sources, conflict over water use, and cage destruction by storms were the main constraints to cage aquaculture adoption, especially during implementation. Efforts aimed at encouraging cage aquaculture adoption should account for these factors. The recommendations provided in this study could help to ensure that adoption of cage aquaculture in Ghana is both productive and sustainable.

Introduction

Freshwater cage aquaculture adoption has the potential to significantly increase fish yields and transform an entire aquaculture industry (Baotong and Yeping 1998). In Ghana, the potential of cage aquaculture to increase fish production was exhibited in 2004, when a single commercial cage farm contributed about 21% (200 tons out of 950 tons of tilapia) to total aquaculture production (Awity 2005). Ofori *et al*. (2010) suggested that if cage farmers in Ghana can produce yields of 50-150 kg/m^3/9 months as done elsewhere in Africa, less than 100 hectares of fish cages can produce yields matching the current capture fisheries production of 90,000 mt. The numbers of Ofori *et al*. (2010) suggest that with only about 450 hectares of water (less than 1% of the area of the Volta Lake), Ghana could eliminate an estimated deficit of 400, 000 mt and produce a surplus of about 5,000 mt.

The fact that cage aquaculture has been practiced consistently in Ghana for about two decades but has failed to contribute significantly to overall local fish production, in terms of capture and culture fisheries, hints that major drawbacks exist in the adoption and use of the innovation. Extensive work has been done to document the constraints affecting aquaculture in Sub-Saharan Africa. Some of the assessments made for aquaculture in general have also been suggested as constraints affecting cage aquaculture in sub-Saharan Africa. Constraints have been categorized into lack of capital (Ridler and Hishamunda 2001; FAO 2004a; Moehl *et al.* 2006), lack of good quality fingerlings and feed (Ridler and Hishamunda 2001; FAO 2004a; Moehl *et al.* 2006; Blow and Leonard 2007; Asmah 2008), lack of technical know-how (Ridler and Hishamunda 2001; FAO 2004a; Blow and Leonard 2007; Asmah 2008), lack of market (Moehl *et al.* 2006), conflict over water use (Halwart and Moehl 2006), lack of access to information and support (Ridler and Hishamunda 2001; Moehl *et al.* 2006; Asmah 2008), and lack of legislation and government support (Ridler and Hishamunda 2001; Blow and Leonard 2007), among others.

Despite a great deal of research on aquaculture in sub-Saharan Africa, valuable tools such as empirical and predictive modeling which can be used to identify major constraints in cage aquaculture are lacking. This is probably because investigators have often been limited by the small number of cases encountered. For example, Blow and Leonard (2007), based on observations of only two commercial cage aquaculture farms, suggested that the lack of locally manufactured high quality feed was the most serious constraint to commercial cage aquaculture in Ghana. Thus, such data limitations may result in lumping findings together and describing problems for the entire sub-Saharan Africa.

Significant changes have occurred in the cage aquaculture industry of Ghana in the last decade. Currently, the industry has over 60 cage aquaculture enterprises with about 10 operating on a medium to large scale (10 cages or more; Anane-Taabeah, unpublished data). Abandonment of cage aquaculture has also been observed. Having multiple primary stakeholders, such as adopters, farmers who have abandoned the business, and potential adopters of aquaculture suggests that the factors affecting cage aquaculture in Ghana may be multifaceted. Constraints to cage aquaculture may vary from stage to stage in the innovation-decision process and should be understood as such. This goal of this study was to identify the factors affecting cage aquaculture that are unique to Ghana, using an empirical modeling technique, to assist policy makers in developing policy strategies and solutions targeting specific factors affecting different stages of adoption in Ghana.

The specific objective was to identify factors affecting cage aquaculture adoption using the cage aquaculture innovation-decision model which I have previously developed for Ghana. The cage aquaculture innovation-decision process model has the following stages: Unawareness; Knowledge, Persuasion, Decision (KPD); and Implementation (Confirmation and Abandonment). My specific research questions were: (1) which factors affect movement from Unawareness to Implementation, and (2) which factors affect adoption at the Abandonment and Confirmation stages?

Methods

Study area

The study was conducted in communities around the Volta Lake with present or past cage aquaculture activities (Figure 2.1). The Volta Lake is currently the main inland water body used for cage aquaculture in Ghana. The 8502 km^2 lake, (ILEC 1999), presents enormous opportunities for aquaculture expansion. Communities around the lake have mostly engaged in farming, and fishing, with the men mostly involved in active fishing and the women focusing on fish processing and trading. The Volta Lake and its tributaries drain 70% of the entire area of Ghana (FAO 2005), covering portions of the Northern, Volta, Eastern, and Brong-Ahafo Regions. The Eastern and Volta Regions were the focus of this study. I selected the respondent groups from several districts in these regions based on recommendations from the Fisheries Directorate.

Study methodology

I conducted the study through a survey in summer 2010 and 2011 with three respondents groups: current cage fish farmers (Adopters), cage fish farmers who have abandoned the trade (Abandoned), and Potential Adopters. My study focused on the Asuogyaman, Upper and Lower Manya Krobo, South and North Tongu, and Kwahu North Districts. These districts represented the hotspots of cage aquaculture in Ghana and areas where cage aquaculture abandonment has been observed. Based on my prior hypothesis that people with fish-related livelihoods were more likely to adopt cage aquaculture, I originally defined Potential Adopters as people already employed in fish activities, including fishermen and land-based fish farmers and fish traders, this made sampling easier for Potential Adopters since I had no sampling frame for this group otherwise. However, during the field surveys, I encountered individuals who did not have fish-related livelihoods but had received training in cage aquaculture and were awaiting cages promised them by the government in order to commence operations. I therefore, included these individuals in my Potential Adopters group.

With the exception of Potential Adopters, all respondent groups identified for this study had small populations. I surveyed the Potential Adopters group by approaching individuals and administering the surveys to those willing to participate in the study after the purpose of the study had been explained to them. For the Adopters and Abandoned, I obtained a list of names from officers at the Fisheries Directorate, Ghana, and other reliable sources. I contacted individuals with active phone numbers before visiting their farms or other work places to conduct the surveys. Where I could not contact farmers directly, I employed opinion leaders such as leaders of fish farmers' associations, and other cage farmers to help access them. With the help of a field assistant, I administered the questionnaires in person to ensure answers provided were directed to exact questions asked. However, some Adopters filled out their own questionnaires. Accordingly, using a follow-up member check, which I conducted by calling Adopters who filled out their own questionnaires, I clarified all their responses to ensure consistency in the data.

Survey instrument

I designed three questionnaires specific to each target group (Appendices D-F). However, to enable modeling of factors affecting adoption across groups, I included similar questions in all questionnaires but modified the wording to suit the particular group. I assessed two main dimensions: socioeconomic constraints and demographics, which the literature (Rauniyar 1998; Manatunge *et al*. 2001; Miyata and Sawada 2006; He *et al*. 2007) suggests are important dimensions when exploring factors predicting the adoption of an innovation.

I measured constraints in two ways. First, I presented the three respondent groups with 9 constraints which I selected based on the information available in the literature. I presented the items to be scored on a four-point interval scale ranging from 1 to 4 where, 1 is "not important" and 4 is "very important" modified from Vagias (2006) level of problem type-scale. I asked respondents to rank the constraints according to how important they were to them, with respect to their group (Appendices D-F). The constraints were: lack of funds (Capital), lack of feed (Feed), lack of good quality feed (QualFeed), lack of fingerlings (Fingerl), lack of extension services (or lack of information in the case of Potential Adopters; Exten), conflict over water use (Conflict), lack of market (Market), theft (Theft), and cage destruction by storms (CageDest).

Second, I asked Adopters and Abandoned to rank the importance of the following sources of information: government extension services (ExtInfo), farmer's personal information (PersInfo), and information from other farmers (FarmerInfo), in their day-today aquaculture operations. I also asked Adopters to indicate whether or not they have overcome any constraints, and how the constraints were overcome.

I asked respondents questions related to education, gender, occupation, tribe, and residence to assess how demographic factors affect cage aquaculture adoption.

Conceptual framework

I used the three stages identified in the cage aquaculture innovation-process model: Unawareness, KPD, and Implementation (Confirmation and Abandonment), to identify factors affecting cage aquaculture adoption at the various stages. The model was previously developed with Adopters, Abandoned and Potential Adopters as the respondent groups. The underlying assumption of the model was that demographic factors are important in predicting adoption from Unawareness to the Implementation stage. This assumption is based on previous results that individuals at the Unawareness stage do not clearly understand constraints or are not concerned about them. Thus, demographic factors, rather than socioeconomic constraints, may directly influence movement of individuals past the Unawareness stage (Figure 2.2). Moreover, since respondents in both KPD and Implementation stages previously seemed to understand constraints and ranked them accordingly, constraints may be important in predicting factors affecting adoption at any stage beyond the Unawareness stage in the innovation-decision process (Figure 2.2).

Data coding

All responses were coded and entered into an Excel 2007 spreadsheet. Education was coded as an ordinal variable on a scale of 0 to 4, where 0 represents no formal education and 4 represents bachelor's degree and above. Gender was coded as a binary variable where female is 1 and 0 otherwise. I subdivided the occupation into four categories: Fishtrader, Fisherman, Fishfarmer, and Other. I also subdivided the tribe into Tribe_Ewe, Tribe_Akan, Tribe_ Ga-Dangme, and Tribe_Other. Respondents' residences were reported as towns or cities, so I used maps to calculate the distance between respondents' residence and the closest area on the Volta Lake where cage aquaculture is practiced. The resulting variable became Distance. Age was measured in years and I used the raw ages reported in my analyses.

Statistical analysis

Prior to modeling the factors influencing adoption at the various stages, I performed a principal components analysis (PCA) as a dimension reduction technique when I noticed that the variables lack of feed, lack of good quality feed, and lack of fingerlings were correlated.

I used discriminant function analysis as my modeling tool to identify the factors that predict the membership of individuals into one of the three stages in my innovation-decision model. Using a stepwise discriminant procedure, I identified important predictors of respondents' stage from my demographic and constraints variables. To answer my first research question "Which factors affect adoption from Unawareness to Implementation?" I ran three sub-models. Since the constraint rankings by the Unaware were not meaningful in themselves, because of the group's lack of knowledge and interest in cage aquaculture, I used only demographic variables to run the first two sub-models. The first sub-model identified which factors affected adoption at the Unawareness, KPD, and Implementation stages. The second sub-model identified which factors affected adoption at the Unawareness versus KPD stages. In the third sub-model, I used only the socioeconomic constraint variables to determine their influence on adoption from KPD to the Implementation stage. To answer my second question, "Which factors affect adoption at the Confirmation and Abandonment stages?" I also modeled only the socioeconomic constraints, again, to determine the influence of socioeconomic constraints on cage aquaculture adoption. I specified a significant level of entry as $\alpha = 0.15$ and a significant level of stay as $\alpha = 0.10$ for all four analyses. I used the SAS software version 9.2 for all my analyses.

The stepwise discriminant analysis is a parametric approach to selecting variables based on p-value cut-offs. Thus, marginal predictors may not be selected. Therefore, I complemented the stepwise discriminant analysis with random forests analysis, an ensemble classification approach where several classification tree models are built, and the result is the average prediction of each tree in the model (Breiman 2001). Random forests analysis is useful in providing a measure of variable importance, to help with variable selection.

Results

Demographics

Overall, males dominated the respondents (72%). Males comprised 100% of Adopters, and 90% of Abandoned. Although the Adopters consisted of owners and caretakers, only one caretaker mentioned that the owner was a female. In contrast, females formed the majority of Potential Adopters (56%; Table 2.1). The distribution of the primary occupation types among the Potential Adopters was: fish traders (46%, including fish processing), fishermen (27%), fish farmers (8%), and others (19%). Ewe was the major tribe represented in the study: 57%, Adopters, 85%, Abandoned, and 54%, Potential Adopters. Akan was the next major tribe (31%) among Adopters, whereas Ga-Dangme was the second major tribe (42%) among Potential Adopters (Table 2.1). Adopters had the most education, and were between the ages of 26 to 35, followed by Abandoned who were within the age class 36 to 45 (Table 2.1). Potential Adopters on the other hand were between the ages of 36 to 45 and had the least education (Table 2.1). The majority (76% and above) of Adopters, Abandoned and Potential Adopters lived less than 6 km away from cage aquaculture hotspots on the Volta Lake. However, 11% of Adopters lived more than 81 km away from the lake (Table 2.1).

Factors affecting cage aquaculture adoption

The PCA analysis showed that lack of feed and lack of quality feed were strongly correlated (0.89). Lack of feed versus lack of fingerlings, and lack of quality feed versus lack of fingerlings had correlation values of 0.69 and 0.66 respectively. Figure 2.3 shows the two-dimensional relationship of the 9 constraint variables using a non-metric multidimensional scaling. Since the first principal component alone explained more than 83% of the variation among the three variables lack of feed, lack of good quality feed, and lack of fingerlings (Table 2.2), I used it to represent the lack of input variables (Prin1).

Stepwise discriminant analysis using the demographic variables showed that Female, Tribe_Ga-Dangme, and Tribe_Akan were the most important variables differentiating Unawareness, KPD, and the Implementation stages in the cage aquaculture innovation-decision process (Table 2.3). Females were associated with Unawareness, suggesting that males are more likely to adopt cage aquaculture than females (Figure 2.4). Additionally, the Ga-Dangme tribe was associated with Unawareness, whereas the tribe Akan was associated with Implementation (Figure 2.5), suggesting that Ga-Dangmes are less likely to adopt cage aquaculture than Akans .The second analysis using the occupation variables showed that Fish trader was the most important variable differentiating Unawareness and KPD . Fishtrader was associated with Unawareness (Figure 2.6), suggesting that fish traders were less likely to adopt cage aquaculture. The third analysis, using the constraint variables: Capital, Prin1, Conflict, Market, Exten, Theft, and CageDest showed that all but Exten and CageDest were important variables differentiating between KPD and Implementation (Table 2.4). Capital and Prin1 were associated with KPD, whereas Theft, Conflict and Market were associated with Implementation (Figure 2.7). The last analysis, using all the constraint variables applicable to Adopters and Abandoned, showed that PersInfo, Conflict, CageDest, and Prin1 were important variables differentiating Confirmation and Abandonment (Table 2.5). PersInfo and Conflict were associated with Confirmation, whereas CageDest and Prin1 were associated with Abandonment (Figure 2.8). The most important variables associated with Unawareness, KPD, and Implementation as ranked by the Random forests models was consistent with the results from the stepwise discriminant analysis for all four sub-models. However, random forests models included other important predictors, which were not selected by the stepwise models (Figure 2.9). Also, the relative importance of some variables in the random forests models differed from that results of the stepwise models (Figure 2.9).

Discussion

Studies have suggested that educational level (Rauniyar 1998; He *et al.* 2007; Ajewole 2010), age (He *et al.* 2007), and distance from the water body (Bulcock and Brugere 2000; Brugere *et al.* 2001) influence adoption decisions. However, I found that educational level, age, and distance (location of a respondent relative to hotspots of cage aquaculture) did not significantly influence cage aquaculture adoption. It is noteworthy that the random forests models suggested that both educational level and distance may be important predictors of adoption. Hence, educational level and distance may require further analysis with appropriate transformation to determine their true importance. For instance, distance appeared to have a log normal distribution which apparently did not obscure its importance in the random forests analysis. Thus, distance may need a transformation before it could be a significant predictor in the stepwise discriminant analyses.

Nevertheless, the finding that educational level, age, and distance may not be significant predictors of adoption suggests an opportunity that can be exploited to significantly increase cage aquaculture adoption. Individuals with varying educational levels, ages, and resident locations can potentially adopt cage aquaculture in Ghana. I found that the variables: Female, Tribe_Ga-Dangme, Tribe_Akan, Fishtrader, Market, Prin1, Capital, Conflict, Theft, PersInfo, and CageDest, affected cage aquaculture adoption in Ghana. The decision to model factors affecting adoption at KPD versus Implementation stages, and Confirmation versus Abandonment stages, using only constraints helped me to assess the most important constraint variables affecting adoption at these stages. However, I recognized that if I combine both demographics and constraints variables in modeling these stages, I could obtain very different results because of variable interactions. Thus, I conducted additional analyses to explore the possible interactions between demographic and constraints variables using random forests. The results suggested that demographic variables may be more important than constraints variables in predicting adoption from KPD to the implementation stage, contrary to my expectation (Figure 2.10). On the other hand, constraints may be more important predictors of adoption at the Confirmation and Abandonment stages, similar to what I expected (Figure 2.10)

Factors affecting cage aquaculture adoption

Gender

Women have been found to be less enthusiastic in adopting agricultural technologies (Kumar 2001; Adesina and Chianu 2002). In this study I found that women were less likely to adopt cage aquaculture. Therefore, programs designed to encourage cage aquaculture adoption must take into consideration the likelihood that women may not be interested and so that specific packages designed to encourage adoption focused on women could be developed. I suspect that a daily task such as feeding, sometimes done by means of canoeing, and occasional cage maintenance through diving are enough to discourage many women from adopting cage aquaculture. Instead of encouraging women to be more involved in mainstream aquaculture production as suggested by Nandeesha (2009), perhaps, it may be better to have a broader perspective of the cage aquaculture industry, which considers women as occupying the post-harvest fish sector niche (Weeratunge 2010).

Tribe

Fishing in Ghana is primarily conducted by the Ga-Dangme and Ewe (Overå 2003; Tetteh 2007), and some Akan men (Overå 2003; Tetteh 2007; Anning 2012) with the women focusing on fish processing and trade. Consequently, even though I found that the Ga-Dangme were less likely to adopt cage aquaculture, I expect that if this study was replicated in fishing communities where Ga-Dangme are dominant, interest in cage aquaculture adoption would be skewed towards the dominant tribe. However, I also suspect that in some fishing communities, such as the Lower Volta area in Ghana, where women are active clam fishers (Trottier 1987; Adjei-Boateng *et al.* 2011), Ewe women may show more interest in cage aquaculture compared to other tribes.

Occupation

The results of the stepwise discriminant analysis suggested that fish traders were less likely to adopt cage aquaculture compared to fishermen and the other occupations represented in this study. It has been suggested that fish trading is lucrative (Robertson 1974), and my interactions with both fishermen and fish traders supported this assertion. I also observed that many fish traders surveyed in the present study, depended solely on wild-caught fish. However, trading exclusively in wild-caught fish may not be a sustainable business since capture fisheries can be expected to decline, considering the rate of human exploitation (FAO 2004b). Fish traders can adopt cage aquaculture as a "safety net," in addition to trading in fish as capture fisheries decline, and they should be encouraged to trade in farmed fish also. Alternatively, fish traders may also be encouraged to assume entrepreneurial roles such as cage aquaculture financing and hiring of men to operate cage aquaculture farms, similar to the roles played by some fish traders in the capture fisheries industry (Overå 1993; Walker 2001, 2002; Overå 2003; Tetteh 2007).

Lack of market

The lack of market affecting cage aquaculture adoption at the Implementation stage rather than at the KPD stage suggests that cage farmers have fish marketing issues. The occupations of the majority of respondents in KPD may explain why lack of market was not a significant constraint for this group. Fish traders and fishermen were the majority occupation among KPD suggesting that the respondents felt confident that they could sell their fish if they adopted cage aquaculture. Asmah (2008) reported that a huge supply deficit existed for tilapia in Ghana; however, the fact that a product is in short supply does not mean that when it is produced, people will buy it (Moehl *et al.* (2006). Possible reasons why this might be true in Ghana include the high price of cultured fish compared with captured and imported fish. High input costs such as feed, seed and maintenance translate into a high fish price in order for the farmer to break even or make profit. Therefore, even if people are interested in farmed fish, they may prefer to buy the affordable fish on the market, which may not be farmed fish.

Many fish farmers I have interacted with complain of inability to sell their fish. Shaw (1990) suggested that good marketing in aquaculture means more than just finding customers for produce. Good aquaculture marketing strategies integrate the needs of all levels of customers to make decisions about when fish should be produced and for whom it should be produced (Shaw 1990). Thus, for cage aquaculture farmers to be successful in marketing their fish, they should be market-oriented by diversifying their markets and being proactive in finding potential buyers before they begin production (Engle and Quagrainie 2006). Further research is required to determine exactly what marketing gaps exists to ensure that cage aquaculture in Ghana is sustainable as far as farmers' profits are concerned.

Lack of inputs

Lack of inputs such as quality feed and fingerlings have been reported as important constraints affecting aquaculture (Ridler and Hishamunda 2001; FAO 2004a; Moehl *et al.* 2006; Blow and Leonard 2007; Asmah 2008). In the present study, however, it appears that the problem is more than just a lack of such inputs as has been suggested for cage aquaculture in sub-Saharan Africa. Farmers indicated that even though feed shortages sometimes occurred and they lacked quality fingerlings occasionally, their foremost constraint was the cost of quality feed. Additionally, the time and cost of transportation to purchase feed, usually, outside of their districts was a major constraint. Potential Adopters interested in cage aquaculture indicated that the lack of quality feed and fingerlings were constraints only because they lacked capital. Rauniyar (1998) found access to inputs as one of the factors that increased the probability of adoption of desirable management and technological practices.

Since feed is regarded as the single most expensive input in aquaculture (Drakeford and Pascoe 2008), farmers would benefit from access to quality feed at reasonable prices to ensure that cage aquaculture adoption is sustainable. This will also serve as leverage for farmers in terms of profit as high feed cost translates to high fish price, resulting in marketing constraints (Anane-Taabeah *et al.* 2011). Franchising, is another medium, which can be explored to increase the number of point of sales of fish feed and other inputs in areas with high demand, to reduce transportation costs.

Lack of capital

According to Beveridge (1984), cage aquaculture is relatively inexpensive in the initial stages. However, my finding that lack of capital to start cage aquaculture was the most important constraint that affected adoption from KPD to Implementation is contrary to Beveridge's suggestion. Miyata and Sawada (2006) reported that the minimum capital to construct 1 unit of a floating net cage was more than several months' income of rural households in Indonesia and suggested that "when introducing and promoting a new technology such as aquaculture, which requires a high initial fixed investment cost, supplementary programs that ease credit constraints are important to the successful adoption of the new technology" (p. 11). Hishamunda and Manning (2002) also found that annual per capita income of farmers in six Sub-Saharan Africa countries (Cote d'Ivoire, Madagascar, Malawi, Mozambique, Nigeria, and Zambia) was very low (in some cases it was lower than $300) and barely enough to support the farmers and their families let alone saving to invest in aquaculture.

Cage aquaculture may be inexpensive at the initial stages, perhaps, if the raw materials for construction are manufactured locally and can be purchased cheaply. Cost in cage aquaculture is variable spanning from initial construction cost, stocking, feeding, maintenance, security and sometimes care of diseased fish. These input costs can be high and require that the potential farmer has enough capital at the onset of operations. Miyata and Sawada (2006, 2007) found that the lack of credit accessibility reduced the likelihood to adopt cage aquaculture for Indonesian households. Apparently, rural communities did not benefit from micro-finance companies around them (Miyata and Sawada 2006), possibly because these financial institutions were skeptical about giving loans to fish farmers (Hishamunda and Manning 2002; Anane-Taabeah *et al.* 2011).

Due to unpleasant past experiences with fish farmers, some rural banks and microfinance companies were skeptical about future loans to fish farmers (Anane-Taabeah *et al.* 2011). However, some financial institutions suggested that with the proper procedures adhered to, potential adopters could access loans for cage aquaculture (Anane-Taabeah *et al.* 2011). Notwithstanding, a government or private credit scheme, such as what the former Ministry of Fisheries, Ghana (David Aidoo, Ministry of Fisheries, pers. comm.) operated could go a long way to encourage cage aquaculture adoption.

Conflict over water use

My prior hypothesis for this study was that conflict over water use would negatively affect cage aquaculture adoption. Thus, I expected conflict over water use to be associated with KPD or Abandonment. However, contrary to my expectation, conflict over water use apparently was positively associated with Confirmation. This finding suggests that conflict over water use is most likely a consequence of adoption. The conflict over water occurred because fishermen felt that cage aquaculture practices inhibited their fishing activities. The conflict with fishermen probably increases with increasing distance between a cage farmer's residence and the location of the cage farm. All Abandoned and Potential Adopters lived less than 11 km away from cage aquaculture hotspots. However, 2 % of Adopters lived between 16 to 30 km away from the lake, and another 11% lived more than 81 km from away from the lake. This suggests that the closer an individual's residence was to the cage farm, the less likely conflicts persist because of increased opportunities for conflict management. Additionally, I expect conflict with non-indigenous cage farmers to be higher than with indigenous cage farmers, since fishermen may likely perceive the former group as intruders.

When common resources are exploited by only a few individuals, as in the case of accessing water for cage aquaculture, social conflicts may arise if some individuals perceive a lack of equity in the use of the resource or are jealous (Hishamunda and Ridler 2002). For cage aquaculture to be sustainable, conflict must be properly managed. One way by which this conflict can be avoided is recognizing communities surrounding the water resource as stakeholders and involving them in aquaculture activities so that they do not perceive their livelihoods as threatened. In the present study, many of the farmers who had experienced conflicts of interest with fishermen cited regular negotiations as the way they have managed the conflicts. Even though it appears KPD, many of whom are fishermen, may not be plagued with such conflicts, I do not expect every potential adopter of cage aquaculture to be a fisherman or live in communities with direct access to areas suitable for cage aquaculture operations. Thus, it may be prudent for potential cage farmers to begin "peace" talks with all stakeholders, especially fishermen, prior to implementing cage aquaculture, even if they have permission to proceed with their intentions.

Theft

Bulcock and Brugere (2000) found that poaching was an important constraint, which influenced cage aquaculture abandonment in Bangladesh. In Ghana, however, the problem of theft in cage aquaculture needs to be properly investigated. Over 53% of respondents in the Implementation stage ranked theft as not important, whereas about 23% of them ranked it as a very important constraint (Appendix G) suggesting that the problem may be minimal. However, the regional and district fisheries officers, as well as the Fisheries Commission, apparently believed that theft is an important constraint affecting cage aquaculture adoption in Ghana (Anane-Taabeah *et al.* 2011). Many cage farmers in Ghana have employed permanent security personnel to curb the theft problem. It also appears that some individuals at the KPD stage who have witnessed cage farmers dealing with theft consider it as a constraint in cage aquaculture, possibly influencing their adoption decisions (Appendix H).

Farmers' information sources

Lack of extension as a constraint appeared to have affected both the Confirmed and Abandoned in similar ways, thus, it was not significant in explaining Abandonment or Confirmation. Interestingly, the importance of farmers' personal information was associated with Confirmation suggesting that the Confirmed relied mostly on their own personal source of information in their cage aquaculture operations. The fact that the Confirmed are the most literate group in the present study but still did not significantly depend on government extension service differs from the findings of Quagrainie *et al.* (2009) who reported that the probability of seeking aquaculture information from government extension services increases with literacy. Perhaps, government extension services were not always readily available when the Confirmed sought for it. Internet search engines and books were the major information sources for the Confirmed which is intuitive since they are the most literate group among the respondents. The Confirmed also sought for private extension services, and had more opportunities to attend workshops and trainings.

Farmers' contact with extension agents have been shown to positively affect adoption of innovations (Adesina *et al.* 2000; Nkamleu and Adesina 2000; Nkamleu and Coulibaly 2000; Rahman 2003; He *et al.* 2007), suggesting that extension agents play significant roles in influencing sustainable adoption of innovations. Many studies have suggested that extension services which are inadequately financed and motivated can dramatically reduce the quality of technological transfer and lower the rate of sustained adoption (Msiska 1991; Haight 1994; Kaunda 1994; Van den Berg 1994). Due to funding and other logistics constraints, fisheries officers are not able to sufficiently assist farmers, even though, the officers themselves may not regard lack of extension as an important constraint (Anane-Taabeah *et al.* 2011).

Every indication suggests that the aquaculture industry in Ghana needs an effective extension program which cage farmers can access to ensure sustainable adoption. The influence of extension agents in sustainable adoption was particularly evident in the fact that many of the farmers who have abandoned cage aquaculture received their training from government extension officers. This suggests that farmers who cannot afford private extension services or seek information elsewhere face the risk of abandonment. Hence, "a more specialized aquaculture extension service accessible to farmers to help with technical issues" (Anane-Taabeah *et al.* 2011, p. 164), is needed to ensure sustainable adoption of cage aquaculture in Ghana.

Cage destruction by storms

Presently, every portion of the Volta Lake is a potential site for cage aquaculture provided an individual has permission to do so. However, the fact that cage destruction by storms was an important contributing factor to abandonment suggests that not every portion of the lake is suitable for cage aquaculture and that site selection should be done carefully. Apparently, the most unsuitable sites for cage aquaculture are those areas with high wind activities and lack of riparian vegetation to act as wind breaks. Some unsuitable areas for cage aquaculture, which were identified by fishermen I interacted with, include portions of the Volta Lake in the Kwahu North and Pru Districts, in the Eastern and Brong Ahafo Regions respectively. Bulcock and Brugere (2000) reported that flooding was a highly important reason for abandonment of cage aquaculture in Bangladesh. In the present study, farmers reported that even in the absence of violent winds that destroy cages, they also had flooding to contend with, often leading to significant loss of fish.

Many of the Confirmed who ranked cage destruction by storms as an unimportant constraint also revealed that they used to be affected by storms but had found ways to manage the problem. Apparently, ensuring that cages are securely anchored reduces the impacts of storms. All the farmers who abandoned their cage aquaculture operations primarily because of cage destruction by storms seemed to suggest that timing of cage siting was the most effective way of dealing with the problem even at the most unsuitable areas of the Volta Lake. With many years of fishing experience, most of the abandoned cage farmers revealed that if fishermen are sufficiently consulted in the planning stages, potential farmers would know the best time to deploy cages. Thus, the incidence of storms destroying cages would be significantly reduced, even though the implication may be that farmers in such unsuitable areas would have to make do with fewer production cycles.

Conclusions

In this study I addressed two main questions: (1) Which factors affect cage aquaculture adoption from Unawareness to Implementation, and (2) which factors affect adoption at the Abandonment and Confirmation stages? The results from the stepwise discriminant analysis provide answers to both questions. First, females, the tribes Ga-Dangme and Akan fish trading, lack of capital, high input costs, conflict over water use, lack of market (inability to adequately market farmed fish), and theft are the most important factors that affect adoption from Unawareness to Implementation. Second, farmers' inability to access information from varying sources, conflict over water use, cage destruction by storms and high input costs are the most important constraints that affect adoption at the Confirmation and Abandonment stages.

Some recommendations for consideration to ensure that cage aquaculture adoption is both sustainable and productive are: (1) the Fisheries Directorate should develop an efficient extension program that farmers can access regularly, especially, for farmers with no other information sources, (2) women who would otherwise not be interested in mainstream cage aquaculture production could be encouraged to be more involved in the post-harvest sector of cage aquaculture, (3) fish traders may be encouraged to assume entrepreneurial roles such as cage aquaculture financing, similar to the roles played by some fish traders in the capture fisheries industry, (4) credit facilities that can be accessed by individuals or cooperatives interested in cage aquaculture should be developed to assist potential farmers who would otherwise not be able to adopt cage aquaculture, (5) production of high quality feed using local ingredients should be encouraged so that farmers can access quality feed at reasonable prices, and (6) additional research to provide a broader understanding of constraints such as lack of market, theft, cage destruction by storms, and conflict over water use, is needed to ensure that the appropriate strategies are developed for these constraints.

Table 2.1 - Comparison of demographic variables among Adopters, Abandoned and Potential Adopters.

	Adopters	Abandoned	Potential Adopters
Gender			
Female	-	10%	56%
Male	100%	90%	44%
Tribe			
Ewe	57.8%	85.0%	54.4%
Akan	31.1%	-	1.8%
Ga-Dangme	6.7%	15.0%	42.0%
Other	4.4%	-	1.8%
Education (high school and above)	64%	30%	14%
Age (years):			
25 or under	4%	5%	12%
26 – 35	40%	10%	23%
36 – 45	31%	40%	32%
46 – 55	11%	25%	23%
56 – 65	7%	10%	9%
66 – 75	7%	5%	-
76 or under	-	5%	2%
Distance (km)			
Under 1	67%	60%	46%
1.0 – 5.9	9%	35%	37%
6.0 – 10.9	11%	5%	18%
11.0 – 15.9	-	-	-
16.0 – 20.9	2%	-	-
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81.0 and above	11%	-	-

Sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

Table 2.2 - Results of Principal Component Analysis (PCA) on the constraints: lack of feed (Feed), lack of quality feed (QualFeed), and lack of fingerlings (Fingerl), affecting cage aquaculture adoption.

PCA	Proportion	Variable Loadings	
		Feed	0.599537
1	0.8327	QualFeed	0.592377
		Fingerl	0.538187
		Feed	- 0.331877
2	0.1302	QualFeed	- 0.427896
		Fingerl	0.840691
		Feed	- 0.728294
3	0.0371	QualFeed	0.682638
		Fingerl	0.059943

Table 2.3 - Results of Stepwise Discriminant Function Analysis of demographic variables for Unawareness; Knowledge, Persuasion, and Decision (KPD); and Implementation.

Variable	F-statistics ($df_1 = 2$, $df_2 = 117$)	P value
Female	29.76	< 0.0001*
Tribe_Ga-Dangme	8.76	0.0003*
Tribe_Akan	2.56	0.0818*

*Variables were significant at $\alpha = 0.10$

Table 2.4 - Results of Stepwise Discriminant Function Analysis of constraint variables for Knowledge, Persuasion, and Decision (KPD) versus Implementation.

Variable	F-statistics ($df_1 = 1$, $df_2 = 96$)	P value
Market	29.72	< 0.0001*
Prin1 (lack of inputs)	6.76	0.0108*
Capital	5.76	0.0183*
Theft	3.01	0.0862*
Conflict	4.14	0.0447*

*Variables were significant at $\alpha = 0.10$

Table 2.5 - Results of Stepwise Discriminant Function Analysis of constraint variables for Confirmation versus Abandonment.

Variable	F-statistics ($df_1 = 1$, $df_2 = 60$)	P value
PersInfo	10.16	0.0023*
CageDest	6.49	0.0134*
Conflict	4.62	0.0356*
Prin1 (lack of inputs)	3.15	0.0809*

*Variables were significant at $\alpha = 0.10$

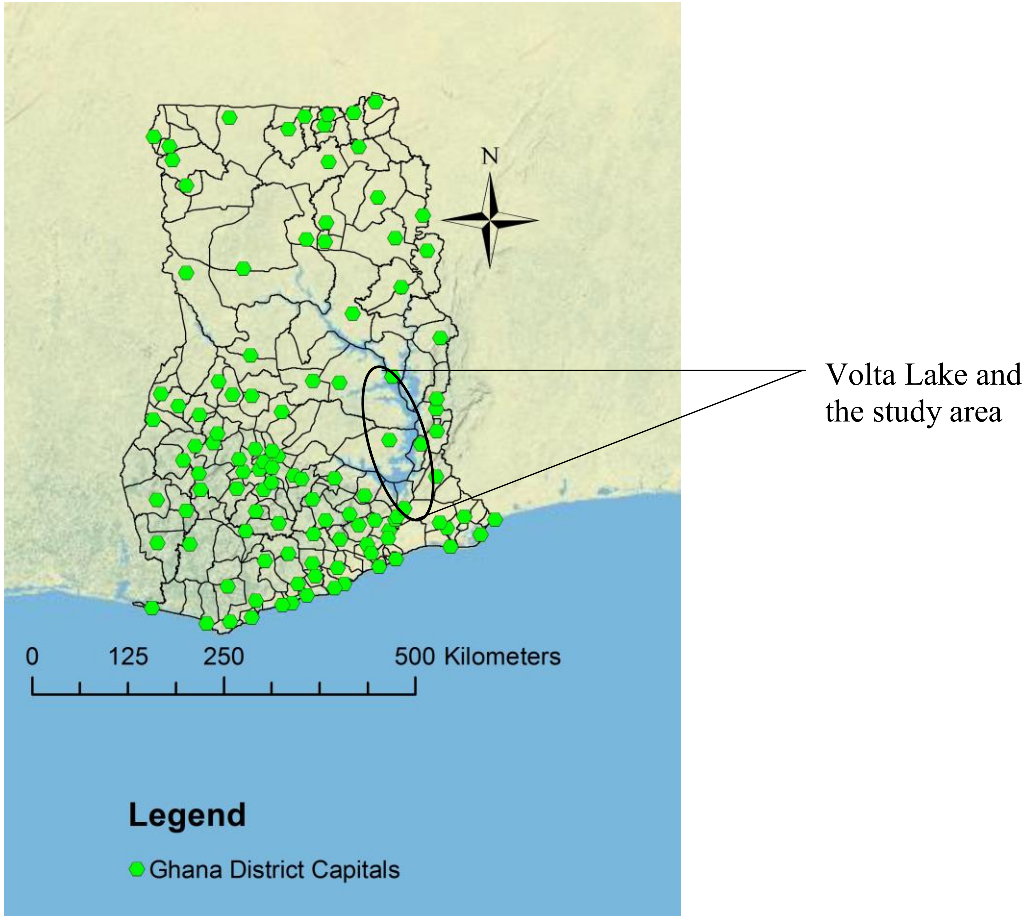

Figure 2.1 - Map of Ghana showing the Volta Lake and the study area.

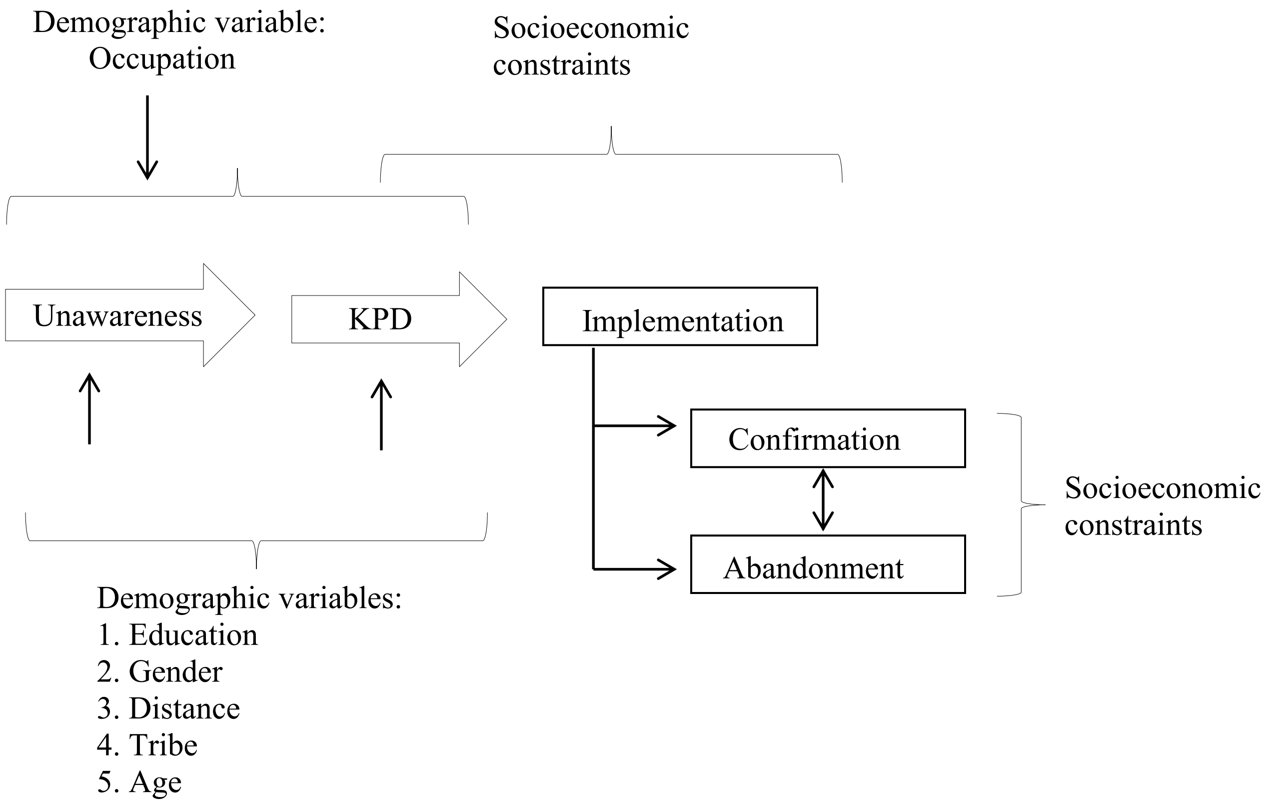

Figure 2.2 - Conceptual model of cage aquaculture innovation-decision process in Ghana. KPD represents Knowledge, Persuasion, and Decision. Adapted from Rogers (2003).

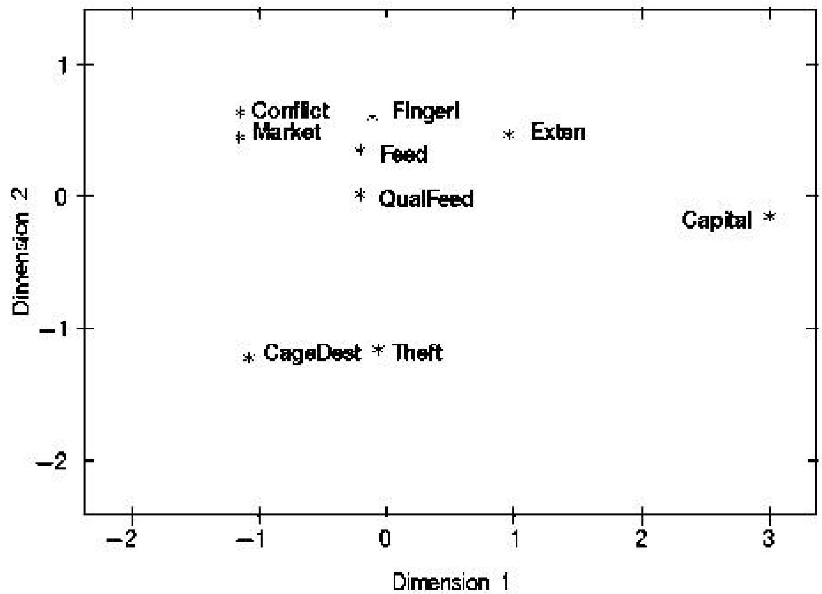

Figure 2.3 - Relationship of 9 constraints in two-dimensional space according to the rankings of Adopters, Abandoned, and Potential Adopters. Sample size (n) for Adopters, Abandoned and Potential Adopters are 45, 20, and 57 respectively.

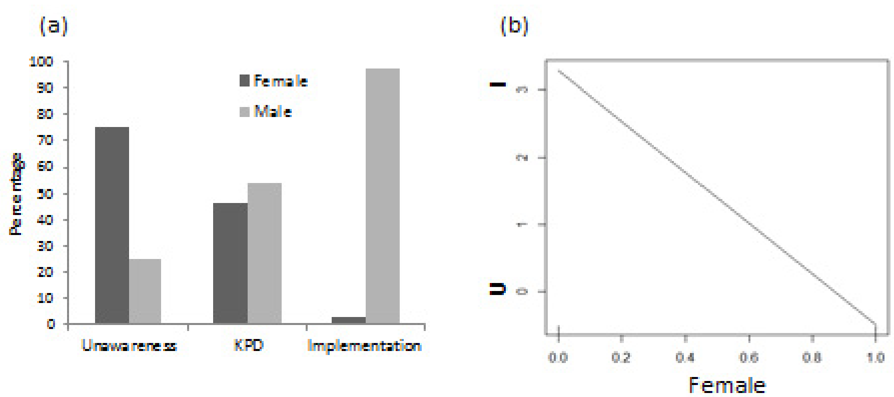

Figure 2.4 - (a) Distribution of gender among the stages Unawareness, Knowledge, Persuasion, and Decision (KPD) and Implementation (Confirmation and Abandonment), and (b) partial dependence plots of the effect of female on adoption from U (Unawareness) to I (Implementation). Total sample size (n) for Unawareness, KPD and Implementation are 20, 37, and 65 respectively.

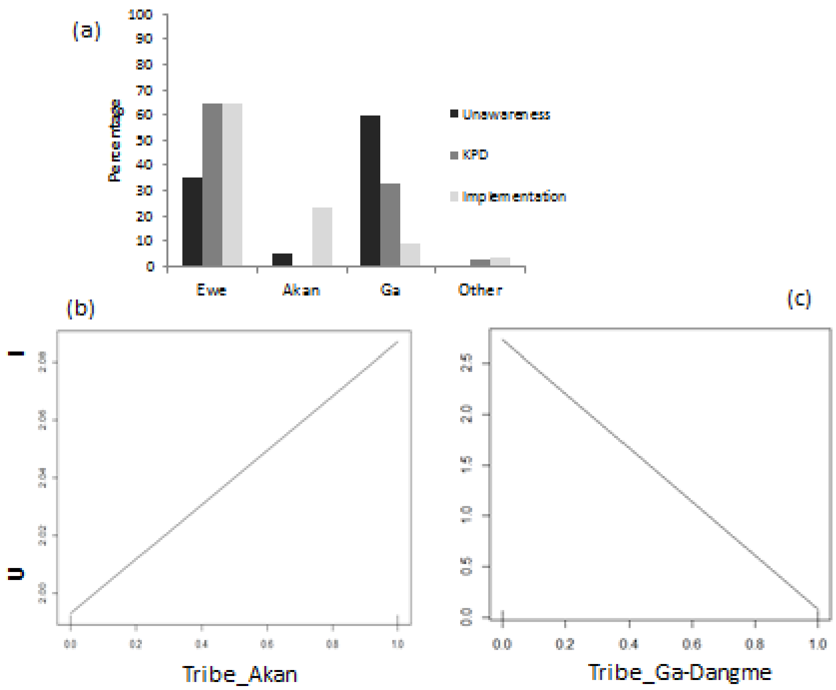

Figure 2.5 - (a) Distribution of tribe among the stages Unawareness, Knowledge, Persuasion, and Decision (KPD) and Implementation (Confirmation and Abandonment), and (b-c) partial dependence plots of the effect of tribe on adoption from U (Unawareness) to I (Implementation). Total sample size (n) for Unawareness, KPD and Implementation are 20, 37, and 65 respectively.

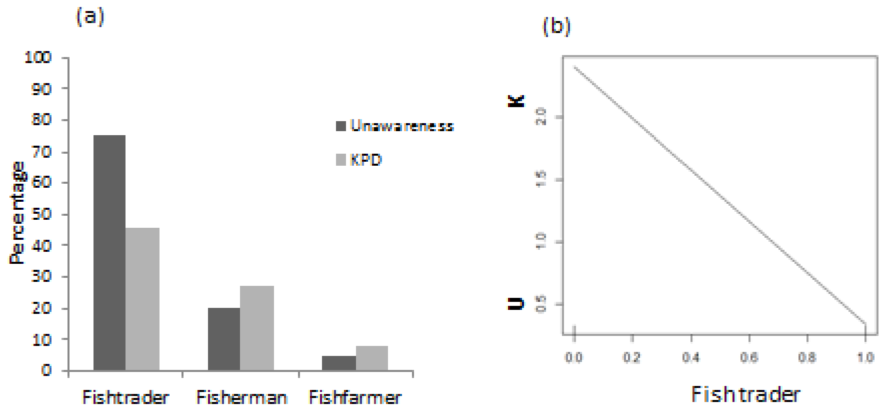

Figure 2.6 - (a) Distribution of occupation among the stages Unawareness and Knowledge, Persuasion, and Decision (KPD), and (b) partial dependence plot of the effect of the occupation, fish trader, on cage aquaculture adoption from U (Unawareness) to K (KPD). Total sample size (n) for Unawareness and KPD are 20 and 37 respectively.

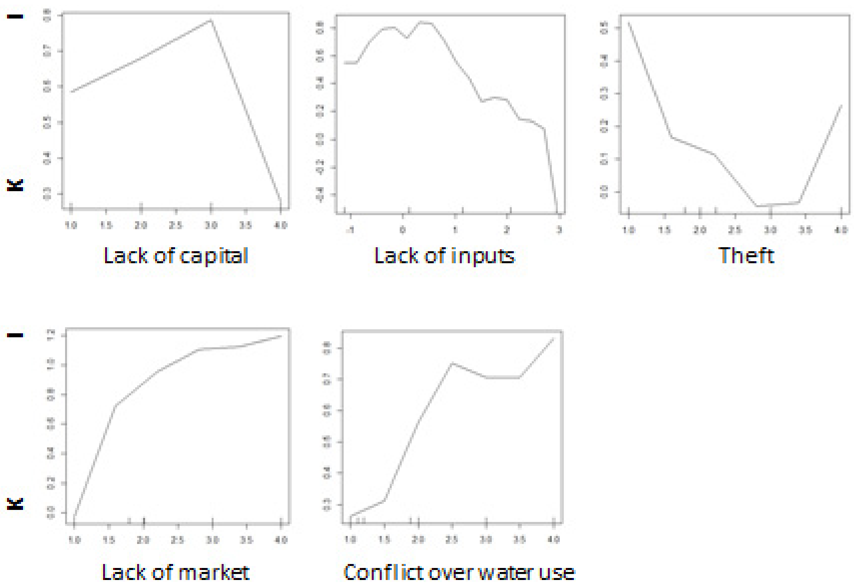

Figure 2.7 - Partial dependence plots of the effect of the five most influential predictors on cage aquaculture adoption from K (Knowledge, Persuasion, and Decision) to I (Implementation) stages.

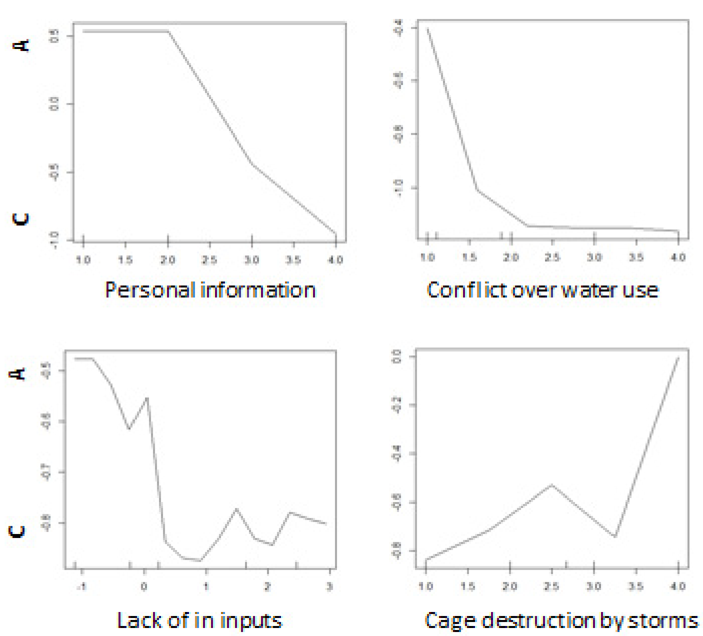

Figure 2.8 - Partial dependence plots of the effect of the four most influential predictors on cage aquaculture adoption at the C (Confirmation) and A (Abandonment) stages.

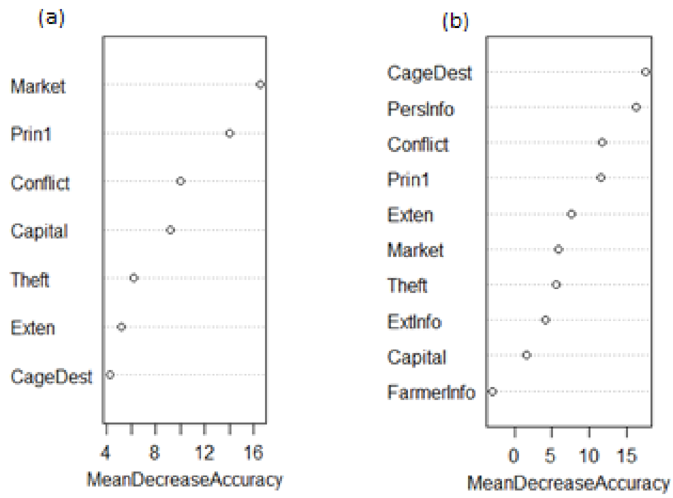

Figure 2.9 - Ranking of the importance of each constraint variable on cage aquaculture adoption at the stages: (a) Knowledge, Persuasion, and Decision (KPD) to Implementation (Confirmation and Abandonment), and (b) Confirmation versus Abandonment.

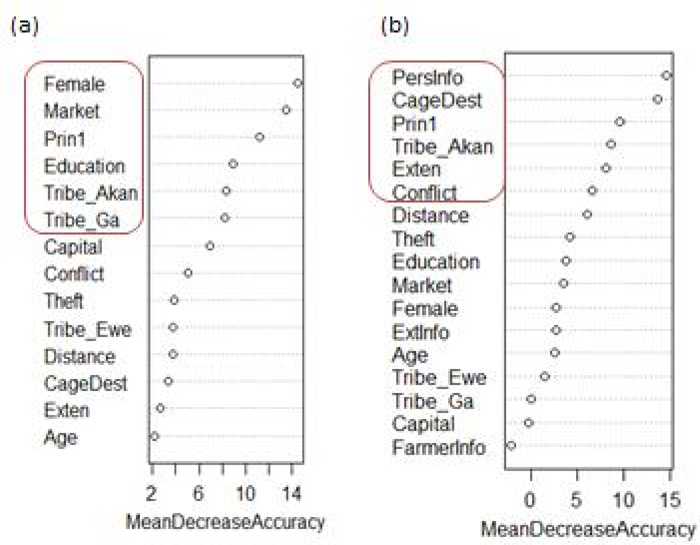

Figure 2.10 - Ranking of the importance of demographic variables versus constraint variables on cage aquaculture adoption at the stages: (a) Knowledge, Persuasion, and Decision (KPD) to Implementation (Confirmation and Abandonment), and (b) Confirmation versus Abandonment.

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Summary and Recommendations

In this study, I examined the decision processes in cage aquaculture adoption using a cage aquaculture innovation-decision model I developed, and identified the factors that affect adoption of cage aquaculture in Ghana. Based on their differences in knowledge and interests, I placed respondents into one of three stages of the cage aquaculture innovation-decision process model: 1) Unawareness, 2) Knowledge, Persuasion, and Decision (KPD), and 3) Implementation (Confirmation and Abandonment). Respondents in the KPD and Implementation stages had knowledge, were more interested in cage aquaculture, and were aware of constraints in cage aquaculture, whereas respondents in the Unawareness stage lacked knowledge and interest in cage aquaculture and did not clearly understand the constraints. I found that respondents who were males, belonged to the tribes Ewe and Akan, and who had fishing experience tended to be more interested in cage aquaculture.

The results of the study suggest that programs aimed at encouraging new entrants into cage aquaculture should focus on demographic characteristics such as gender, and tribe. In particular adoption programs could focus on males, Ewes and Akans, as well as fishermen. As far as constraints are concerned, I found that lack of capital, high input costs, lack of market, theft, lack of information sources, conflict over water use, and cage destruction by storms negatively affected cage aquaculture adoption in Ghana.

The innovation-decision process model developed for cage aquaculture in this study provides a useful framework of understanding the decision processes in cage aquaculture adoption in Ghana. This study is useful in providing a good understanding of the dynamics of the decision processes among potential adopters, in particular, and can form the basis upon which future studies are designed to study cage aquaculture adoption decisions. Moreover, the results of this study can reliably inform policy makers and other institutions promoting cage aquaculture adoption about the opportunities to focus on, and constraints that need to be addressed, to ensure the sustainable adoption of cage aquaculture in Ghana.

The results of the study also suggest a high potential for cage aquaculture adoption due to the apparent high interest in cage aquaculture among respondents. However, the institutional structures and policies needed to ensure sustained adoption is yet to develop. Major constraints affecting cage aquaculture identified from this study have implications for cage aquaculture development and need to be addressed. Particularly, high cost of inputs such as feed, fish marketing constraints, and lack of capital, when adequately addressed, could ensure that cage aquaculture is sustainable in the long term.

For instance, it was evident that government extension services play significant roles in sustaining the adoption interest, but government extension services was lacking. In addition to recommending that an efficient extension program be developed to assist farmers, I include herein some suggestions that can ensure that the extension program to be developed is efficient. First, extension officers should be highly trained for aquaculture extension. Second, extension officers should be well motivated to encourage them to work. Access to readily available transportation and competitive remuneration are ways to ensure that extension officers are motivated.

The fact that farmed fish may be more expensive than wild-caught or imported fish suggests that without appropriate intervention measures, the cage aquaculture industry will not be sustainable in the long term. A number of policy alternatives exist which can ensure that farmed fish is competitive with wild-caught fish or imported fish. First, import taxes can be imposed on fish to discourage fish importation and promote patronage of locally farmed fish. Second, quotas can be imposed on fishing, in addition to taxes on fishing gears and other equipment, to control overdependence on wild-caught fish. Third, since feed is the single most expensive input, feed can be subsidized to enable farmers produce fish that can sell locally and would be competitive with wild-caught or imported fish. Import taxes and fishing quotas are two policy alternatives which may likely not succeed if implemented. Due to inadequate monitoring and law enforcement, imposing import taxes on fish may not adequately address the need of securing a local market for farmed fish. Also, we can expect strong opposition with any policy option limiting capture fisheries, considering that for many individuals living around water bodies, fishing is their major livelihood. Thus, the most feasible policy options may be subsidizing fish feed costs for farmers.

To further address the fish marketing problems, I recommend that comprehensive market analysis be conducted for cage aquaculture farmed fish, to identify the marketing gabs, and appropriately address them. In the meantime, cage fish farmers should be proactive in marketing their fish. Prior to starting production, cage farmers should identify potential niche markets. Basic information on who is interested in farmed fish, the size of fish desired, and consumer price ranges, would ensure that farmers produce fish for a target group. Having a niche market will guarantee that farmers are able to sell their fish without having fish prices dictated to them by consumers or distributors.

Moreover, farmers can be market oriented by forming cooperate groups. Fish farmers' cooperative groups that can reliably supply fish will have a strong market base. Cooperative groups would be useful in developing a market for cage aquaculture produce, especially, since government policies to ensure farmed fish are competitive require time to be implemented. Cooperative groups also have many advantages that can ensure sustainable cage aquaculture adoption. Cooperative groups can be beneficial to both adopters and potential adopters in that, they can access credit from banks and other microfinance institutions, which would otherwise be difficult to access if they applied as individuals (Anane-Taabeah *et al.* 2011). The ability to access loans and expand fish production could create a local demand for high quality feed, which can encourage the production of high quality feed locally and sold at competitive prices. Since the current volume of fish production from cage aquaculture can be considered low, it may be not be profitable to produce high quality feed locally.

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Appendices

Appendix A. – Subset of questions used in this study from the Adopters' questionnaire.

1. How did you come to the decision to start cage aquaculture?
2. Do you have experience in other fish farming operations apart from cage aquaculture?

3. Have you had specific training in cage aquaculture before?
   a. Yes, proceed with questions
   b. No, skip to question 5

4. Where did you get your training for cage aquaculture? Please list all applicable places and type of techniques you learned through the training.

5. When did you get your training for cage aquaculture? Please list all applicable dates and type of techniques you learned through the training.

6. Is there a government policy limiting the extent of cage aquaculture on the Volta Lake?
   a. Yes
   b. No

7. If yes, please describe the policy in your own words?

8. Is there a government policy to promote cage aquaculture on the Volta Lake?
   a. Yes
   b. No

9. If yes, please describe the policy in your own words?

Please use the scale below to indicate how important the following problems are, in your cage aquaculture operations. Please circle the option applicable to you.
Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important = NI, Not Sure = NS.

10. Lack of funds	VI	SI	SU	NI	NS
11. Lack of feed	VI	SI	SU	NI	NS
12. Lack of good quality feed	VI	SI	SU	NI	NS
13. Lack of fingerlings	VI	SI	SU	NI	NS

14. Lack of extension services VI SI SU NI NS

15. Conflict over water use VI SI SU NI NS

16. Lack of market VI SI SU NI NS

17. Theft VI SI SU NI NS

18. Cage destruction by storms VI SI SU NI NS

19. Is a farmer required to have a government permit to put a cage on the Volta Lake for aquaculture?
    a. Yes
    b. No
    c. Don't know
20. How profitable would you describe your cage aquaculture business?
    a. Very profitable
    b. Moderately profitable
    c. Break even
    d. Slightly unprofitable
    e. Very unprofitable

21. Would you recommend cage aquaculture to a potential farmer?
    a. Yes
    b. No

22. Please give reasons for your answer.

23. What is your level of education?
    a. No formal education
    b. Middle school graduate
    c. High School graduate
    d. Undergraduate and above
    e. Other, please specify

24. What is your gender?
    a. Male
    b. Female

25. Is cage fish farming your full-time or part-time occupation?
    a. Full-time occupation
    b. Part-time occupation

26. What is your age?

27. What is your tribe?

28. Where do you live?

Appendix B. – Subset of questions used in this study from the Abandoned's questionnaire.

1. What fish farming facility were you operating?
   a. Cage
   b. Pen

Please use the scale below to indicate how important the following constraints were, in your decision to abandon cage/pen aquaculture operations. Please circle the option applicable to you. Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important = NI, Not Sure = NS.

2. Lack of funds	VI	SI	SU	NI	NS
3. Lack of feed	VI	SI	SU	NI	NS
4. Lack of good quality feed	VI	SI	SU	NI	NS
5. Lack of fingerlings	VI	SI	SU	NI	NS
6. Lack of extension services	VI	SI	SU	NI	NS
7. Conflict over water use	VI	SI	SU	NI	NS
8. Lack of market	VI	SI	SU	NI	NS
9. Theft	VI	SI	SU	NI	NS
10. Cage destruction by storms	VI	SI	SU	NI	NS

11. Have you had specific training in cage/pen aquaculture before?
    a. Yes, proceed with questions
    b. No, skip to question 14

12. Where did you get your training for cage/pen aquaculture? Please list all applicable places and type of techniques you learned through the training.

13. When did you get your training for cage/pen aquaculture? Please list all applicable dates and type of techniques you learned through the training.

14. Is there a government policy limiting the extent of cage aquaculture on the Volta Lake?
    a. Yes, proceed with questions
    b. No, skip to question 16

15. Please describe the policy in your own words?

16. Is there a government policy to promote cage aquaculture on the Volta Lake?
    a. Yes
    b. No

17. If yes, please describe the policy in your own words?

18. Are you still interested in practicing cage/pen aquaculture if constraints are removed?
    a. Yes
    b. No
    c. Not sure

19. Please give reasons for your answer.

20. Is a farmer required to have a government permit to put a cage/pen on the Volta Lake for aquaculture?
    a. Yes
    b. No
    c. Don't know

21. What is your level of education?
    a. No formal education
    b. Middle school graduate
    c. High School graduate
    d. Undergraduate and above
    e. Other, please specify

22. What is your gender?
    a. Male
    b. Female

23. Was cage/pen aquaculture your full-time or part-time occupation?
    a. Full-time occupation
    b. Part-time occupation

24. What is your current occupation?
25. What is your age?
26. What is your tribe?
27. Where do you live?

Appendix C. – Subset of questions used in this study from the Potential Adopters' questionnaire.

1. Do you have knowledge about how to operate a cage aquaculture farm?
    a. Yes, proceed with questions
    b. No, skip to question 4

2. Where did you get your training for cage aquaculture? Please list all applicable places and type of techniques you learned through the training.

3. When did you get your training for cage aquaculture? Please list all applicable dates and type of techniques you learned through the training.

4. Is there a government policy limiting the extent of cage aquaculture on the Volta Lake?
    a. Yes
    b. No

5. If yes, please describe the policy in your own words?

6. Is there a government policy to promote cage aquaculture on the Volta Lake?
    a. Yes
    b. No

7. If yes, please describe the policy in your own words?

8. Are you interested in starting a cage aquaculture business on the Volta Lake?
    a. Yes
    b. No
    c. Not sure

9. Please give reasons for your answer.

10. Is a farmer required to have a government permit to put a cage on the Volta Lake for aquaculture?
    a. Yes
    b. No
    c. Don't know

Please use the scale below to indicate how important the following constraints are in your decision to start or not to start cage aquaculture business. Please circle the option applicable to you. Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important= NI, Not Sure= NS.

11. Lack of capital	VI	SI	SU	NI	NS
12. Lack of feed	VI	SI	SU	NI	NS
13. Lack of good quality feed	VI	SI	SU	NI	NS
14. Lack of fingerlings	VI	SI	SU	NI	NS
15. Lack of information	VI	SI	SU	NI	NS
16. Conflict over water use	VI	SI	SU	NI	NS
17. Lack of market	VI	SI	SU	NI	NS
18. Theft	VI	SI	SU	NI	NS
19. Cage destruction by storms	VI	SI	SU	NI	NS

20. Would you adopt cage aquaculture if the constraints important to you are removed?
    a. Yes
    b. No

21. If no, please give reasons.
22. What is your level of education?
    a. No formal education
    b. Middle school graduate
    c. High School graduate
    d. Undergraduate and above
    e. Other, please specify
23. What is your gender?
    a. Male
    b. Female

24. What is your current occupation? Please specify type of operation if a fish farmer.

25. What is your age?

26. What is your tribe?

27. Where do you live?

Appendix D. - Subset of questions used in this study from the Adopters' questionnaire.

Please use the scale below to indicate how important the following problems are, in your cage aquaculture operations. Please circle the option applicable to you. Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important = NI, Not Sure = NS.

1. Lack of funds	VI	SI	SU	NI	NS
2. Lack of feed	VI	SI	SU	NI	NS
3. Lack of good quality feed	VI	SI	SU	NI	NS
4. Lack of fingerlings	VI	SI	SU	NI	NS
5. Lack of extension services	VI	SI	SU	NI	NS
6. Conflict over water use	VI	SI	SU	NI	NS
7. Lack of market	VI	SI	SU	NI	NS
8. Theft	VI	SI	SU	NI	NS
9. Cage destruction by storms	VI	SI	SU	NI	NS

10. Have you overcome any of the constraints?

11. If yes, which ones?

12. How did you overcome these constraints?

Please use the scale below to indicate how important the following sources of information are in your cage aquaculture operations. Please circle the option applicable to you. Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important= NI.

13. Government Extension Services	VI	SI	SU	NI
14. Other farmers	VI	SI	SU	NI
15. Personal Knowledge	VI	SI	SU	NI

16. What is your level of education?
    a. No formal education
    b. Middle school graduate
    c. High School graduate
    d. Undergraduate and above

e. Other, please specify

17. What is your gender?
    a. Male
    b. Female

18. What is your age?

19. What is your tribe?

20. Where do you live?

Appendix E. - Subset of questions used in this study from the Abandoned's questionnaire.

Please use the scale below to indicate how important the following constraints were, in your decision to abandon cage/pen aquaculture operations. Please circle the option applicable to you. Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important = NI, Not Sure = NS.

1. Lack of funds	VI	SI	SU	NI	NS
2. Lack of feed	VI	SI	SU	NI	NS
3. Lack of good quality feed	VI	SI	SU	NI	NS
4. Lack of fingerlings	VI	SI	SU	NI	NS
5. Lack of extension services	VI	SI	SU	NI	NS
6. Conflict over water use	VI	SI	SU	NI	NS
7. Lack of market	VI	SI	SU	NI	NS
8. Theft	VI	SI	SU	NI	NS
9. Cage destruction by storms	VI	SI	SU	NI	NS

Please use the scale below to indicate how important the following sources of information were in your cage/pen culture operations. Please circle the option applicable to you**.** Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important= NI.

10. Government Extension Services	VI	SI	SU	NI
11. Other farmers	VI	SI	SU	NI
12. Personal Knowledge	VI	SI	SU	NI

13. What is your level of education?
    a. No formal education
    b. Middle school graduate
    c. High School graduate
    d. Undergraduate and above
    e. Other, please specify

14. What is your gender?
    a. Male

b. Female

15. What is your age?

16. What is your tribe?

17. Where do you live?

Appendix F. - Subset of questions used in this study from the Potential Adopters' questionnaire.

Please use the scale below to indicate how important the following constraints are in your decision to start or not to start cage aquaculture business. Please circle the option applicable to you.
Very Important = VI, Slightly Important = SI, Slightly Unimportant = SU, Not Important= NI, Not Sure= NS.

1. Lack of capital	VI	SI	SU	NI	NS
2. Lack of feed	VI	SI	SU	NI	NS
3. Lack of good quality feed	VI	SI	SU	NI	NS
4. Lack of fingerlings	VI	SI	SU	NI	NS
5. Conflict over water use	VI	SI	SU	NI	NS
6. Lack of market	VI	SI	SU	NI	NS
7. Theft	VI	SI	SU	NI	NS
8. Cage destruction by storms	VI	SI	SU	NI	NS

9. What is your level of education?
    a. No formal education
    b. Middle school graduate
    c. High School graduate
    d. Undergraduate and above
    e. Other, please specify

10. What is your gender?
    a. Male
    b. Female

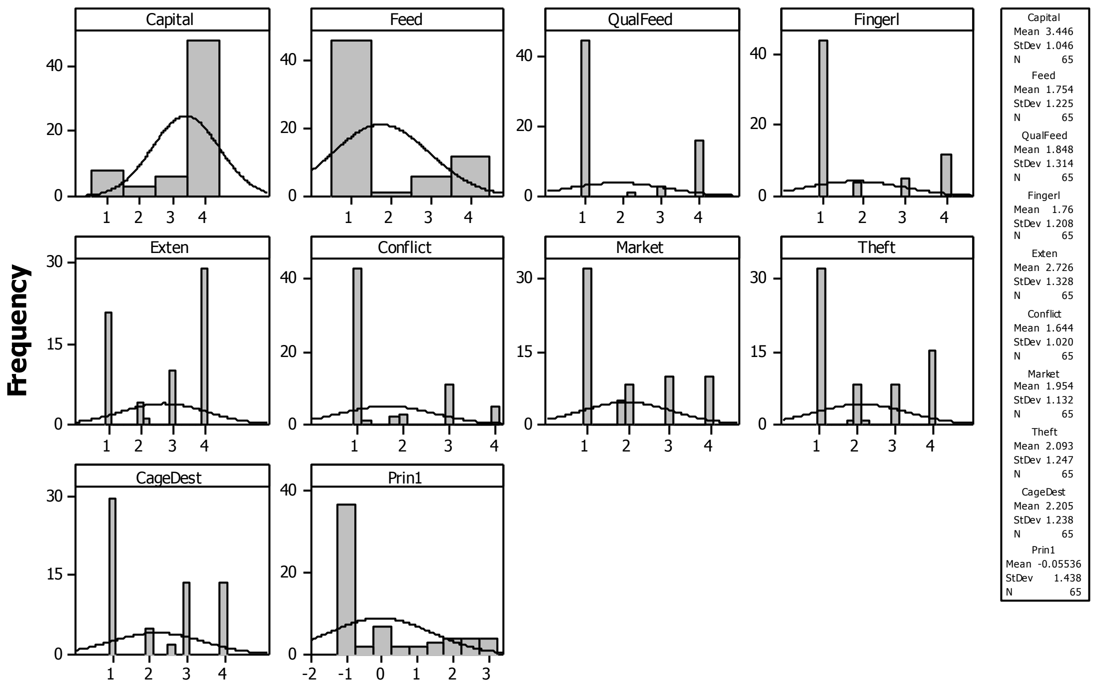
11. What is your current occupation? Please specify type of operation if a fish farmer.

12. What is your age?

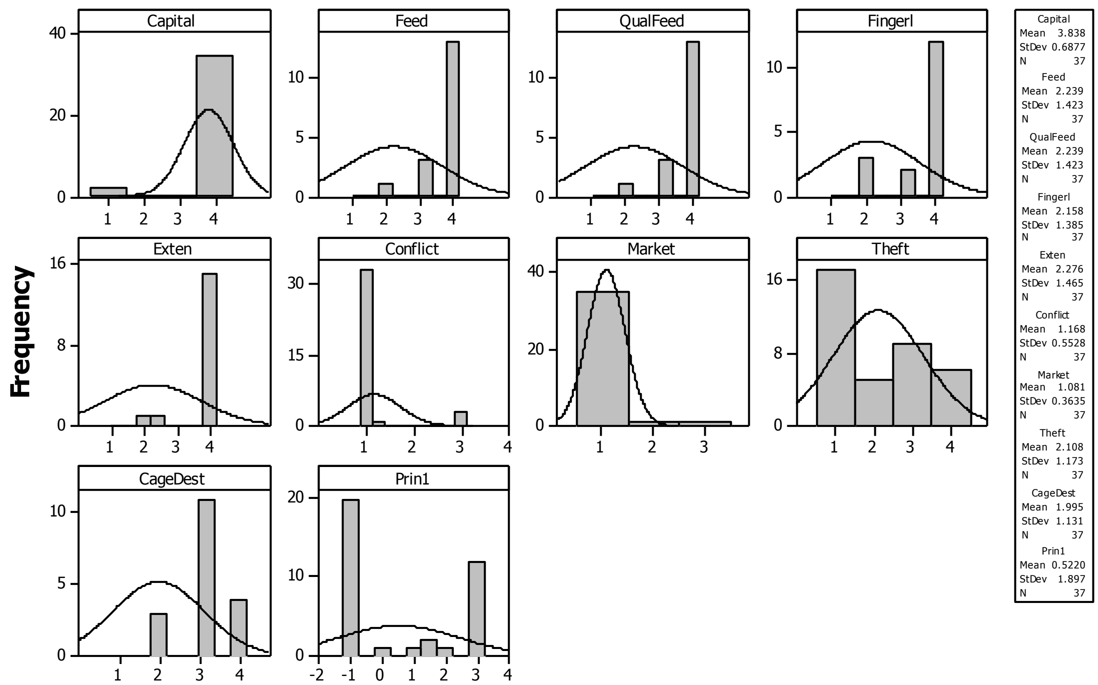
13. What is your tribe?

14. Where do you live?

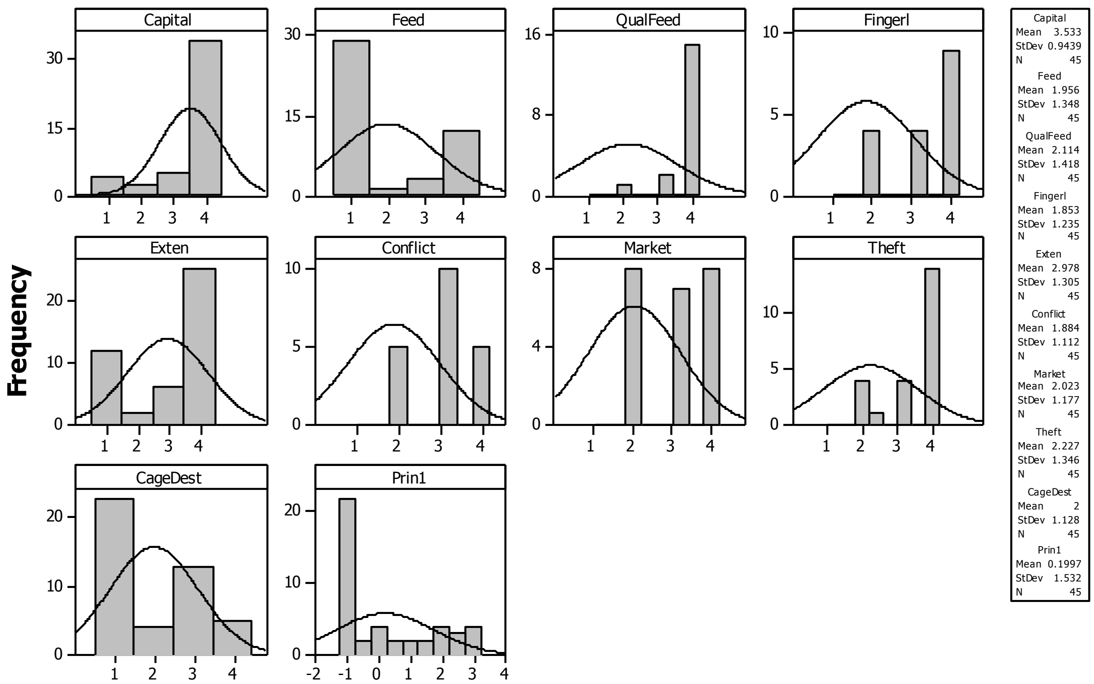
Appendix G. - Distribution of the rankings of 9 constraints by respondents in the Implementation stage (responses of the Confirmed and Abandoned have been combined). Prin1 represents lack of inputs, the first principal component derived from lack of feed, lack of quality feed, and lack of fingerlings. The ranking is based on a 4-point scale, where 1 is not-important and 4 is very-important. Total sample size (n) is 65.



Appendix H. - Distribution of the rankings of 9 constraints by respondents in the KPD (Knowledge, Persuasion and Decision) stage. Prin1 represents lack of inputs, the first principal component derived from lack of feed, lack of quality feed, and lack of fingerlings. The ranking is based on a 4-point scale, where 1 is not-important and 4 is very-important. Total sample size (n) is 37.



Appendix I. - Distribution of the rankings of 9 constraints by respondents in the Confirmation stage. Prin1 represents lack of inputs, the first principal component derived from lack of feed, lack of quality feed, and lack of fingerlings. The ranking is based on a 4-point scale, where 1 is not-important and 4 is very-important. Total sample size (n) is 45.



Appendix J. - Distribution of the rankings of 9 constraints by respondents in the Abandonment stage. Prin1 represents lack of inputs, the first principal component derived from lack of feed, lack of quality feed, and lack of fingerlings. The ranking is based on a 4-point scale, where 1 is not-important and 4 is very-important. Total sample size (n) is 20.