Aqua Climate

2010

Perception of climate change impacts and adaptation of shrimp farming in India

Farmer focus group discussion and stakeholder workshop Report

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NATIONAL CENTRE FOR SUSTAINABLE AQUACULTURE

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The report communicates the Aqua Climate project Indian case study Focus Group Discussion and Stakeholder Workshop results on perception of climate change impacts and adaptation of shrimp farming.

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About AQUACLIMATE

AQUACLIMATE is a three year project funded by the Ministry of Foreign Affairs, Norway, through the Royal Norwegian Embassy, Bangkok, Thailand.

Title of project: Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region

Disclaimer

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List of acronyms

ANGARU	Acharya NG Ranga Agricultural University
AP	Andhra Pradesh
BMP	Better Management Practice
BMP-	Better Management Practice
BSCC	Broodstock Collection Centre
CAA	Coastal Aquaculture Authority
CIBA	Central Institute of Brackishwater Aquaculture
CIFA	Central Institute of Freshwater Aquaculture
CIFE	Central Institute of Fisheries Education
CMFRI	Central Marine Fisheries Research Institute
COC	Code of Conduct
CoF	College of Fisheries
CoP	Code of Practice
CWC	Central Water Commission
DoA	Department of Agriculture
DoF	Department of Fisheries
EB	Electricity Board
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
FGD	Focus Group Discussion
IITM	Indian Institute of Tropical Meteorology
IMD	Indian Meteorological Department
IPCC	Inter-Governmental Panel on Climate Change
KVK	Krishi Vignan Kendra
MoEF	Ministry of Environment and Forestry
MPEDA	The Marine Products Export Development Authority
NACA	Network of Aquaculture Centers in Asia-Pacific
NaCSA	National Centre for Sustainable Aquaculture
NFDB	National Fisheries Development Board
NIH	National Institute of Hydrology
PCR	Polymerase Chain Reaction
PL	Postlarva, Postlarvae (plural form)
RI	Research Institute
SIFT	State Institute of Fisheries technology
SW	Stakeholder Workshop

1 Executive summary

Global green house gases emissions will continue to grow over the next few decades even with the current climate change mitigation policies and related sustainable development practices and thus climate change (CC) is inevitable.

The project on “Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region” also known as "*Aquaclimate*" coordinated by Network of Aquaculture Centers in Asia-Pacific (NACA) aims to strengthen the adaptive capacities of rural shrimp farming communities to the impacts of climate change. The project has several case studies including one in India. The focus of the project is on mapping the small scale farmer’s perceptions and attitudes towards climate change impacts and their adaptive capacities to address the impacts.

This publication sets out the lessons and experiences that have emerged from focus group discussion (FGD) meetings and stakeholder workshop (SW) of Indian case study.

Tiger shrimp, *Penaeus monodon* has been the mainstay of India's seafood exports and has immense potential as a foreign exchange earner. It also has substantial contribution towards socio-economic development in terms of income and employment. Shrimp aquaculture is threatened by changes in temperature, precipitation, drought and storms/floods that affect infrastructure and livelihoods which can impact aquaculture both negatively and positively. Ecological changes, inundation of low-lying lands and saline intrusions into freshwater regions are likely to cause substantial dislocation of communities and disruption of farming systems. In the face of potential complexities of climate change interactions and their possible scale of impact, the primary challenge for the shrimp aquaculture sector will be to deliver food supply, strengthen economic output and maintain and enhance food security. It is expected that the climate change impacts will be disproportionately felt by small-scale shrimp farmers who are already amongst the most poor and vulnerable members of society. The small scale farmers are typically unorganized and most of the farmers did not have access to technological innovations and scientific applications. There is a need to forecast the likely effects of climate change on the shrimp aquaculture sector and to develop strategies to assist farmers and rural communities to adapt to the upcoming changes.

Adaptation to climate change has the potential to substantially reduce many of the adverse impacts of climate change and enhance beneficial impacts. Successful adaptation must be accomplished through actions that target and the most vulnerable who are typically poor people. Improving and applying knowledge on the constraints and opportunities for enhancing adaptive capacity is necessary to reduce vulnerabilities associated with climate change. The starting point for this is a common understanding of the concepts of adaptation, vulnerability, resilience, security, poverty and livelihoods, as well as an understanding of the gaps in current adaptation approaches. There has been little research to date on the roles and responsibilities in adaptation of individuals, communities, private and public institutions, governments, and international organizations.

Central Institute of Brackishwater Aquaculture (CIBA) is the national partner to organize the FGDs and SW in conjunction with the National Centre for Sustainable Aquaculture (NaCSA), part of The Marine Products Export Development Authority (MPEDA). NaCSA organized societies in the country to reduce the impact of shrimp disease through the implementation of better management practices (BMPs) in small-scale farming clusters. Krishna District in Andhra Pradesh state has been identified as the study area and the NaCSA societies in the district have been identified to study the perceptions of climate change impacts and adaptation to shrimp farming.

Andhra Pradesh has the longest coastline of all the states in the country. The state has had many weather related impacts in recent years such as the worst drought in 50 years occurred in early to mid 2009 followed by a severe flood of once in 100 years in Krishna River during October 2009. These extreme climatic events have had severe consequences including heavy economic losses to shrimp farmers in the State. The temperatures registered in summer are very high and as high as 50°C was recorded in the study area during 2007. The study area, Krishna delta coast with mudflats, mangrove swamps, and lagoons/backwaters is much more vulnerable to sea level rise in the future and is at very high-risk.

In order to understand the perception of climate change impacts and adaptation of improved extensive shrimp farming, focus group discussion (FGD) meetings were conducted simultaneously in inland (Chinnapuram) and coastal (Gullalamoda) shrimp farming areas of the district on 3rd December 2009 and a stakeholder workshop (SW) was organized at Vijayawada on 4th December 2009.

Focus Group Discussion

A cross section of farmers varying in age, experience in farming and owning farms of different sizes from different societies of the study area participated in the FGD meeting. The FGDs were conducted in Telugu (local language) and English with translations between the two languages. FGD meeting process involved the discussions among the sub-groups and the ideas were posted on the cards.

The farmers identified the important climate change events including the extreme events and ranked their importance. The farming problems and resulting impacts including economic impacts were identified and quantified approximately for the prioritized climate change events. Adaptation measures to be taken were disused and the actions taken by the farmer to deal with or rectify the problem and the agency that could help the farmers in future climate change problems / extreme events were identified and were prioritised.

The inland and coastal area shrimp farmers have experienced more or less similar climate change extremes though there was a difference in the order of priority. The climate change impacts identified on priority were seasonal changes, heavy rains, floods and cyclone in inland shrimp farming area and high temperature, floods, low/un-seasonal rain fall, low temperature, cyclone and low tidal amplitude in coastal shrimp farming area. The seasonal changes were mainly temperature variations and delay in monsoon. The water inundation in ponds is due to heavy rainfall caused by both floods and cyclone. Cyclones are not a problem as they are not very frequently occurring event. However, if cyclone occurs with heavy rainfall, then the economic loss was hundred per cent.

Individual farmers face risks associated with climate variability and climate change. Their livelihoods are exposed to climate risks and associated impacts. Risk identification and assessment were performed for the successful implementation of adaptation practices. Each impact was assessed in terms of consequences and likelihood and their scores were averaged for the group and then multiplied to get the risk rating. Floods and seasonal changes are under extreme risk category whereas heavy rain and cyclone are under high risk category in inland area. High temperature, floods and low rainfall were under high risk category while less cyclone, low tidal movement and low temperature were under medium risk category in coastal area.

Month-wise shrimp farming activities were displayed on the chart and the farmers after discussions within and between the groups matched the crop activities with the seasonal changes. Crop activities such as pond preparation including repair of pond dykes, intake and sluice structures, draining and drying the ponds were taken in the dry months January and February for the first crop and May/June for the second crop. During this time the weather is dry and allows the pond bottom to dry faster. Water filling and bloom development is during February and March for the first crop and July to August/September for the second crop. The harvesting time spreads over May and June for the first crop and November/December for the second crop. Diseases were more during monsoon and post monsoon period. Hence in most of the areas second crop was not a successful one. The production, fry and market prices were also high during the first crop compared to second crop. The occurrence of floods, cyclones and high tides are of unusual occurrence in the months of May and November. Crop planning meetings were done only in societies in December and January months before the first crop and these meetings were not serious for the second crop as many of the farmers are not taking second crop. The society farmers will visit the hatcheries in advance during January/February for getting quality seed.

The adaptation measures identified in FGDs for a particular climate change are more or less same in inland and coastal shrimp farming area. In both the cases shrimp farming has to be adapted to seasonal changes by following better management practices at farm level. In coastal areas the major adaptive measures are for high temperature as the areas near coast experiences high temperatures and for flood protection measures.

Stakeholder workshop

Key stakeholders, individuals and organizations were characterised based on their understanding on CC issues and impact on shrimp farming, adaptive capacity and interests in implementing them. Primary stakeholders are those ultimately affected, either positively or negatively by CC actions. Secondary stakeholders are the 'intermediaries', that is, persons or organizations who are indirectly affected by the CC actions. The tasks of all the identified stakeholders related to shrimp farming and climate change such as the role they play in shrimp farming sector, financial, technical and research support, natural resources and aquaculture policy management, and collection/maintenance/dissemination of data were analysed.

The workshop was attended by 90 stakeholders including small-scale grow out shrimp farmers, hatchery operators, fishermen (shrimp broodstock collectors), non Government organisation (NGO) representatives, inputs dealers, aquaculture consultants, credit institutions representatives, government officials in aquaculture development & policy, researchers and the local and international project partners.

All the participants were divided into three groups to deliver the farmer's, technical and institutional /policy adaptive measures for the identified climate change events and impacts. Based on the results of FGD meetings and personal experience CC issues were identified. Adaptive measures and the responsible agency that can implement the measures along with the time line (Immediate, short-term and long-term) to adapt them were identified.

The farmers group identified seasonal changes, low and high temperatures, heavy and low rainfall, flooding, cyclone and low tidal movement as the important climate change events. The adaptive measures to be implemented by farmer are mostly better management practices for which they need advice from DoF, NaCSA and CIBA. The most important assistance they are in need from Government is supply of electricity for 24 hours, loans and insurance and the construction of flood walls (common dykes) and de-silting and deepening of source water bodies.

The technical/scientific adaptive measures are mainly refinement of the existing or innovation of new technologies to adapt the shrimp farming to the forthcoming climate change events. The important measures are improvement of BMPs, identification of alternate species and development of technology, scientific principles in planning mitigation measures such as mangrove plantations, de-silting and deepening of drains, and construction of flood walls.

The policy measures are mostly on quality input supply, electricity supply, loans and insurance schemes, flood walls construction and mangrove plantations, and efficient forecasting of extreme climatic events. These measures have to be implemented by the respective govt. organizations. Institutions play a critical role in supporting or constraining people's capacity to adapt to climate change. There is a clear need for the development of policy related to climate change adaptation to enhance shrimp farmers' adaptive capacity. The key stakeholders provided useful insights into local governance structures and status of implementation of local policies and programs. Power issues within and between communities and other stakeholders also surfaced during open house discussion.

A very strong focus on building general adaptive capacity can help the poor shrimp aquaculture communities to cope with new challenges. The farmers should have a commitment to implement the adaptive measures at the farm level (better management practices) and all the Govt. Departments, research organizations and NGOs have to help them in increasing their adaptive capacity. Both Central and State Govt. should make strong policies on climate change with a focus to increase the adaptation capacity of all the stakeholders involved in the shrimp farming sector. Integration of climate change considerations into the policies in aquaculture sector can facilitate adaptation and ensure that they contribute to adaptive capacity from national to local levels. In order to adopt the scientific adaptive measures reasonably, research has to be carried out in the areas such as, refining and development of adaptive tools to make aquaculture sustainable and productive, planning for uncertainty to take care of extreme weather events, understanding on changes in shrimp yield resulting from climate change.

The use of participatory processes such as facilitated semi-structured focus group discussion and facilitated stakeholder workshop, a novel technique for the shrimp farmers and stakeholders in Andhra Pradesh helped in understanding the perceptions, vulnerability, and adaptability to climate change on small scale shrimp farmers. The researchers and other stakeholders must step up efforts to fill the critical knowledge gaps on climate change impacts, assessment of aquaculture related vulnerability, development of prediction models for different scenarios, refining and development of adaptive tools to make aquaculture sustainable and productive in the face of climate change. Climate change could manifest through extreme events like cyclones and hence a proper understanding of the current coastal zone management practices, early warning systems and hazard insurance, could provide useful insights about the potential future adaptation strategies. Existing management plans for the fisheries and aquaculture sectors, coastal zones and watersheds need to be reviewed and, if needed, further developed to ensure they cover potential climate change impacts, mitigations and adaptation responses. Increased awareness amongst policy-makers and consumers stimulating demand for carbon sensitive aquaculture and aquatic resources management strategies is required. National information gaps and capacity-building requirements need to be identified and addressed through networks of research, training and academic agencies.

2 Introduction

Climate change is projected to impact broadly across ecosystems, increasing pressure on all livelihoods and food supplies, including fisheries and aquaculture sector. The demands of a growing population will require substantial increases in aquatic food supply mainly through aquaculture in the next 20 to 30 years during which climate change impacts are expected to increase. Global green house gases emissions will continue to grow over the next few decades even with the current climate change mitigation policies and related sustainable development practices. Climatic scenarios generated by computer models show that India could experience warmer and wetter conditions as a result of climate change including an increase in the frequency and intensity of heavy rains and extreme climatic events.

Brackishwater aquaculture in India is synonymous with shrimp farming and mainly carried out by small scale farmers. Shrimp aquaculture has been accepted as a vehicle for rural development, food and nutritional security for the rural masses considering its substantial contribution towards socio-economic development in terms of income and employment through the use of un-utilised and under-utilised resources in several regions of the country. Shrimp has been the mainstay of India's seafood exports as the nation ranks as one of the largest producers of the black tiger species *Penaeus monodon.* It also has immense potential as a foreign exchange earner. Shrimp contributed to 21 per cent by volume and 44 per cent by value of Indian seafood exports during 2008-09 (www.mpeda.com).

It is expected that the climate change impacts will be disproportionately felt by small-scale farmers who are already amongst the most poor and vulnerable members of society. The east coast of India is subject to frequent cyclonic storms and occasional tidal waves which cause loss of aquaculture stock and damage to aquaculture facilities. Ecological changes, inundation of low-lying lands and saline intrusion into freshwater regions are likely to cause substantial dislocation of communities and disruption of farming systems. There is a need to forecast the likely effects of climate change on the shrimp aquaculture sector and to develop strategies to assist farmers and rural communities to adapt to the upcoming changes.

2.1 Shrimp farming in Andhra Pradesh

It is estimated that the country has 1.2 million hectares (ha) of brackishwater area and 5.4 million ha of freshwater sites for development of shrimp and fish farming respectively. Andhra Pradesh (AP) contributes more than half of country's shrimp production in India and the state has been in the forefront since the beginning. Though the ideal tidal amplitude conditions of 1-2 m daily range with an absolute annual range of 2-3 m for shrimp farming do not exist in the state, shrimp aquaculture expanded through the excavation of ponds to depths that would allow tidal water exchange or to avoid excavation by putting a dyke around and use pumps for filling and water exchange. Both the processes introduce heavy cost elements and technical uncertainties, risking both the technical and economic viability. The water quality in respect of year-round salinity distribution, chemical and physical nature of soil, and availability of seed in the state are favorable for coastal shrimp aquaculture. Availability of vast tracts of saline lands coupled with abundant quantity of wild seeds and strong export demand for shrimp were initially responsible for attracting the entrepreneurs towards shrimp farming.

The Tiger prawn, *Penaeus monodon* was the main species cultured. The development of more commercial hatcheries coupled with credit facilities from commercial banks and technical and financial assistance programs from The Marine Products Export Development Authority (MPEDA) led to a phenomenal increase in the area under shrimp farming. A large number of corporate shrimp farms with foreign collaboration also emerged adopting scientific culture system with integrated facilities for production of shrimp seeds, feed, and processing, but did not continue this trend for long as they failed to make profits, and consequently, shrimp farming became more or less a small farmer activity. The small scale farmers were unorganized and most of the farmers did not have access to technological innovations and scientific applications.

Small scale farmers are innovative and productive, but because of poor organization, lack of skills, inadequate information, and knowledge base, they are vulnerable to the numerous risks and hazards that impact their livelihoods and farm productivity. Shrimp farms are operated on both leased out government/private lands and owner operated lands. A credit system functioned throughout the sector, operated and controlled primarily and intermediaries also acted as input suppliers and providers of credit at each stage in the supply chain by buying back the harvested shrimp. On average, farmers end up paying a whopping 30% interest on the loans from the intermediaries that affect the profitability of their operations.

2.1.1 Shrimp production details and farming systems

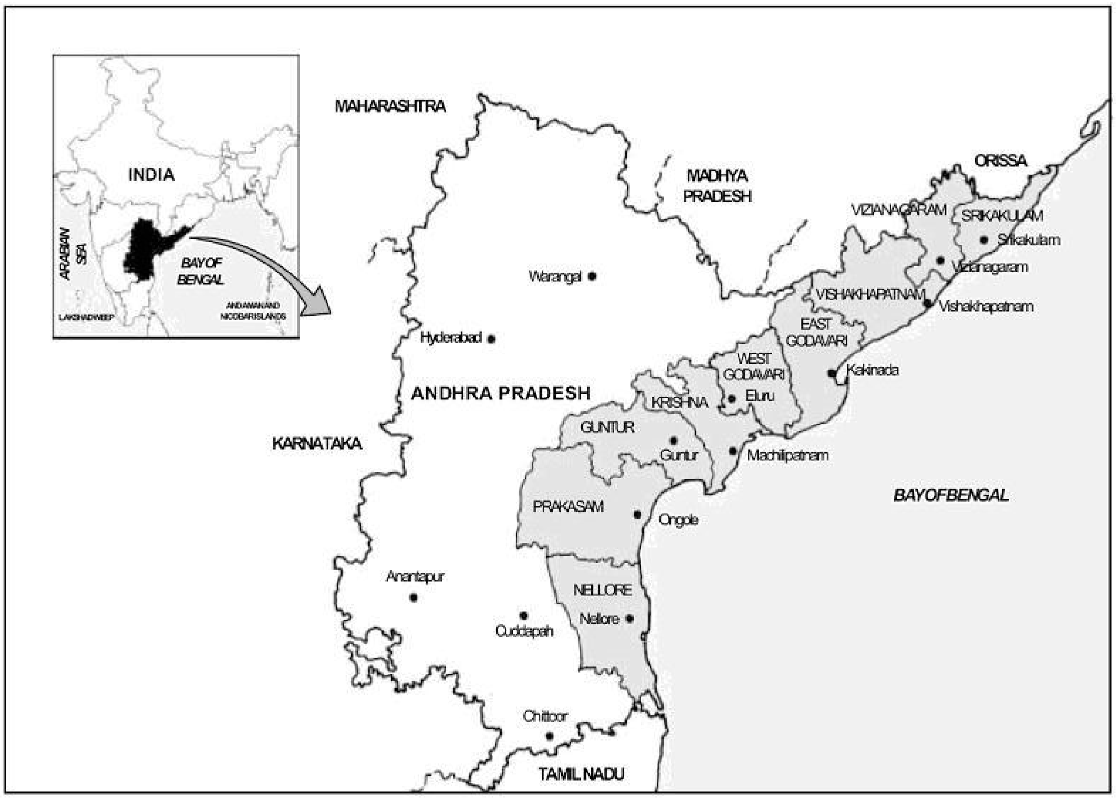
The culture systems adopted in the state vary greatly depending on the inputs available in any particular region as well as on the investment capabilities of the farmer. An average production of 500 to 1500 kg is expected per crop by adopting scientific farming practice in low input systems. Semi-intensive farming technology with production levels reaching 4 to 6 tonnes/ha has been demonstrated (Surendran *et al*., 1991). The culture practice was also gradually intensified and varied levels of intensification were noticed depending on the investment capabilities of the farmer/ entrepreneur.

In 1993, viral diseases such as Monodon baculo virus and white spot virus disease affected the farmed shrimp due to unplanned and uncontrolled development of shrimp farms, heavy stocking densities and poor farm management practices and there was a slump in shrimp farming. Later in 1996 following the verdict of Supreme Court and the establishment of Aquaculture Authority with powers to issue licenses and guidelines, the shrimp culture sector is gradually going through a regulated regime and is slowly returning to its previous production level.

2.1.2 Shrimp aquaculture statistics

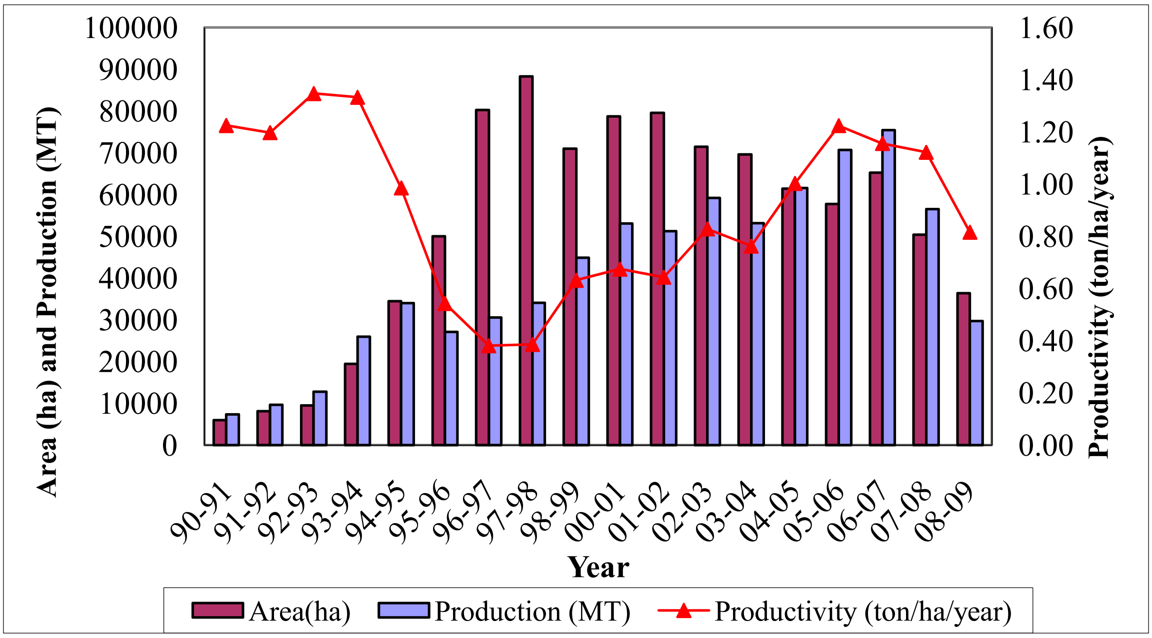
Andhra Pradesh (AP) is the fourth largest state in India in terms of geographical area (275,068 sq. km) and fifth largest in terms of population (75.7 million in 2001). The state has a coastline of 1050 km with two gigantic delta systems formed by the rivers Godavari and Krishna that encompass major wetlands of the state. The length of rivers and canals in the state was 11,514 km and the area under reservoirs and tanks, and ponds was 0.234 and 0.517 million ha respectively (GOI, 2006). The potential area available for brackishwater aquaculture in the state was 0.15 million ha with a network of 172 brackish water bodies in 9 coastal districts (Aquaculture Authority, 2001) (Fig.1). This accounts for 12.6 % of the total potential area in the country (1.2 million ha). Out of total potential area 84,951 ha (56.63%) has been developed for shrimp farming (MPEDA, 2006).

Shrimp belonging to *Penaeus monodon* and *Penaeus indicus* are cultured extensively in the state. Growth of shrimp farming in AP was phenomenal during the years 1990-1994. In 1990, a total of 6,000 ha was under shrimp farming which has risen to about 88,290 ha during 1997 (Fig.2) and then a decreasing trend was observed continuously registering an area of 36,395 ha during 2008-09 (MPEDA statistics). The productivity of shrimp was more than one ton/ha/year during 1990-91 (1.23 ton/ha/year) to 1993-94 (1.33 ton/ha/year) and then decreased to less than one in subsequent years due to disease problems (lowest productivity of 0.38 ton/ha/year during 1996-97) and again increased to more than one from 2004-05. Most of the area is based on brackishwater/ estuarine creeks (96%) and the remaining area (4.0 %) is based on sea. Department of Fisheries, Govt. of AP conducted a rapid macro survey on the shrimp farming area details during 2004-05. It is estimated that out of total area developed into shrimp ponds (84,163 ha) in the state, 70.1 % area was within coastal regulation zone (CRZ) and 29.9 % of the area was located beyond CRZ and out of the total area under culture (53,247 ha) during the same period, 61.8 % area was within CRZ and 38.2 % of the area was outside CRZ.



Source: Coastal Aquaculture Authority (2001)

Fig.1. Coastal districts in Andhra Pradesh (shaded portion) with brackishwater aquaculture



* Data for 1999-2000 and 2000-2001 is not available. (Source: MPEDA statistics)

Fig. 2. Area, production and productivity details of shrimp farming in Andhra Pradesh

2.1.2.1 Distribution of shrimp farms based on size of farms

The farming of shrimp is largely dependent on small holdings of less than 2 ha and these farms account for 90% of the total area utilized for shrimp culture, 7% of farms are between 2 and 5 ha and the remainder has an area of greater than 5 ha (Yadava, 2002; MPEDA, 2006). As per the recent survey of 2004-05, 94 % of the total developed area for shrimp farming in the state was less than 2.0 ha farm holding (53,908 ha); 26 % of the area was in the farm holdings of 2.0 – 5.0 ha (22,178 ha); 10 % area was larger than 5.0 ha (8,076 ha). The total no. of farmers were 57,711 with 93.4% having less than 2 ha, 5.82% between 2 and 5 ha and 0.8% with greater than 5 ha.

Ancillary units such as feed mills, hatcheries and diagnostic labs have been developed to support in the industry, thus boosting regional and local economies even more. The number of hatcheries in 2006 were 191 in the state with a production capacity of 9,335 million PL per year and the number of feed mills was 25, PCR labs was 41 and LCMS-MS labs were 4 (MPEDA, 2006).

2.1.2.2 Employment generation

Shrimp farming is another avenue for generating employment opportunities and increasing income of fishermen. A study conducted by CIBA (1996) reported that in Nellore District of Andhra Pradesh, employment increased by 2–15 percent after the establishment of shrimp farms, with a corresponding increase of 6–22 percent in income of farm labourers. According to the Fisheries Commissioner of Andhra Pradesh, scientific shrimp farming generates maximum employment opportunities of 650 man-days per ha per annum as against 225 man-days per ha per annum through other agricultural operations.

2.1.3 National Centre for Sustainable Aquaculture (NaCSA)

Farmers Society is a group of aqua farmers in a farming cluster or locality (village) that provides an opportunity to the members of the societies to organize themselves to implement and manage the aquaculture activities through participatory approach in order to accomplish their common goal of reducing risks, maximize returns and meet market demands through sustainable shrimp farming. Organized farmers groups (societies/aqua clubs) are one of the key mechanisms for supporting farmer empowerment. They have the potential for cooperative action, which can change the position of the farmer in relation to the opportunity structures, and thus influence the business environment of the farming community. Farmers group also improve information exchange and sharing among group members. Small scale farmers through organization can gain the advantages of economy of scale in accessing services and markets, which are otherwise limited to large commercial farmers. Department of Fisheries, Govt. of AP started the concept of aqua clubs but it was not success due to the less involvement by the Department owing to the limited number of staff. Few clusters of farmers started the association voluntarily and these also do not work due to monopoly of few individuals.

2.1.3.1 Inception of National Centre for Sustainable Aquaculture (NaCSA)

The shrimp farmer associations in Andhra Pradesh began as part of an initiative to reduce the impact of shrimp disease through the implementation of better management practices (BMPs) in small-scale farming clusters. The initiative was established under a cooperative program between the MPEDA and Network of Aquaculture Centers in Asia-Pacific (NACA). The participating farmers began to realise the improved crop outcomes, market power and profitability and the message spread with farmers from adjacent clusters and villages forming their own associations and adopting BMPs. Over the last few years this has brought about a revival of small scale tiger shrimp farming in AP and other coastal states of India. It has also lead to policy and institutional change within India, culminating in the formation of the National Centre for Sustainable Aquaculture (NaCSA).

2.1.3.2 Working of NaCSA and society management

NaCSA is in support of sustainable aquaculture in India by creating a participatory movement that empowers the marginalized and poor rural aquaculture farmers through capacity building at grass root level. NaCSA is achieving this objective through organizing aquaculture societies to improve information exchange and sharing resources among group members, disseminating technologies and information on better farming practices, sustainable and judicious use of natural resources to produce safe and sustainably farmed shrimp (Umesh et al., 2009). The long term objective of NaCSA is to enable aquaculture farmers to adopt sustainable and environment friendly farming practices to produce quality and safe aquatic products such as shrimps, scampi and fish for export and domestic markets. NaCSA will facilitate links between aquaculture stakeholders and strengthen farmer societies, and farmers to facilitate formulation of common policies, strategies and voluntary guidelines to benefit farming community as a whole in the country. The main objectives of NaCSA are:

- Promoting BMPs to improve aquaculture productivity and profits
- Capacity-building and empowerment of primary producers,
- Facilitating improved service provision,
- Connecting farmers to markets to receive a better price for quality product,
- Technology transfer and diversification to other commercially important species,
- Supporting improved food security and sustainable livelihoods in aquaculture communities.

2.1.3.3 Society management

NaCSA is working towards developing these societies as potential business model through public-private partnership where all the concerned stakeholders help the societies to sustain for the mutual benefit. Each society has its own guidelines and implements them. Societies which fail to implement them would lose their society registration. Some features of the registered society are:

- A society consists of 20-75 farmers and has a clear organization with strict conditions for membership, and elected board members.
- Membership to a society is purely on voluntary basis.
- Each society has its own guidelines and audited every year by MPEDA for the implementation of guidelines and BMPs.
- In a society, all the members register their farms with the CAA.
- The members contribute an admission fee of Rs. 1,000 and in addition members have to pay 0.5% of their revenue to the society corpus fund.
- The optimum stocking density for each cluster is decided and abided by farmers/members
- Seed purchase is through contract hatcheries 45 days prior to stocking.
- All the cluster farmers stock at the same time (within 2 weeks period)
- Agreement by all society farmers for not using any antibiotics and no/reduced chemical use.

To facilitate farmer involvement, ensure commitment, and inculcate confidence, the NaCSA field staff stays close to farmer societies for the entire cropping season. Each of the farmer societies has one coordinator selected among its members or from the community by society farmers with a prescribed minimum education level. The society coordinator is trained in society management, BMPs, and extension technique by NaCSA. The coordinator will be responsible for implementing BMPs in societies, and act as link between society farmers and NaCSA. MPEDA's society scheme provides partial financial assistance for farmers to employ a society coordinator for the first 2 years. Each field manager of NaCSA will coordinate the activities of ten such societies. Key farmers from other villages where MPEDA/NACA, NaCSA had worked previously are invited to new villages to share their experiences. Wherever possible, field visits are arranged for farmers to other villages for first hand information exchange among farmers. Farmer's field days are organized at the end of successful crop cycles in societies to spread the message of success to more farmers. Societies procure their entire seed requirement form one hatchery, use feed from one company and planning to link the societies to exporters so that all the shrimp from the particular society is marketed to one exporter. The benefits for the farmers is there will be better price realization as there is no agent or middle men involved for the processors they can buy all the produce from the society as one unit which provides the advantage of larger integrated units where the harvests can be coordinated and better harvest and post harvest practices can be implemented in societies to improve the overall quality of the product and traceability can be maintained.

2.1.3.4 Implementation of better management practices (BMPs) in societies

The key to putting the BMPs into sustained practice was the farmers being associated and motivated. Compared to previous years there was an improved awareness about BMPs among society farmers and for the first time more BMPs were implemented in more than 200 societies during 2008-09. The societies are in a better position today to gain these benefits compared to the situation when they were un-organized. The important BMPs implemented in each society are:

- Plan crop activities well in advance of the cropping season using the society.
- Plan the crop within the financial capacity and farm management skills of individual farmers and consider local environment capacity such as water quality and water availability.
- Follow a crop calendar system for shrimp farming.
- Implement BMPs in a disciplined and cooperative manner.
- Adopt BMPs for shrimp farming.
- Farmer society should meet at least once a week at a fixed time in a fixed place to discuss the crop activities, problems and solutions.

2.1.3.5 Benefits to society members

- Maintenance of records such as internal records (hatcheries, nurseries and farms on general management and key parameters), purchasing and distribution records in a uniform manner helps in traceability.
- Gathering of information on a collective basis.
- Societies are also closely monitored by NaCSA through society coordinators to make sure that there is no use of antibiotics in society farms.
- Gaining higher productivity, reducing cost of operations, improving accessibility to lucrative niche markets, accessibility to government, banks and other interested agencies that wish to contribute to rural development, and in helping to generate synergies within the community.
- Reduction of pollution by following less than 6 pieces per square meter stocking, reduced use of chemicals, antibiotics, efficient use of feed and limited discharge of sediments and water exchange.
- Moving towards carbon neutral shrimp by the process of converting all the society farms from diesel based energy source to electricity.

2.1.3.6 NaCSA society's statistics

NaCSA has organized 386 societies as on 31 December 2009 with membership of 25 to 50 registered farmers in each society in five coastal districts of Andhra Pradesh alone as this is the key state which produces almost 50% of the farmed shrimp in India and there are about

8885 registered farmers involved in these societies, and the total area under shrimp farming was about 8633 ha (Table 1). The numbers of societies existing during 2008-09 in Tamil Nadu, Orissa, and Karnataka states are 28, 6 and 10 and it is targeted to increase the number to 60, 30 and 15 by 2009-10 (NaCSA, 2009 a & b). In West Bengal a beginning was made and it is projected to register 20 societies.

Table 1. Details of societies as on 31st December 2009

District Name	Total Societies registered with state registrar	Total Area (ha)	Total no of farmers
East Godavari	83	2158	1909
West Godavari	72	1512	1584
Krishna	107	2461	2568
Guntur	53	1060	1219
Prakasam	14	280	294
Nellore	46	920	1058
Srikakulam	11	242	253
Total	**386**	**8633**	**8885**

The quantity of production in NaCSA societies in AP during summer crop of 2009 was 2774 MT and from all the societies it was 4082 MT (Table 2).

Table 2. Quantity of material harvested during the summer crop of 2009 from the societies

Sl. No.	Name of the District	Number of Farmers	WSA (ha)	Quantity (MT)
1	East Godavari	1143	1315	1380
2	West Godavari	440	417	374
3	Krishna	715	692.6	249.5
4	Guntur	802	588	510
5	Prakasam	140	125	260
6	All districts of Tamil Nadu	507	1059	1086
7	All Districts of Karnataka	184	216	220
8	All Districts of Orissa	7	3.3	2
TOTAL		3938	4415.9	4081.5

2.2 Climate change in Andhra Pradesh

Climate change is one of the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc. While a changing climate poses a challenge to humanity as a whole, the available evidence suggests that the developing countries particularly are more vulnerable. Climate change will seriously hit the agriculture sector in Andhra Pradesh (AP), affecting the incomes of farmers by as much as 20 per cent. According to the latest World Bank report on "The impact of climate change on India", dry land farmer's incomes in AP plunge by 20 per cent. Under a modest to harsh climate change scenario of a substantial rise in temperatures (2.3^0 C to 3.4^0 C) and a modest but erratic increase in rainfall (4% to 8%), small farmer incomes could decline by as much as 20%.

The east coast of India bordering the Bay of Bengal is a passive continental margin developed during separation of India from Antarctica in the Late Jurassic (Bastia and Nayak

2006). Administratively, the 2,350-km-long east coast forms the eastern seaboard of three States—Orissa in the north, Andhra Pradesh in the centre, and Tamil Nadu in the south. The Pennar delta and Pulicat Lake are the dominant features along the coast south of the Krishna–Godavari delta region. Andhra Pradesh lies between 12°41' and 22°N latitude and 77° and 84°40'E longitude, and is bordered by Maharastra, Chhattisgarh and Orissa in the north, the Bay of Bengal in the East, Tamil Nadu to the south and Karnataka to the west. Andhra Pradesh is historically called the "*Rice Bowl of India*". More than 77% of its crop is rice. Geographically, Andhra Pradesh is composed of most of the eastern half of the Deccan plateau and the plains to the east of the Eastern Ghats. It is the fourth largest state in India. The coastal plains are, for a major part, delta regions formed by the rivers Godavari, Krishna, and Pennar. The Eastern Ghats are a major dividing line in the state's geography. Most of the coastal plains are put to intense agricultural use. West and South west parts of Andhra Pradesh have semi-arid conditions.

The climate of Andhra Pradesh varies considerably, depending on the geographical region. The major role in determining the climate of the state is played by monsoons. The summer season lasts from March to June. In the coastal plain the summer temperatures are generally higher than the rest of the state, with temperature ranging between 20°C and 41°C. July to September is the season for tropical rains in the state. The state receives heavy rainfall during these months. About one third of the total rainfall in Andhra Pradesh is brought by the North-East Monsoons. October and November see low-pressure systems and tropical cyclones formed in the Bay of Bengal which, along with the north-east monsoon, bring rains to the southern and coastal regions of the state. Winters in Andhra Pradesh are pleasant. November, December, January and February are the winter months in AP. Since the state has a long coastal belt the winters are not very cold in those regions. The range of winter temperature is generally 12°C to 30°C.

2.2.1 Precipitation

Approximately 70% of the total annual rainfall over the state is confined to the southwest monsoon season (June-September). Recent decades have exhibited decline in the number of rainy days along east coast (De and Mukhopadhyay, 1998; Singh and Sontakke, 2002). Due to this it is projected, the gross per capita freshwater availability in India will decline from about 1,820 m^3/yr in 2001 to as low as about 1,140 m^3/yr in 2050 (Gupta and Deshpande, 2004) and will reach a state of water stress before 2025 (CWC, 2001). The same trend can be observed in the state also. Some changes are taking place in the character of the monsoon. There is substantial decline in monsoon depressions and increase in low pressure systems. In 2000, Hyderabad witnessed 350 mm rainfall in a day when the yearly average is 700 mm (Source: www.tropmet.res.in) which led to flooding of the city. The lakes do not have capacity to hold this amount of water and it resulted in flooding of colonies and the loss of lives and property.

2.2.2 Temperature

Most of the observed increase in global average temperatures since the mid-twentieth century is very likely to be due to the observed increase in anthropogenic greenhouse gas concentrations (Rosenzweig et al., 2008). The predictions of climate change over India are increasing trends in annual mean temperature, warming more pronounced during post monsoon and winter, increase in frequency of hot days and multiple-day heat wave (Kripalani et al., 1996) and a similar trend was observed in AP state. Water and air temperatures are expected to rise during summer months and this will be more pronounced in southern states.

2.2.3 Extreme Weather Events

One of the most significant consequences of global warming would be an increase in magnitude and frequency of extreme events like heat waves (IPCC, 2007). Most of the available impact estimates however, do not account for impacts due to extreme climate events (ECEs) such as cyclones and droughts, whose frequency and intensity could also increase under the changed climatic conditions. These natural disasters currently cause significant damages in developing countries. The east coast of India is subject to frequent cyclonic storms and occasional tidal waves and studies conducted by CIBA revealed the extent of loss of aquaculture stock and damage to aquaculture facilities due to ECEs. Andhra Pradesh has had many weather related impacts in recent years such as the worst drought in 50 years occurred in early to mid 2009 followed by a severe flood of once in 100 years in October 2009. These extreme climatic events have had severe consequences including heavy economic losses to shrimp farmers in the State.

2.2.3.1 Cyclones

Andhra Pradesh has the longest coastline of all the states in the country. The AP coast is known for frequent tropical cyclones and associated floods and tidal surges causing loss of life and property in the region (Bastia and Nayak 2006). There is the risk of cyclones, the intensity of which is predicted to rise. The segment of Andhra Pradesh coast between Ongole and Machilipatnam is most vulnerable to high storm surges that have been a regular feature in the Bay of Bengal**.** In this century alone, the state has been pounded by 18 devastating storms causing enormous loss of life and property. The 1977 Diviseema Cyclone that was accompanied by a 5-m storm surge killed about 10,000 people and 0.2 million livestock besides causing enormous damage to property worth Rs. 175 millions in 2300 villages in the Krishna delta region. During 1996 the disaster cyclone accompanied by six-meter high tidal waves which hit the coast at Nellore -Prakasam-Konaseema has taken a toll of thousands of lives and at least 100 villages were washed away. Millions of acres of ready-to-harvest paddy and about five million coconut trees spread over an area of 1000 sq.km have been destroyed. (Source: http://www.envis.nic.in/soer/ap/cme_cyc_AP.htm).

2.2.3.2 Tsunami

The AP coast is also prone to tsunamis. Though tsunamis are not climate related, the impacts from these devastating events can be similar to some extreme climate events such as cyclonic tidal waves. During the 2004-tsunami although the coast of the southern state of Tamil Nadu was the most affected with tsunami inundation limits exceeding 800 m at some places (Chadha et al. 2005) killing about 10,000 people, the tsunami impacted the AP coast as well leading to loss of life and property at several locations, especially in the low lying zones along the Krishna and Godavari deltas (Nageswara Rao et al., 2007).

2.2.3.3 Drought

At least half of the severe failures of the Indian summer monsoon since 1871 have occurred during El Niño years (Webster et al. 1998). Consecutive droughts between 2000 and 2002 caused crop failures. The agriculture sector in Andhra Pradesh was worst hit by the 2002 drought. The area under food grains during 2002 was 30 percent less than the normal acreage covered by the crops. The production of rice decreased to such an extent that the state needed to import rice.

2.2.3.4 Heat waves

The four hottest years in Andhra Pradesh since 1901 have occurred in the last 10 years. The year 2002 was the warmest year in Andhra Pradesh on the record since 1901 followed by 2006, 2003 and 2007. During 2009 heat wave conditions also prevailed over parts of Coastal Andhra Pradesh during second fortnight of May. Even in October 2009, temperatures are soaring when there should be a chill in the air (Source: National Climate Centre, India Meteorological Department).

2.2.3.5 Sea level rise

Climate change and associated sea-level rise (SLR) is one of the major environmental concerns of today. Global mean sea-level has risen by about 0.1-0.2 mm yr^{-1} over the past 3,000 years and by 1-2 mm yr^{-1} since 1900, with a central value of 1.5 mm yr^{-1}. Global warming during the past few hundred years is likely to result in a sea level rise of up to half a meter, possibly more, by 2050 (Nicholls, 1998; Nicholls and Mimura, 1998; Nicholls and Lowe, 2004). Nicholls and Branson (1998) used the term "coastal squeeze" to describe the progressive loss and inundation of coastal habitats and natural features located between coastal defenses and rising sea levels. The inter-tidal habitats will continue to disappear progressively, with adverse consequences for coastal biological productivity, biodiversity, and amenity value. An estimate by Nicholls et al. (1999) suggests that by the 2080s, sea-level rise could cause the loss of as much as 22% of the world's coastal wetlands. The total flood-prone area in India is about 40 m ha (Mirza and Ericksen, 1996).

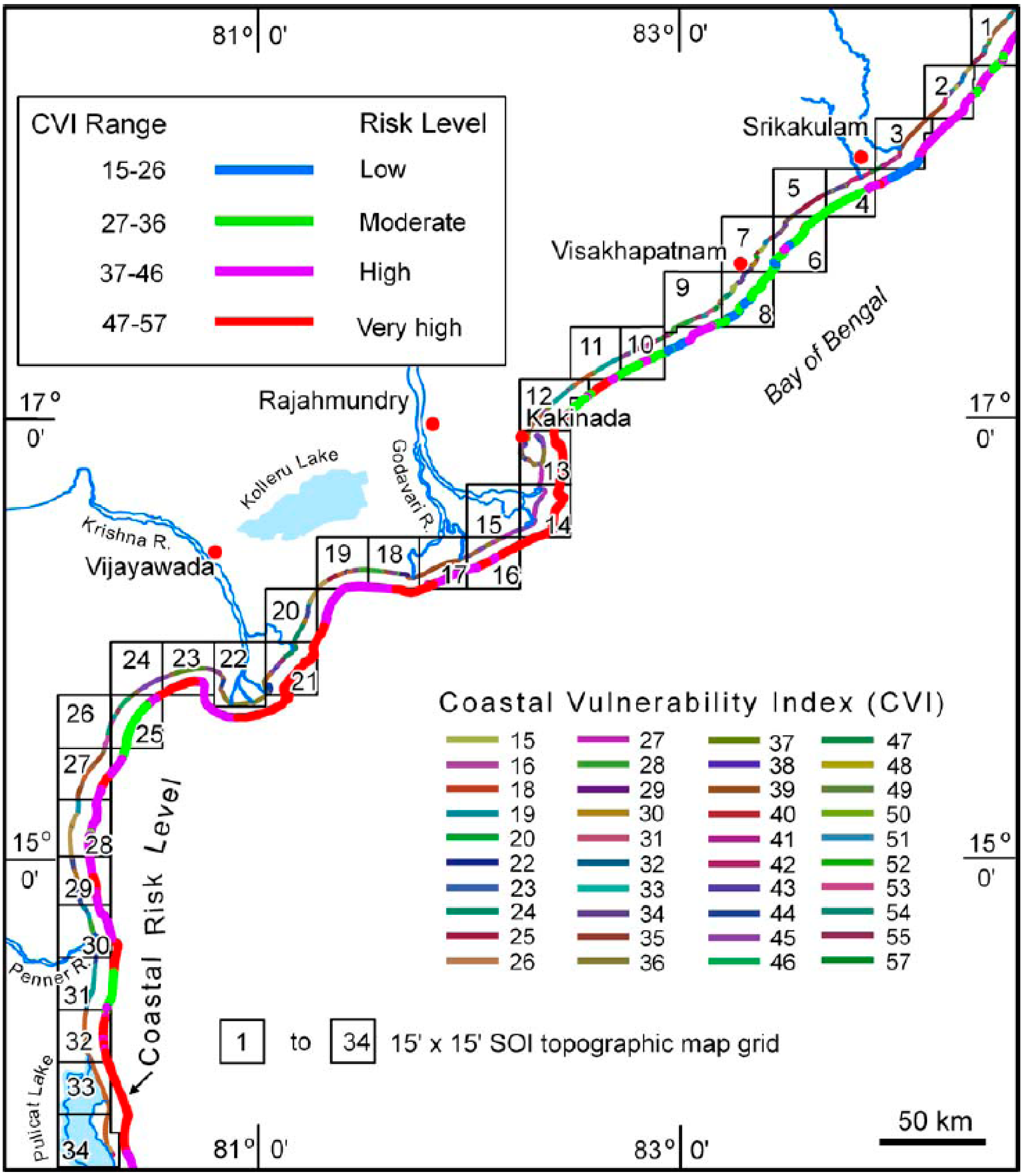
The threat of rise in sea-levels as a result of changing climate makes the coastal resources, coastal infrastructure and population living in the coastal areas highly vulnerable. Rising sea levels, which could flood land (including agriculture and aquaculture) and cause damage to coastal infrastructure and other property, poses another threat. Beyond actual inundation, rising sea levels will also put millions of people at greater risk of flooding. Increased sea water percolation may further reduce fresh water supplies.

Sea levels are rising at a rate of about 1.0–1.75 mm per year along Indian coast due to global warming (Unnikrishnan et al. 2006; Unnikrishnan and Shankar 2007) as revealed by long-term tide-gauge data from various stations and corrections for vertical land movements. Pronounced erosion even along certain major depocentres like deltas of the east coast of India was mainly attributed to anthropogenic forcing (Baskaran, 2004; Hema Malini and Nageswara Rao, 2004; Nageswara Rao et al., 2008).

i) Vulnerability to sea level rise

The future sea-level rise is likely to further intensify the storm surges (Pendleton et al. 2004), besides accelerating shoreline erosion and other problems like seawater intrusion and damage to coastal structures, thereby making the AP coast much more vulnerable in future. About 43% (442.4 km) of the 1,030-km-long AP coast is under very high-risk (Krishna, Godavari and Pennar delta front coastal sectors which are very low-lying and almost flat with mudflats, mangrove swamps, and lagoons/backwaters) (Fig.3) Each color of the coastline indicates a particular coastal vulnerability index (CVI) value from 15 to 57 (except for the CVI values 17, 21 and 56). The thick colored parallel line all along the coast shows the risk levels of the coast based on the categorization of CVI values into four risk classes as per the classification scheme shown in the upper left legend in the figure. The black colored squares along the coastline (from 1 to 34) represent the grid of SOI topographic maps.

Even the small tidal range in these areas can reach far inland since the gradient is extremely gentle. About 35% (363.7 km) are under high-risk (southern part of the AP coast near Pulicat Lake; north of Pennar delta; south of Krishna delta; and between Krishna and Godavari deltas in the central part of AP coast) if the sea level rises by ~0.6 m displacing more than 1.29 million people living within 2.0 m elevation in 282 villages in the region (Nageswara Rao et al., 2008). In the remaining part, 193.9-km-long coast (19% of the total) mainly the non-deltaic dune-front sections, come under moderate-risk category, while the rocky coast on both sides of Visakhapatnam and some embayed/indented sectors over a combined length of 30 km (3%) are in the low-risk category. No part of the Krishna–Godavari delta coast is in the low or moderate risk levels. If the sea level rises by 0.59 m as predicted by IPCC (2007), an area of about 565 km^2 would be submerged under the new low-tide level along the entire AP coast of which 150 km^2 would be in the Krishna–Godavari delta region alone. The new spring high tide reaches further inland by another ~0.6 m above its present level of 1.5 m, i.e., up to 2.1 m. In such a case, an additional area of about 1,233 km^2 along the AP coast including 894 km^2 in the Krishna and Godavari delta region alone would go under the new inter-tidal zone thereby directly displacing about 1.29 million people (according to 2001 census) who live in 282 villages spread over nine coastal districts of Andhra Pradesh. Notably, the inhabitants of these villages are mainly hut-dwelling fishing communities who are highly vulnerable in socio-economic terms as well. Further, there is every possibility of increased storm surges (Unnikrishnan et al; 2006) reaching much inland than at present with the rise in sea level.



Souce: Nageswara Rao et al. (2008)

Fig. 3 Coastal vulnerability index (CVI) and risk levels of different segments of AP coast.

3 Background to the project and case study

The project on “Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region” also known as "*Aquaclimate*" aims to strengthen the adaptive capacities of rural farming communities to the impacts of climate change. The three year project focuses on small-scale aquaculture and related sectors that are comprised largely of poor people who depend on aquatic resources for their livelihoods. The project coordinated by Network of Aquaculture Centers in Asia-Pacific (NACA) is implemented in India, Vietnam, Philippines and Sri Lanka and is funded by the Norwegian Agency for Development Cooperation (NORAD).

The focus of the project is on mapping the farmer’s perceptions and attitudes towards climate change impacts and their adaptive capacities to address the impacts in specific farming sectors in the countries of Vietnam (catfish and improved extensive shrimp farming), Philippines (milkfish farming), India (improved extensive shrimp farming) and Sri Lanka (reservoir fisheries). The project is developing future scenarios of climate change impacts based on the current trends, assessing the potential adaptive measures for different aquatic farming systems and developing and prioritising better management practices, suggesting codes of practices and improved methodologies for such systems. The project is also developing guidelines for policy makers to help in framing appropriate regional adaptation strategies and associated policy developments. Interaction with stakeholders including small farmer organizations, managers, policy makers and researchers in the region to gain from their experiences, jointly develop scenarios and adaptation strategies is part of the project strategy.

3.1 Objectives and expected outputs of the Aquaclimate project

The overall project objective was to select suitable and appropriate aquatic farming systems, which provide livelihoods to small scale farmers, in each of the countries that are likely to be impacted and or subjected to different elements of climate change impacts (e.g. sea level rise, flooding, extended drought periods) and to determine/ assess the degree of vulnerability of each system, and to provide guidelines on suitable adaptive measures, ranked according to relevant criteria (e.g. economic, social, etc.) for consideration for adaptation by the communities / policy makers and so forth.

3.1.1 Specific Objectives

- Assess the impacts of climate change (CC) on small scale aquaculture sectors (environmental and socio-economic) in selected areas and aquatic farming systems.
- Assess the vulnerability of different aquatic farming systems to climate change.
- Explore potential adaptive measures for different aquatic farming systems.
- Prioritise better practices for the most “adaptive” aquatic farming systems.
- Develop future scenarios for small-scale shrimp aquaculture systems in India (up to 2020).
- Propose risk-mitigating strategies compatible with the scenarios.
- Determine awareness/knowledge level, perceptions of risks, and attitudes of farmers towards perceived risks from climate change.
- Determine risk-management behaviours and strategies of farmers to climate change induced risks.
- Develop guidelines for policy measures and decision support tools.
- Benchmark adaptive capacities of small farming households.
- Develop wider awareness of the results by publishing and disseminating through various sources and networks.

3.1.2 Expected outputs

The project will provide small-scale farmers with strategies to maintain their resilience in the face of climatic change. Outputs of the project are recommendations that address the environmental and social changes (and conflicts) likely to arise from climate change impacts on the respective farming systems, improve management/governance mechanisms and decision support systems, build capacity and strengthen institutional partnerships and alliances. It will provide information for investments in research, technology development and transfer, public education, training, infrastructure and systems, markets, financial and other support services for the poor farmers and aquatic resource users. End users of the outputs from the project are farmers, policy makers, academia, producer organizations, regional organizations and Non Governmental Organizations (NGOs).

3.1.3 Project implementation

The project is implemented by international and national partners, with each partner bringing different areas of expertise and having different areas of responsibility within the project.

The international project partners for the study are:

- Network of Aquaculture Centers in Asia-Pacific (NACA), Bangkok, Thailand
- Faculty of Fisheries, Kasetsart University, Bangkok, Thailand
- Bioforsk – The Norwegian Institute for Agricultural and Environmental Research- Norway
- Akvaplan-niva AS – Tromso, Norway

The project will be implemented via five work packages, as follows:

- Assessment of impacts of climate change on small-scale aquatic farming systems risk perceptions, attitudes and risk management behaviour status of resiliency, adaptive capacities and adaptation strategies of small-scale farmers.
- Developing adaptive solutions and scenario-building of the changes on the resources and livelihoods options of poor and small aquaculture households, and the risks and opportunities presented by climate change.
- Policy and analysis and adaptation strategy development.
- Project coordination, results dissemination and follow up action.

3.2 Indian case study

The Aquaclimate project case study in India will investigate the climate change impacts and adaptation of extensive shrimp farming. The information on the likely impacts of climate change on shrimp farming is very limited and hence it is essential that there is concerted research effort to understand the impacts and develop adaptive measures. Shrimp aquaculture is threatened by changes in temperature, precipitation, drought, storms/floods that affect infrastructure and livelihoods which can impact aquaculture both negatively and positively. However, proper focus was not given to this sector compared to agriculture in terms of the damage assessment, relief measures, and crop insurance schemes,

This case study aims to assess the degree of vulnerability of the small-scale shrimp farmers in Andhra Pradesh, and to provide guidelines on suitable adaptive measures to assist them to adapt to climate change and sustain their livelihoods. Central Institute of Brackishwater Aquaculture (CIBA) is the national partner to conduct a comprehensive study, in conjunction with the National Centre for Sustainable Aquaculture (NaCSA), part of the MPEDA. NaCSA societies in Krishna District of AP have been selected to study the impacts and adaptation of small scale shrimp farmers in this Aquaclimate project.

The expected deliverables from this sub- project are likely to be:

- A knowledge on different scenarios on impacts of climate change impacts, for shrimp farming systems
- The impacts of extreme events on shrimp farming systems.
- Range of adaptation measures to different climatic change elements and suggested improvements to practices and or introduction of new practices to maintain livelihoods of aquatic farming systems.
- A series of publications and reports and associated dissemination materials targeted at different audiences.

3.2.1 Study area - Krishna District, Andhra Pradesh

Krishna District in AP has been identified as study area and the NaCSA societies in the district have been identified for pre-testing of questionnaires and also to organize focus group discussions to study the perceptions of climate change impacts and adaptation to shrimp farming. The area of Krishna district is 8727 sq. km and the length of the coastal line is 111 Km and continental shelf area is 865 sq.km. The district is endowed with Kolleru lake, Upputeru and good number of fish and brackishwater resources for development of aquaculture. Out of 50 mandals in the district 10 mandals (Nagayalanka, Avanigadda, Koduru, Machilipatnam, Pedana, Bantumilli, Kruthivenu, Mudinepalli, Kalidindhi and Kaikalur) contributed to the development of shrimp farming in brackishwater. In Kolleru and surrounding areas viz., Kaikaluru, Mandavalli, Nandivada, Mudinepalli, Gudivada and Kalidindi mandals shrimp farming was done in freshwater areas. The potential area available in the district was 50,000 ha and the area developed was 36,143 ha with water spread area of 11,494 ha (MPEDA, 2006). About 15,000 ha has been abandoned in the district due to the disease problems, non-availability of electric supply lines, steep increase in production cost and also due to the volatility and loss of market prices. The farmers are not able to recover even the working capital amount spent and the profit margin is greatly reduced. The average size of aquaculture farms in the district is about 0.75 ha and 95% of the farmers cultivate less than 2 hectares (Fisheries Department Unpublished documentation). At the end of the 1990s, the development of aquaculture had come out of the control of the concerned governmental departments (Anonymous 2005) and resulted in the outbreak of diseases due to poor management practices. Despite increasing the inputs, shrimp yield decreased (Anonymous 2005; MPEDA 2006). The details of fisheries and aquaculture statistics for the period 2008-09 related to aquaculture are presented in box 1.

Box 1 Fisheries and aquaculture statistics in Krishna District during 2008-09

<u>Production details</u>

Inland fish production	251312 MT
Marine fish production	16172 MT
Fresh water prawn production	11026 MT
Brackish water aquaculture production	5903 MT
Total fish and Prawn production	284413MT

<u>Area and farmers details</u>

	Brackishwater	Freshwater
No. of farmers	3236	7249
Water spread area (ha)	4063	20647
Utilized area (ha)	2580	5003

Size of farm holding	1-2 ha
No. of Registered farms under CAA	2550

(Source:. Department of Fisheries, Krishna district (2008-09) Machilipatnam (Unpublished)

3.2.2 Shrimp farming systems and practices in Krishna District

Eighty per cent of shrimp farms are extensive and 10 per cent of shrimp farms are traditional type and 10 per cent of shrimp farms are modified extensive type in Krishna District. Almost all farmers cultivate tiger shrimp *Penaeus monodon*. However, very few farmers cultivate Indian white shrimp (*Fenneropenaeus indicus)*. There is a high prevalence of usage of water from agriculture canals and drains (>70%). Extensive farming system operates with low stocking density and lime and organic materials are used to stimulate production of natural food for their shrimp. In medium density semi-intensive system pond preparation was elaborate, with dry-out once or twice a year, tilling and liming, and fertilisation with nitrogen and phosphorus compounds to promote natural production. Various extra cellular enzyme preparations, probiotics and bacterial inocula are used to improve water quality, but the benefits of these treatments have not been conclusively established. Most farmers in this region use a reduced water exchange system (20-30% water exchange per month). Recently farmers are practicing zero-water-exchange systems, where 9 to 10 weeks after stocking the pond ecology shifts during the production cycle from an autotrophic phytoplankton-based community to a heterotrophic bacteria-based community. This shift improves water quality through fast digestion of organic waste and without production of toxic metabolites. Disease out break is the most feared threat to the shrimp aquaculture in the district. Disease out break started from in 1994 onwards and the frequency of disease occurrence ranged from 2.7 to 8 crops out of 10 crops.

3.2.3 Climate in Krishna District

The climate in Krishna district is summer in March to June, rainy season (southwest monsoon), winter during November to January. Recently the temperatures registered in summer are very high and as high as 50^{0}C was recorded during 2007 in IMD Observatory located at Gannavaram. The climate normals in the district based on the weather parameter values from 1950 t0 1980 are given in Appendix-1.

4 Stakeholder consultation meetings in India

Focus group discussions (FGD) in inland and coastal shrimp farming areas, and stakeholder workshop (SW) were conducted in Krishna District, Andhra Pradesh focusing on the farmer’s perception of climate change and their and other relevant stakeholder’s suggestions of adaptation measures. Focus group discussions together with stakeholder workshop will help to understand the perceptions, vulnerability, and adaptability to climate change on small scale shrimp farmers.

4.1 Focus Group Discussions (FGD)

Focus group discussion (FGD) is a participatory process that involves all participants to obtain their perceptions about climate change impacts and adaptation measures that are being used or they think could be used to adapt to climate change. The focus group discussions are to be facilitated by skilled moderators using a semi-structured discussion guide. The size and selection of the focus groups are important, and the purpose of the study will guide the selection of the focus group members. The normal recommended size of a focus group is 8-10. The focus groups can generate a lot of relevant information during the discussions. The objectives of focus group discussion are:

1. To map farmers perceptions about climate change and likely impacts on small scale shrimp aquaculture systems in particular.
2. To estimate the economic losses for the farmers due to extreme climate events.
3. To identify adaptation measures that farmers/communities respond with, when exposed to extreme climatic events and responsible agencies

4 To conduct risk assessment
5 To develop seasonal and crop calendar of shrimp farming activities

4.2 Stakeholder Workshop (SW)

The primary objective of stakeholder workshop (SW) is to analyze the stakeholder perceptions, vulnerability, and adaptability to climate change. Key stakeholders can provide useful insights into local governance structures and status of implementation of local policies and programs. Power issues within and between communities and other stakeholders can also be surfaced through interviews with key stakeholders. The objectives of stakeholder workshop are:

1 To identify the key stakeholders
2 Characterization and classification of key stakeholders and task analysis
3 To map the farmers, scientific/technical and institutional/policy adaptation measures
4 To identify the agencies involved with the implementation adaptive measures.

5 Materials and methods

In order to understand the perception of climate change impacts and adaptation of shrimp farming, focus group discussions (FGDs) and stakeholder workshop (SW) were conducted in the study area, Krishna District, Andhra Pradesh on 3rd and 4th December 2009, respectively. The FGDs and SW were supported and organized by the local partners Dr M. Muralidhar, National coordinator and Dr M. Kumaran, National co-coordinator from Central Institute of Brackishwater Aquaculture (CIBA) and National Centre for Sustainable Aquaculture (NaCSA) team led by N. R. Umesh and, Senior Research Scholar of the project B.Muniyandi in collaboration and technical assistance from international partners Dr Nigel William Abery, the overall project coordinator from NACA, Dr Udaya S. Nagothu from Bioforsk, Norway, Ms Sirisuda Jumnongsong from Kasetsart University, Thailand and Ms Jocelyn Hernandez from Akvaplan-niva, Norway .The brief description of the methodology followed in FGD and SW is given below.

5.1 Focus Group Discussion with the shrimp farmers

Shrimp farming is being undertaken in coastal and inland areas of the study area. In order to analyse the climate change impacts encountered and adaptation measures followed on the 3rd December 2009 two FGD meetings were conducted simultaneously with 16 and 17 small-scale shrimp farmers from NaCSA societies and non-society in Chinnapuram (Inland area) and Gullalamoda (Coastal area), respectively in Krishna District.

5.1.1 Focus Group Discussion process

The farmers varying in age, experience in farming and owning farms of different sizes were selected through stratified random sampling from different societies of the study area to participate in the FGD meeting and were informed in advance. The FGDs venue was selected close to the farmer's farms in a comfortable setting where farmers can express their opinions freely. The FGDs were conducted in Telugu (local language) and English with translations between the two languages.

In the beginning, the programme schedule of the FGD meeting (Appendix-2) is displayed on a chart to the farmers and participant kit and registration forms were handed over to them. In the registration form participants were asked to give the details of farm characteristics such as size of the farm, type of cultivation etc. Adequate background information was provided to the farmers about the project, purpose of the meeting and expectations from the meeting by the Project coordinator from NACA and National coordinator at Gullalamoda and by the international partner from Bioforsk and National co-cordinator at Chinnapuram. The topics to be discussed in different sessions were briefed to the participants. All the sessions were moderated by the facilitator who can speak Telugu and some English and a rapporteur (note taker), good in Telugu and English for taking notes and for debriefing after the meeting. Simultaneous translation helped in maintaining the group dynamics. The participants were given freedom to express themselves, disclose their practices and ideas, both positive and negative in the local language Telugu and translated into English by facilitators for the purpose. Least interference by scientific personnel was ensured to allow free expression of opinions and the group responses are taken as collective opinion. The sessions in FGD meeting are:

Session 1: Introductions and grouping of the farmers (10-15 mts)

All the scientific staff, facilitators, note taker and farmers introduced themselves along with their back ground. Farmers were divided into four smaller groups with four members in each group to facilitate them to discuss among themselves and present their findings to the others at each step of the process. Materials such as A3 paper, cellotape, colour markers, color cards etc. were provided to the participants.

Session 2: Farmer's perception of climate change (20 mts)

In this session farmers have identified the important climate change events including the extreme events. Discussion was held within sub groups and the ideas were posted on the cards. Cards were collected by facilitators and pinned on the wall. Prioritisation and ranking of the climate change events was done.

Session 3: Impact of climate change on shrimp farming (20 mts)

Identifying the resulting impacts and farming problems for the prioritized climate change events was done in this session. Brainstorming within the sub-groups was done and the ideas were posted on the cards and later pasting the cards on the wall and matched them with the related climate change events. Ranking and prioritization of impacts was done.

Session 4: Economic impacts (15- 20 mts)

Economic impacts of identified climate change events on shrimp farming were discussed within the groups. The impact (loss) has been quantified approximately. Final check was done by the facilitator.

Session 5: Solutions and responsible agencies (25 – 30 mts)

Adaptation measures to be taken were disused during this session. Actions taken by the farmer to deal with or rectify the problem and the agency that could help the farmer's in future extreme events were identified by brainstorming within the sub-groups and posted the ideas on the cards. Later the cards were pasted on the wall and matched them with the related climate change events. Ranking and prioritisation was done.

Session 6: Risk assessment (45 mts)

Explained the purpose and the method (see at 5.1.2) of risk assessment to the participants. Each individual farmer provided the inputs and after analysis preliminary results were displayed on the chart.

Session 7: Seasonal and crop calendar (45 mts)

The purpose and method was explained to the farmers (see at 51.3). Seasonal changes and crop activities calendar was put on the wall and the farmers provided the inputs to fill in the calendar. Final check was done by the facilitator.

Session 8: Discussion - Open group (45 mts)

Final results of FGD meeting were displayed to the participants. Later the participants were asked to express their opinions in open group discussion.

5.1.2 Risk analysis

Individual farmers face risks associated with climate variability and climate change. Their livelihoods are exposed to climate risks and associated impacts. Risk assessment is a methodology to determine the nature and extent of risk by analyzing potential threats and evaluating existing conditions of vulnerability that could pose a potential threat to property, livelihoods and the environment on which they depend. Risk identification and assessment are the two important steps that form the basis for successful implementation of adaptation practices. Risk is the result of physically defined hazards interacting with exposed systems taking into consideration the properties of the systems, such as their sensitivity or social vulnerability.

Climate risk identification is the process of defining and describing a climate-related hazard, including its physical characteristics, magnitude and severity, probability and frequency, exposure and consequences. This involves identification and assessment of current (climate variability) and future (climate change) risks and associated societal vulnerabilities. Climate risk identification has three basic elements: probability, exposure and consequences. Each climate risk can be identified by its own natural characteristics, including geographic area (aerial extent), time of year it is most likely to occur and its severity. In most cases, a climate event may create multiple hazards. Thus, it is necessary to identify the potential primary hazard and also it's triggering effect on secondary hazards. Knowledge of the nature of risks, their geographic coverage and their potential future behaviour is fundamental for designing a viable adaptation practice to reduce the impact of climate change in the aquaculture sector.

5.1.2.1 Elements of risk identification

Risk can be considered as the combination of an event, its likelihood and its consequences. Risk equals the probability of climate hazard multiplied by a given system's vulnerability.

i) Probability or likelihood rating

Probability or likelihood measures how frequently an event is likely to occur. Frequency can be expressed as the average time between occurrences of an event or the per cent chance or probability of the event occurring within a given time period. Some climate change impacts, such as increasing average temperatures and sea level rise are virtually certain. The degree to which these changes affect the existing problems has to be evaluated in vulnerability assessment. Probability can be assessed qualitatively (high, medium, low), particularly in cases where resources are limited, information is limited, or the consequences of the impacts are small. In cases where a quantitative estimate of probability is warranted, more technical and analytical techniques have to be considered. Likelihood ratings that were made are mentioned in Table 3.

Table 3. Risk likelihood ratings

Rating	Recurrent Risks
Almost Certain	Could occur several times per year
Likely	May arise about once per year
Possible	May arise once in ten years
Unlikely	May arise once in 10 years to 25 years
Rare	Unlikely to occur during the next 25 years

ii) Consequence rating

Consequence means the full or partial damage, injuries or loss of life, property, environment and business that can be quantified, usually in economic or financial terms. This estimation may be qualitative (high, medium, low) and/or quantitative. The consequences of potential CC pacts were considered in terms of the magnitude of the impact. This can be judged by the severity of the impact and the socio-economic implications. Consequence ratings were made according to the Table 4.

Table 4. Table Risk Consequence Scales

Rating	Economic
Catastrophic	Business failure
Major	Business is unable to thrive
Moderate	Significant general reduction in economic performance relative to others
Minor	Individually significant but isolated areas of reduction in economic performance relative to others
Insignificant or positive	Minor shortfall in profitability relative to others or positive

5.1.2.2 Risk assessment process - Evaluation of Risk priority levels

In order to obtain a qualitative assessment of potential impacts of climate change identified in session one, each impact was assessed in terms of consequences and likelihood. The likelihood (L) and consequence (C) scores were averaged for the group and then multiplied to get the risk rating (RR).

Results from consequence and likelihood assessments were entered into the risk priority matrix to give an initial risk priority level (Table 5). Risk priority levels from each group were compared. If levels differed, further discussion and comparison of the relative risks have to be carried out till a risk priority level agreed upon. When all priority levels were collated, they were reviewed as a whole and risks considered to have been over- or under- rated and were adjusted. Mixed ratings, such as high/medium were assigned to the climate change events.

Table 5. Risk priority level matrix

		Consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelyhood	Almost Certain	Medium	Medium	High	Extreme	Extreme
	Likely	Low	Medium	High	High	Extreme
	Possible	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	Medium
	Rare	Low	Low	Low	Low	Medium

5.1.3 Seasonal/crop calendar

Changes in temperature and rainfall are very common to occur in different months and each geographical region has these changes in analogous manner over the years unless otherwise there are deviations from the normal values. Each species to be cultured will have its own temperature and water requirements and the culture practices are planned in such a way based on the seasonal changes. However, sometimes deviations in seasonal changes will result in crops failure. Hence it is very important to plan the culture as per the changes in weather parameters in different seasons. In order to understand this concept, seasonal changes were mentioned on the chart and the farmers were asked to mention the changes in every month including extreme climatic events. Month-wise shrimp farming activities were also displayed on the chart and the farmers were asked to match the activities with the seasonal changes. Farmers discussed within the groups and also between the groups and provided inputs to fill in the calendar. Final check was done by the facilitator.

5.2 Stakeholder’s Workshop

Stakeholder perception on climate change in relation to shrimp involves the process of stakeholder mapping, their characterization and classification, analysis of tasks and organization of stakeholder workshop (SW).

5.2.1 Stakeholder mapping

The first step in building any stakeholder map is to develop a categorised list of the members of the stakeholder community. The interaction with the potential list of stakeholders will always exceed both the time available for analysis and the capability of the mapping tool to sensibly display the results. A stakeholder is any person or organization, who can be positively or negatively impacted by, or cause an impact on the actions of climate change. The challenge is to focus on the ‘key stakeholders’ who are currently important and to use the tool to visualise this critical sub-set of the total community. The list of stakeholders has been reasonably prepared and then assigned priorities in such a way that the ‘highest priority’ stakeholders have been categorised.

5.2.2 Stakeholder characteristics and classification

After identification of key stakeholders (individuals and organizations), they were characterised with respect to the issues such as understanding on CC issues and impact on shrimp farming, adaptive capacity and interests in implementing them. Key stakeholders will have significant influence in the sector on the adaptation measures.

5.2.3 Stakeholder task analysis

Stakeholder analysis tables were prepared by the Indian project partners prior to inviting the selected stakeholders to the workshop, and the details were sent to NACA for their advice. Stakeholder analysis has the goal of developing cooperation between the stakeholder and the project team and, ultimately, assuring successful outcomes for the project. A stakeholder analysis is performed when there is a need to clarify the consequences of envisaged changes or at the start of new projects and in connection with organizational changes generally. It is important to identify all stakeholders for the purpose of identifying their success criteria and turning these into quality goals. The multiple tasks of the stakeholders have been analysed.

5.2.4 Stakeholder workshop Process

On 4th December 2009 in Vijayawada, Andhra Pradesh a larger stakeholder workshop was conducted with relevant shrimp farming stakeholders. The stakeholders were invited to the workshop based on the work done on the characterisation and analysis of stakeholders. All the participant stakeholders were provided with the participant kit, programme schedule (Appendix - 3), and the project flier at the time of registration to understand the background of the project.

5.2.4.1 Stakeholder Workshop meeting format

During the inaugural session presentations were made on the project details (Dr. Nigel William Abery), workshop objectives (Dr. Udaya Sekhar Nagothu), status of shrimp culture in Andhra Pradesh with special reference to study area, Krishna District (N. R. Umesh), climate change impacts on shrimp aquaculture with a focus on extreme events in India (Dr. M. Muralidhar), climate change - adaptation for sustainability (Dr. M. Kumaran). Brief remarks about the importance of workshop were made by Dr. T. C. Santiago (HOD, AAH&ED, CIBA, Chennai), G. Rathina Raj (Deputy Director, MPEDA, Vijayawada) and Dr. B. Chamundeswari Devi (Principal, CoF, Nellore). The results of focus group discussions from the previous day (3rd December 2009) about the key impacts on shrimp farmers in inland and coastal areas from climate change were presented by Ms Sirisuda Jumnongsong to the stakeholder workshop participants and were used as the starting point for the workshop group discussions. Simultaneous translations in Telugu language were made by the facilitators.

5.2.4.2 Grouping of stakeholders

The stakeholder workshop was attended by 90 stakeholders including 18 small-scale grow out shrimp farmers, 5 hatchery operators, 4 fishermen (shrimp broodstock collectors), 5 Non Government Organization (NGO) representatives, 5 inputs dealers, 5 aquaculture consultants, 4 credit institutions representatives, 16 government officials in aquaculture development & policy, 10 researchers and the 14 (CIBA & NaCSA) local and 4 international project partners. High levels of participation were observed from all stakeholders about the key climate change impacts and current and possible adaptations. All the participants were divided into three groups viz., farmer, scientist and policy/ institutional to deliver the farmer's, technical and institutional /policy measures for the identified climate change events and impacts. All the groups were comprised of mixed participants. Among the major groups smaller sub-groups were created to encourage active participation. The discussions in each group were moderated by the facilitators and note takers having knowledge in both English and Telugu languages. The agenda for the group's discussion process is as follows:

Step 1: CC Issue identification (based on the results of FGDs and personal experience or observation)
Step 2: Identification of impacts corresponding to identified CC
Step 3: Identification of adaptive measures (existing or ways on how to address)
Step 4: Identification of the responsible agency that can implement the adaptive measures and the timeline to adapt them (Immediate, short-term and long-term).

5.2.4.3 Plenary Workshop/Open Group session

The outcome of group discussions was presented in the open group session. Later, stakeholders were given a chance to express their opinions.

5.2.4.4 Meeting with Key Stakeholders

After the workshop, project coordinator and local coordinators have met few stakeholders who have not attended the workshop viz., Coastal Aquaculture Authority, Indian Meteorological Department and few other individuals involved in climate change work and got their opinions on climate change impact on shrimp farming and their role in adaptation to CC.

6 Results

The results of focus group discussions and stakeholder workshop are presented in this section.

6.1 Focus Group Discussion with the shrimp farmers – farmers perceptions

The farmer's perceptions on climate change, impacts on shrimp farming, economic impacts and adaptation measures to be followed and the agencies identified by farmers in implementing the measures, climatic events risk assessment and seasonal and crop calendar are presented for both inland and coastal shrimp farming areas.

6.1.1 Inland shrimp farming area (Chinnapuram)

In the FGD meeting conducted at Chinnapuram (Inland shrimp farming area), the responses of 16 farmers representing different NaCSA societies and non-society was obtained.

6.1.1.1 Farmer's perception on climate change.

The results of farmer's perceptions on climate change, economic impacts and adaptation measures to be followed and the agencies to help them and the time line for implementation in inland shrimp farming area are presented in Table 6.

The climate change events identified on priority were seasonal changes, heavy rains, floods and cyclone by 13, 10, 8 and 7 farmers respectively. The seasonal changes were mainly temperature variations and delay in monsoon. The water inundation in ponds is due to heavy rainfall caused by both cyclones and floods and the impacts are same in both the cases.

Focus Group Discussion Process at Chinnapuram, Inland shrimp farming area

Table 6. Results of farmer's focus group discussion conducted at Chinnapuram (Inland shrimp farming area), Krishna District

Climate Change Event	Impacts (I)	Risks	Economic loss	Auto-Adaptations (By farmers)	Planned Adaptations & Who will do it?	When (Period)
A. Heavy/ Torrential Rain	I1. Salinity reduction I2. p^H fluctuations I3. Reduced dissolved oxygen	I1, I2 & I3. • Reduced molting & • Disease outbreak	I1, I2 & I3. • 70% loss in summer crop if it occurs on or above 80 days of culture. • 50% loss in monsoon crop if it occurs on or above 80 days of Culture.	I1, I2 & I3. • Stocking of quality seed • Water exchange I2 Application of Lime I3. Increased aeration	I1, I2 & I3. 1. Production and supply of quality seed (**Hatchery operators**) 2. Technical guidance on BMPs (**DoF & NaCSA)** 3. Diversification & crop rotation- Summer crop – shrimp& Winter crop – finishes (**RIs-CIBA**) 4.Provision of crop insurance **(Govt-Insurance agencies)** 5. Early Warnings **(IMD/ District Admn**.)	. Short-term (1- 2 years) Short term (1-2 years) Medium term (2-3 years) Medium term (2-3 years) Whenever required
	I4. Breach of pond dykes I5.Submergence of ponds I6. Damage to farm shed	I4, I5 & I6. Infrastructure damage	I4, I5 & I6. Rs.25000 – 50,000/ha for repairing dykes and ponds.	I4 &, I5 ❖ Strengthening pond dykes ❖ Deepening pond bottoms	I4, I5 & I6. **1.** Provision of subsidized credit **(Govt. & Banks)** **2.** Construction of flood bunds **(Govt.)** 3. Dredging of Canals **(Govt.)**	Short term (1-2 years) Medium term (2-3 years) Medium term (2-3 years)

Climate Change Event	Impacts (I)	Risks	Economic loss	Auto-Adaptations (By farmers)	Planned Adaptations & Who will do it?	When (Period)
					4. Provision of crop insurance (**Govt-Insurance agencies)**	Medium term (2-3 years)
	I7. Damage to. electricity lines & power failure I8. Difficulty in access to shrimp ponds	I7 & I8. High Cost of production per kg of shrimp	I7 & I8. Rs.17,500 to Rs.30,000/ha extra electricity charges	I7 & I8. ❖ Low stocking density (2-3 PLs/sq.m) ❖ Alternative power supply (Generator)	**1.** Awareness & Education **(DoF & NaCSA)** 2. Free/subsidized electricity tariff on par with agriculture **(EB-Govt.).** 3. Provision of subsidized credit **(Govt. & Banks)**	Short-term (1- 2 years) Short-term (1- 2 years) Medium term (2-3 years)
Seasonal Variations	I1. High salinity I2. High pond water temperature I3. Reduced Dissolved Oxygen	I1, I2 & I3 • Retarded growth & • Low productivity	I1, I2 & I3 Loss of income • At 40 DoC – 100% loss • At 80 Doc – 50% loss • At 120 Doc – 10% loss	I1, I2 & I3 • Stocking of quality seed • Water exchange I3. Increased aeration	I1, I2 & I3 1. Production and supply of quality seed. (**Hatchery operators**) 2. Technical guidance on BMPs (**DoF & NaCSA)** 3.Provision of crop insurance **(Govt-Insurance agencies)**	Short-term (1-2 years) Short term (1- 2 years) Medium term

Climate Change Event	Impacts (I)	Risks	Economic loss	Auto-Adaptations (By farmers)	Planned Adaptations & Who will do it?	When (Period)
						(2-3 years)
	I4. Delaying of crop planning /season	I4. Low productivity	I4. Loss of income	I4. Collective planning by the farmers group	I4. 1. Advise on crop planning **(RIs, DoF & NaCSA)** 2.Provision of crop insurance **(Govt-Insurance agencies)**	Short-term (1-2 years) Medium term (2-3 years)
	I5. Temperature fluctuations I6. Low feed intake I7. Stress to the animal	I5, I6 & I7 • Molting problem & Slow growth • Low production	I5, I6 & I7 • Loss of income up to 25%	I5, I6 & I7 • Stocking of quality seed • Water exchange • Increased aeration	I5, I6 & I7 1. Production and supply of quality seed. (**Hatchery operators**) 2. Technical guidance on BMPs (**DoF & NaCSA)** 3.Provision of crop insurance **(Govt-Insurance agencies)**	Short-term (1- 2 years) Short term (1-2 years) Medium term (2-3 years)
Floods	I1. Death of shrimps (due to rapid oxygen depletion) I2. Escape of the shrimps due to breaching of ponds I3. Occurrence of diseases	I1, I2 & I3 • Loss of stock • Low production	I5, I6 & I7 • 70-100% loss	I5, I6 & I7 • Strengthening pond dykes	I1 to I7 1. Provision of crop insurance **(Govt-Insurance agencies)** 2. Provision of subsidized Credit **(Govt. & Banks)** 3. Construction of flood bunds **(Govt.)** 4. Dredging of canals **(Govt.)**	Medium term (2-3 years) Short term (1- 2 years) Medium term (2-3 years)
	I4. Submergence of ponds I5. Breach of pond dykes & sluice	I4, I5, I6 & I7 • Severe damage to infrastructure	I4, I5, I6 & I7 • Rs.60,000/ha loss	I4, I5, I6 & I7 • Strengthening of pond dykes		

Climate Change Event	Impacts (I)	Risks	Economic loss	Auto-Adaptations (By farmers)	Planned Adaptations & Who will do it?	When (Period)
	I6. Damage to electricity lines & power failure I7. Loss of human life & livelihood				5. Early Warnings **(IMD/ District Admn**.)	Whenever required
Cyclones	I1. Damage to electricity lines & power failure I2. Loss of human life & livelihood I3. Vanishing of shrimp stock I4.Contamination across the ponds I5. Loss of farm infrastructure	I1 to I5 • Lack of access to farm site & ponds • Loss of life, livelihood & property	I1 to I5 • 100% loss of livelihood	I1 to I5 • Strengthening of pond dykes	1. Provision of crop insurance **(Govt-Insurance agencies)** 2. Provision of subsidized credit **(Govt. & Banks)** 3. Construction of flood bunds **(Govt.)** 4. Dredging of canals **(Govt.)** 5. Early Warnings **(IMD/ District Admn**.)	Medium term (2-3 years) Short term (1- 2 years) Medium term (2-3 years) Medium term (2-3 years) Whenever required

Note: Impacts are denoted as I1, I2, I3…. and so on and other columns are referred to these impacts.

6.1.1.2 Risk Analysis

The likelihood and consequence ratings (rounded off to lower number) of extreme events identified by the farmers in inland area is presented in Table 7. Based on the actual total risk score obtained without rounding the figures, the climatic extremes were ranked in priority as flood (19.20), seasonal changes (18.71) heavy rain (14.79) and cyclones (13.92).

Table 7. Likelihood and consequence ratings of extreme events observed in inland area (Chinnapuram)

Change/Risk	Consequence (C)	Likelihood (L)	Total Risk score (CxL)	Risk ranking
Flooding	4.23	4.54	19.20	1
Seasonal change	4.77	3.92	18.71	2
Heavy rain	3.92	3.77	14.79	3
Cyclone	3.77	3.69	13.92	4

The likelihood and consequence ratings were plotted in a matrix table to arrive at the risk priority level for each extreme event. It was observed that floods and seasonal changes are under extreme risk category, whereas heavy rain and cyclone are under high risk category (Table 8).

Table 8. Risk priority matrix of extreme events in inland area (Chinnapuram)

Consequence / Likelihood	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5.Almost certain				**Flood**	
4. Likely				**Heavy rain, cyclone**	**Seasonal change**
3. Possible					
2. Unlikely					
1. Rare					

	Extreme		**High**		**Medium**		**Low**

6.1.1.3 Seasonal and crop calendar

The details of changes in seasons and crop activities with respect to weather changes over a period of one year are presented in Table 9. Rainy season is from June to September with more rains in July and August months. Dry season is from January to May with more magnitude in March, April and May during which hot wind flows were more. Cold season is from December to February and it is colder is in the last two months. Occurrence of cyclones and hot wind flows is unusual.

Crop activities such as pond preparation including repair of pond dykes, water intake and sluice structures, draining and drying the ponds were taken in the dry months January/ February for the first crop and June/July for the second crop. During this time the weather is dry and allows the pond bottom to dry faster. Water filling and bloom development is during February and March for the first crop and July to September for the second crop. Stocking of the seed for the first and second crops is during February to March and July to September, respectively. The harvesting time spreads over May to June for the first crop and November to December for the second crop. Diseases were more during monsoon and post monsoon period. Hence in most of the areas second crop was not a successful one. The production, fry price and market prices (for harvested shrimp) were also high during the first crop compared to second crop.

Table 9 . Seasonal and crop calendar activities of Inland shrimp farming area

Seasonal calendar												
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainy season						R	R++	R++	R			
Dry season	D	D	D++	D++	D+++							
cold winter	C++	C+										C
Hot			H+	H++	H+++							
Cyclones											Cy	
SW monsoon						SW++	SW++	SW	SW			
NE monsoon											NE	
Hot wind flow			W++	W++								
Unusual occurrence												
Crop calendar												
Activities	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Pond preparation	P	P				P	P					
Drying	D					D						D
Water coloring (plankton growth)		WC	WC				WC	WC	WC			
Stocking		S	S				S	S	S			
Harvesting					H	H					H	H
Diseases						D	D	D	D	D	D	D
Repair	R	R				R	R					R
Production price* (H/M/L)	M	M	H	H	HH	HH	L	L	L	L	L	L
Fry Price (PL)	+++	+++	+++	+++	+++	-	- -	- - -	+	++	+	
Market Price	++		+++	+++	+++	-	-	- -	- -	-	++	++

+ = increasing magnitude and high units   - = decreasing magnitude and low units
* L –Low, M- Medium, H-High

6.1.2 Coastal shrimp farming area (Gullalamoda)

In the FGD meeting conducted at Gullalamoda (coastal shrimp farming area), the responses of 17 farmers, some farmers from different societies of NaCSA and some non-society farmers was obtained.

6.1.2.1 Farmer's perception on climate change

The farmer's perceptions on climate change, impacts on shrimp farming, economic impacts and adaptation measures to be followed and the agencies to help them and the time line for implementation are presented in Table 10.

The climate change events identified by priority were high temperature, floods, low/un-seasonal rain fall, low temperature, cyclone and low tidal amplitude by 15, 13, 10, 9, 7 and 7 farmers respectively. The water inundation in ponds is due to both heavy rainfall and floods. Cyclones are not a problem as they are not a very frequent event. However, if cyclone occured with heavy rainfall, then the economic loss was hundred per cent.

Focus Group Discussion Process at Gullalamoda, coastal shrimp farming area

Table 10. Results of farmer's Focus group discussion (coastal shrimp farming area) conducted at Gullalamoda, Krishna District

Climate change	Impacts (I)	Risks	Economic loss	Auto-adaptations (By farmers)	Planned adaptations & Agencies responsible (Time line in parentheses)
High temp	I.1 Increase in pH levels I.2 Increase in salinity I.3 Low water availability	I1, I2 & I3. • Low growth rates • Increase in culture period • Loose shell syndrome (LSS) • Reduced market • Increased cost of production	I1, I2 & I3. • Shrimps die and 90% loss	I1& I2 • Water exchange • Better management practices General -Don't burn rice straw	Advice from NaCSA, DoF, CIBA (Immediate) Grow trees – Forest Department (Short term)
Low/ un-seasonal rain fall	I.1 Increase in salinity I.2 Low water availability	I.1 • Favours culture up to some extent and further increase leads to economic loss I.1 & I.2 • Low growth rates • LSS • Reduced market, Increased cost of production	I.1 & I.2 • Rs. 5000/- loss due by 30 days increase in culture period	I.1 & I.2 • Pumping water • Less water exchange • Better management practices General - Don't cut forests	Advice from NaCSA, DoF, CIBA (Immediate) Reforestation of mangroves – Forest Department (Short term)

Climate change	Impacts (I)	Risks	Economic loss	Auto-adaptations (By farmers)	Planned adaptations & Agencies responsible (Time line in parentheses)
Floods	I.1 Water pollution I.2 Increase in viral infections I.3 Damage to dykes I.4 Damage to farm buildings and feed stock	I.1 & I.2 • Leads to diseases I.3 & I.4 • Infrastructure damage	I.1 & I.2 • 50% loss due to viral infections I.3 & I.4 • 100% stock escape from ponds nearer to water source	I.1 & I.2 • Use of mesh for filtration of intake water. • Early harvesting of crop	Advice from NaCSA, DoF, CIBA (Immediate) I.3 & I.4 Early warnings - CWC (as and when required) Construction of common flood dykes by Govt. (Immediate)
Low temperature	I.1 Increase in viral/ bacterial infections and increased virulence	I.1 Leads to diseases	I.1 Rs. 10000/- loss per acre	I.1 • Apply lime • Increase the water level General - Control air pollution	Advice from NaCSA, DoF, CIBA (Immediate)
Cyclone	I.1 Safe culture with normal rain fall I.2 If cyclone with heavy rainfall – leads to flooding	I.1 Good profit no loss I.2 - I.1 to I.4 points under floods	I.2 • If cyclone - 100% loss I.2 - I.1 to I.4 points under floods	I.2 • I.1 & I.2 points under floods	I.2 Advice from NaCSA, DoF, CIBA (Immediate) Early warnings - IMD (as and when required)
Low tidal amplitude	I.1 Decreased water level due to non-availability of water for pumping	I.1 Shrimps under stress	I.1 Shrimp die 25% loss	I.1 • Reservoir maintenance • Requires more pumping	I.1 Advice from NaCSA, DoF, CIBA (Immediate) Digging channels of more depth (Mid term)

Note: Impacts are denoted as I1, I2, I3…. and so on and other columns are referred to these impacts.

6.1.2.2 Risk Analysis

The likelihood and consequence ratings (rounded off to lower number) of extreme events identified by the farmers in coastal area are presented in Table 11. Based on the actual total risk score obtained without rounding the figures, the extreme were ranked in the order of priority as high temperature (15), flooding (12.25), low rainfall (11), less cyclone (8.75), low tidal movement (8.5) and low temperature (7.25).

Table 11. Likelihood and consequence ratings of extreme events observed in coastal shrimp farming area (Gullalamoda).

Change/Risk	Consequence(C)	Likelihood(L)	Risk score(CxL)	Risk ranking
High temperature	4.00	3.75	15	1
Flooding	2.50	4.75	12.25	2
Low rainfall	3.50	3.00	11	3
Less cyclone	3.00	2.75	8.75	4
Low tidal movement	3.75	2	8.5	5
Low temperature	3.50	2.25	7.25	6

The likelihood and consequence ratings were plotted in a matrix table to arrive at the risk priority level for each extreme event. It was observed that flooding, high temperature and low rainfall were in a high risk category. Less cyclone, low rainfall and low temperature were in medium risk category (Table 12).

Table 12. Risk priority matrix of extreme events in coastal shrimp farming area (Gullalamoda).

Consequence / Likelihood	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5.Almost certain			**Flooding**		
4. Likely				**High temperature**	
3. Possible			**Less cyclone**	**Low rainfall**	
2. Unlikely				**Low tidal movement, Low temperature**	
1. Rare					

Extreme	**High**	**Medium**	**Low**

6.1.2.3 Seasonal and crop calendar

The details of changes in seasons and crop activities with respect to weather changes over a period of one year are presented in Table 13. The summer season is from March to June with more temperatures in April and May. Winter season is from November to January and the maximum cold is in the month of January. Very high temperatures are observed during May and June and the lowest temperatures during December and January. There are no or low rains in the month of

September. The occurrence of floods, cyclones and high tides are of unusual occurrence in the months of May and November.

Table 13. Seasonal changes and crop calendar activities in coastal shrimp farming areas

Seasonal Calendar												
Weather /climate change	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Summer			S	S+	S++	S						
Winter	W++										W	W+
Rainy Season						R	R++	R	R			
High Temp				HT	HT++	HT+						
Low Temp	LT+											LT
Flood					F						F	
Low rain									LR			
Cyclone					Cy						Cy	
Tidal Movement					TM+						TM+	
Crop Calendar												
Activity	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Crop plan meeting	*											*
Pond drying	*,#	*,#						#				
Pond preparation	*,#	*,#	*,#					#				
Hatchery visit	*	*										
Water Pumping		*, #	*, #					#				
Seed stocking		*, #	*, #					#				
Harvesting	#					*, #	*, #					#
Crop Running	↔				↔						↔	

* NaCSA societies   # Non-Societies

+ = Increasing magnitude

Unusual occurrences highlighted in Yellow

Crop planning meetings were done only in societies in December and January months before the first crop and these meetings were not serious for the second crop as many of the farmers are not taking second crop. The first crop is from February/March to June/July and the second crop is from Aug/Sept to December/January. Crop activities such as pond drying for the first crop are in January and February during which the weather is normally dry and without rains and for the second crop this activity is in the month of August. The society farmers will visit the hatcheries in advance during January/February to get quality seed. Water pumping and seed stocking operations for the first crop are in February/March and for the second crop during August. Pond preparation including repair of pond dykes, intake water and sluice structures, and ploughing are taken in the dry months January and February for the first crop and August for the second crop. The harvesting time spreads over June/July for the first crop and December /January for the second crop.

6.2 Stakeholder Workshop

The results of stakeholder mapping including characterization and classification of key stakeholders and their tasks towards shrimp farming and climate change, perception of stakeholders towards CC and the adaptation measures evolved from the Stakeholder workshop (SW) are presented in this section.

6.2.1 Stakeholder mapping

The categorised list of 'highest priority' stakeholders after initial analysis is shown at column 1 in Table 14. Farmers, hatchery operators, Input and feed dealers, broodstcok collectors, NGOs - National Association of Fishermen (NAF), Society of Aquaculture Professionals (SAP), Govt. organizations - The Marine Products Export Development Authority (MPEDA), National Centre for Sustainable Aquaculture (NaCSA), National Fisheries Development Board (NFDB), Coastal Aquaculture Authority (CAA), Indian Meteorological Department (IMD), Central Water Commission (CWC), Departments of Fisheries, Agriculture and Irrigation, College of Fisheries (CoF), Research Institutes -, Central Institute of Brackishwater Aquaculture (CIBA) Central Institute of Freshwater Aquaculture (CIFA), Central Institute of Fisheries Education (CIFE), SIFT (State Institute of Fisheries Technology), Krishi Vignan Kendra (KVK) and Research Station of Acharya NG Ranga Agricultural University (ANGARU), National Institute of hydrology (NIH), credit Institutions - Indian Bank (Lead Bank in the District), State Bank of India and Andhra Bank are the key stakeholders involved in the shrimp farming sector and climate change. The identified stakeholder is any person or organization, who can be positively or negatively impacted by climate change in shrimp framing sector or had the significant influence on adaptations towards the problems.

6.2.2 Stakeholder characteristics and classification

The stakeholders characteristics such as type (beneficiaries or implementers or financing agents or decision makers at National/State/local level), description (farmer/Govt./Research Institutions/Private organisations/NGOs), level of stake held in adaptation of shrimp farming to CC (primary/secondary/tertiary), their interest and influence over CC adaptation (very low, low, moderate, high, very high), the knowledge towards CC problems of shrimp farming, required actions to support the shrimp farmers for CC adaptation and the resources at their disposal for assistance of shrimp farmers adaptation to CC are presented in Table 14. Primary stakeholders are those ultimately affected, either positively or negatively by CC actions. Secondary stakeholders are the 'intermediaries', that is, persons or organizations who are indirectly affected by the CC actions.

6.2.3 Stakeholder task analysis

Stakeholder task analysis will help in developing cooperation between the stakeholder and the project team for the successful outcomes for the project. The tasks of all the identified stakeholders related to shrimp farming and climate change such as the role they play in shrimp farming sector, financial, technical and research support, natural resources and aquaculture policy management, and collection/maintenance/dissemination of data are presented in Table 15.

Table 14. Stakeholder characteristics and classification (Ranks: Very low, low, moderate, high, very high)

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Farmers	Societies nearer to coast	Beneficiaries	Primary stakeholders	Small scale farmers, rural	**Low** influence, Not much influence on policy	**High** as livelihood are impacted	High – observed directly	Production and profitability impacted by CC; more vulnerable to ECEs.	Govt. support	Shrimp farming	Low
Farmers	Societies in inland area	Beneficiaries	Primary stakeholders	Small scale farmers, rural	**Low** influence, Not much influence on policy	**High** as livelihood are impacted	High – observed directly	Production and profitability impacted by CC; less vulnerable to ECEs (Flooding and inundation but not drought)	Govt. support	Shrimp farming	Low
Joint Director of Agriculture	Department of Agriculture, Krishna District	Implementers/Local level	Secondary stakeholders	Government of Andhra Pradesh	Moderate influence on policy	Moderate as end users, farmers are affected	Not much. But have more knowledge in agriculture	Motivating farmers to implement adaptation measures	Adaptation and policy measures to be implemented	Extension, Assessment of extreme climatic events impact on agricult	Not for aquaculture, but for agriculture farmers. The knowledge can be shared.

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
										ure, Implementation of Govt. schemes and relief measures,	
CEO/Regional Coordinator /Field manager NaCSA	National Centre for Sustainable Aquaculture	Implementers /Local level Working in the field with farmers	Secondary stakeholders	Government	Moderate influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Motivating farmers to implement BMPs and also to implement any CC adaptation,	Policy measures to be implemented	Extension and mobilisation of small scale farmers	Moderate
Deputy Director (Aqua) MPEDA	Marine Products Export Development Authority	Implementers / Local level	Secondary stakeholders	Government	Moderate influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Motivating farmers to continue the culture	Schemes to be formulated for implementation	Promotion and development through schemes	Moderate
Deputy Director, Assistant Directors and FDOs	AP State Fisheries Department	Implementers / Local (District) level	Secondary stakeholders	Government	Moderate influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Preparedness and Damage assessment in case of ECEs and motivating farmers to	Actual assessment of damage in case of ECEs and implementa	Extension activities, capacity building,	Moderate

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
								continue the culture	tion of measures	vulnera bility and damage assessm ent	
Secretary/ Director (Tech.) – CAA	Coastal Aquaculture Authority	Decision makers/National level	Secondary stakeholde rs	Government	**High** influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Deciding policy measures	Policies to be formulated	Regulati on of aquacul ture, Licensin g and policies formula tion	High
Chairman/ Directors - NFDB	National Fisheries Development Board	Decision makers/ National level	Secondary stakeholde rs	Government	**High** influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly in farms	Deciding policy measures and schemes for adaptation solutions	Policies and supporting schemes to be formulated	Capacity building, training, Increase the producti vity of fisheries and aquacul ture	Very High
Officer-in charges of	District level Disaster	Implementers/ Local level	Secondary stakeholde	Government	Moderate influence on	Moderate as end	High – Observed	Damage assessment in	Actual assessment	Prepare dness,	Moderate

Stakeholders		**Stakeholder characteristics**									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Departments such as Fisheries/ Agriculture /Revenue etc.	Management Committee		rs		policy	users, farmers are affected	indirectly in case of ECEs	case of ECEs	of damage in case of ECEs and implementation of measures	and mitigation measures and damage assessment due to ECEs	
In-charge Observatory	Indian Meteorological Department	Data source/ Local level	Secondary stakeholders	Government	Moderate influence on policy	**Low** interest as not involved directly	High on CC but low related to aqua farmers	Accurate forecast and advise to aqua farmers	Reliable and advanced forecast	Forecasting of cyclones / storms and daily meteorological data	Low
Officer-in-charge of District	Central Water Commission	Data source/ Local level	Secondary stakeholders	Government	Moderate influence on policy	**Low** interest as not involved directly	High on CC but low related to aqua farmers	Accurate forecast and advise to aqua farmers	Reliable and advanced forecast	Forecasting of floods	Low
Scientists	Central Institute of Brackishwater Aquaculture	Researchers/National	Secondary stakeholders	Government - Research Institution	Moderate influence on policy	Moderate as end users, farmers are	High on CC from literature and moderate	Understanding CC problems and development of mitigation and	Research for adaptive solutions and methodolog	Projects on climate change, Researc	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
						affected	related to aqua farmers	adaptation strategies	y for damage assessment in case of ECEs	h on develop ment of adaptiv e measur es	
Scientists	National Institute of Hydrology – Kakinada Centre	Researchers/ National	Secondary stakeholde rs	Government - Research Institution	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC but low related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions	Researc h on develop ment of adaptiv e measur es	Low
Scientists	Central Institute of Freshwater Aquaculture – Regional Centre, Vijayawada	Researchers/ National	Secondary stakeholde rs	Government - Research Institution	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions	Researc h on develop ment of adaptiv e measur es	Low
Scientists/ Training Organisers	KVK-ANGARU & Undi Research Station	Researchers/ Trainers - National level	Secondary stakeholde rs	Government - Research and Extension Institute	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to	Understanding CC problems and development of mitigation and adaptation	Research for adaptive solutions and training the farmers	Extensio n and Training	Low

Stakeholders		**Stakeholder characteristics**									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
							aqua farmers	strategies			
Trainers/ Scientists	State Institute of Fishery Technology – AP State Fisheries	Researchers/ Trainers - state level	Secondary stakeholders	Government - Research and Extension Institute	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions and training the farmers	Extension and Training	Low
Feed manufacturer	CP Feed, Chennai	Beneficiaries	Secondary stakeholder	Private manufacturer	**Low** influence on policy	High as production is affected by supply of fish meal (FM)	Low	Quality production of feed	Supply of quality feed	Manufacturing of feed	Low
Feed manufacturer	The Waterbase Ltd, Nellore	Beneficiaries	Secondary stakeholder	Private manufacturer	Low influence on policy	High as production is affected by FM s	Low	Quality production of feed	Supply of quality feed	Manufacturing of feed	Low
Feed manufacturer	East Coast Aqua feeds	Beneficiaries	Secondary stakeholder	Private manufacturer	Low influence on policy	High as production is affected by supply of fish meal	Low	Quality production of feed	Supply of quality feed	Manufacturing of feed	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Input dealer	Feed dealer	Beneficiaries	Secondary stakeholders	Private dealer	Low influence on policy	Moderate as end users, farmers are affected	Low	Decrease in the sale of products	Supply on credit basis	supply of feed	Low
Processors	Processing plants	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	Moderate as farmers are affected	Low	Decrease in the supply for processing	Offering good price to farmers	Processing of harvested produce	Low
Technicians	Aqua and PCR labs	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	Moderate as end users, farmers are affected	Low	Decrease in the no. of samples and thus livelihood	Economical testing rates	Analysis services such as PCR seed testing and soil and water quality testing	Low
Hatcheries	All India Shrimp Hatcheries Association (AISHA)	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	High due to erratic supply of brood stock	Moderate – observed indirectly	Quality seed production	Good quality seed	Production and supply of seed	Low
Brood stock suppliers	Fishermen	Beneficiaries	Secondary stakeholde	Private	Low influence on	High as livelihood	Moderate – observed	Quality brood stock supply	Good quality	Collection of	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
			r		policy	s are impacted directly	indirectly		broodstock	brood stock	
Brood stock suppliers	Fishermen (Boat owners)	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	High as livelihoods are impacted directly	Moderate – observed indirectly	Quality brood stock supply	Good quality broodstock	Hiring boats, Collection of brood stock	Low
NGO	Society of Aquaculture Professionals (SAP)	Implementers	Secondary stakeholder	NGO	Low influence on policy	Moderate as end users farmers are affected	Low	Overall improvement of the sector	Involvement in all the sectors for adaptive solutions	Development of aquaculture	Low
NGO	NGO - National Association of Fishermen (NAF)	Implementers	Secondary stakeholder	NGO	Low influence on policy	Moderate as end users fishermen are affected	Low	Alternative livelihood measures	Livelihood measures	Livelihood improvement	Moderate
Prof. / Senior lecturer	Fisheries College, Nellore	Implementers	Secondary stakeholder	Research and Education	Low influence on policy	Moderate as teaching material should include chapters on CC	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions and training the farmers	Training	Low

Stakeholders		**Stakeholder characteristics**									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
						impacts					

Table 15. Stakeholder tasks analysis

	Tasks related to shrimp farming and climate change										
Stakeholder name/ Organisation / sector	**Shrimp culture**	**Support: shrimp seeds / processing**	**Direct financial support**	**Budget allocation for projects**	**Aqua-Farmer Extension**	**Marketi ng**	**Aquaculture policy / management**	**Natural resource management impacting on aquaculture**	**Technical support and training**	**Research on understanding CC issues**	**Collect/ record/ disseminate weather/ climate date**
Farmers	✓										
Shrimp hatchery		✓									
NaCSA					✓				✓		
MPEDA			✓ (through subsidy schemes)	✓	✓	✓			✓		
State Fisheries Department					✓		✓		✓		
Coastal aquaculture authority							✓				

Tasks related to shrimp farming and climate change											
Stakeholder name/ Organisation / sector	**Shrimp culture**	**Support: shrimp seeds / processing**	**Direct financial support**	**Budget allocation for projects**	**Aqua-Farmer Extension**	**Marketi ng**	**Aquaculture policy / management**	**Natural resource management impacting on aquaculture**	**Technical support and training**	**Research on understanding CC issues**	**Collect/ record/ disseminate weather/ climate date**
National Fisheries Development Board							✓				
District level Disaster Management Committee								✓			
Research and Academic Institutes	✓			✓	✓				✓	✓	
Indian Meteorological Department											✓
Central Water Commission								✓			✓
Office / Department responsible for climate change								✓			
Water authorities								✓			
NGOs	✓				✓				✓		

Tasks related to shrimp farming and climate change											
Stakeholder name/ Organisation / sector	**Shrimp culture**	**Support: shrimp seeds / processing**	**Direct financial support**	**Budget allocation for projects**	**Aqua-Farmer Extension**	**Marketi ng**	**Aquaculture policy / management**	**Natural resource management impacting on aquaculture**	**Technical support and training**	**Research on understanding CC issues**	**Collect/ record/ disseminate weather/ climate date**
Feed manufacturers		✓									
Input dealers (Feed, Chemicals and probiotics)		✓									
Broodstock suppliers (Fishermen)		✓									
Farm consultants		✓									
Banks			✓ (through loans)								
Processors/Exporters		✓				✓					

6.3 Stakeholder Workshop –Stakeholder perceptions and adaptive measures

The SW participants discussed adaptation measures in three key themes: farmer adaptation measures, scientific/technical adaptation measures and institutional/policy adaptation measures in farmers, scientists and policy group respectively. The perception of stakeholders towards climate change in shrimp farming and the outcome of the adaptive measures based on priority and the to implement the adaptation measures along with the time line are presented in Tables 16, 17 and 18.

6.3.1 Farmer group

The farmers group identified seasonal changes, low and high temperatures, heavy and low rainfall, flooding, cyclone and low tidal movement as the important climate change events. These events are almost similar to the events identified in focus group discussions. The adaptive measures to be implemented by farmers are mostly better management practices for which they need advice from DoF, NaCSA and CIBA (Table 16). The most important assistance that they need from the Government is the constant (24 hours per day) supply of electricity, loans, insurance; the construction of flood walls (common dykes); de-silting and deepening of source water bodies.

6.3.2 Research/science group

The research/science group identified technical/scientific adaptive measures. These measures are mainly refinement of the existing or innovation of new technologies to adapt the shrimp farming to the forthcoming climate change events (Table 17). The important measures are improvement of BMPs, identification of alternate species and development of technology, scientific principles in planning mitigation measures such as mangrove plantations, de-silting and deepening of drains, and construction of flood walls.

6.3.3 Institution /government group

The institutional group has recommended the policy adaptive measures to the climate change events already mentioned. These measures are mostly on quality input supply, electricity supply, loans and insurance schemes, flood walls construction and mangrove plantations, and efficient forecasting of extreme climatic events (Table 18). These measures have to be implemented by the respective Govt. organizations. Institutional group analysis provides useful information to plan the scope of the policy analysis, and to identify key stakeholders for further investigation. Institutions play a critical role in supporting or constraining people's capacity to adapt to climate change. Other important issues highlighted by the group are:

- All farmers should register with Coastal Aquaculture Authority.
- Single window system to be in place for execution of policies.

- Electricity tariff / services on par with agriculture.
- Consideration of aquaculture on par with agriculture.
- Control of pollution from industries situated along the coastal creeks. Strict regulations are to be enforced Pollution Control Board (PCB).
- Capacity building / stakeholders meetings to be organised regularly by DoF / MPEDA/ Research Institutions.

Table 16. Farmer's adaptive measures

Climate change	Impacts	Measures based on priority (P)	Identified agency by the farmer (Time line within parentheses)
Seasonal change	• Crop season delayed • Variation in salinity, pH, oxygen levels and diseases incidence • Temperature variation (slow growth and less feeding) • Brood stock collection problem	P.1 Water quality monitoring P.2 Alternative marketing strategy P.3 Alternative species culture (farmer as per need) P.4 Continuous supply of electricity P.5 Specify the good farm location	P.1 Analysis by consultant and scientists (Immediate) P.2 Govt. - MPEDA and NFDB (Immediate) P.3 R&D Institutes (Short term) P.4 Govt. (Immediate) P.5 Farmers - help from experienced consultants (Short term)
Low temperature	• Decline in oxygen level (disease) • Pathogenic attack (less feeding, survival reduced) • Poor growth moulting problem (crop reduced)	P.1 Better management practices P.2 Continuous supply of electricity	P.1 Farmer – help from scientists from research organizations and universities, feed technicians (Immediate) P.2 Govt. (Immediate)
Heavy rainfall	• Variation in salinity and oxygen levels • Disease incidence • Dyke damages (animals escape, ponds submerged, infrastructure damage) • Electricity problem • Approach to farm is difficult	P.1 Netting around the pond P.2 Strengthening the bund with sand bags P.3 Permanent solution for bund with HDP polythene lining	P.1 Farmer (Immediate) P.2 Farmer – help from Govt. (Immediate) P.3 Govt./agencies (Immediate)
High temperature	• Increase in pH (disease, moulting) and salinity (slow growth and extension of culture period • Less income • Decline in DO levels • Algal blooms development	P.1 Increase in water levels, manual de-weeding P.2 Aeration, water exchange P.3 Continuous supply of electricity	P.1 Farmer (Immediate) P.2 Farmer - advise from consultant/feed technicians (Immediate) P.3 – Govt. (Immediate)
Flooding	• Destruction of dykes • Water pollution (disease, moulting) • Production loss	P.1 Insurances, loan reschedule P.2 Harvesting of crop (solve production loss immediately) P.3 Netting around the pond P.4 Strengthening of the bunds with sand bags P.5 Proper integrated farming	P.1 Banks and Govt. (Immediate) P.2 Farmer advise from Department (Immediate) P.3 Farmer (Immediate) P.4 Farmer with the help from Govt. (Immediate) P.5 R&D Institutions and Govt. Departments

Climate change	Impacts	Measures based on priority (P)	Identified agency by the farmer (Time line within parentheses)
Cyclone	• Heavy rain, flood and wind (damage to life and farm infrastructure and crop loss) • High risk • Production loss		(Long term)
Low rain fall	• Increase in salinity (slow growth, culture period extended • Increase in pH (disease problem and moulting) • Less income	P.1 Reservoir maintenance and water treatment P.2 Topping-up of water and water management	P.1 Farmer (Continuous process) P.2 Farmer (Continuous process- daily)
Low tidal movement	• Effect on water exchange • Deterioration in water quality (mortality)	P.1 Reservoir maintenance and water treatment P.2 Topping-up of water and water management P.3 Deepening of drains and creeks	P.1 Farmer (Continuous process) P.2 Farmer (Continuous process- daily) P.3 Govt. (Immediate)

Table 17. Technical adaptive measures from scientists group

Climate change	Impacts	Measures based on priority (P)	Responsible agency (Time line within parentheses)
Floods (due to heavy rains and cyclones)	• Destruction of dykes • Water pollution	P.1 Farm peripheral dykes (Engineering structures) P.2 De-silting the drain P.3 Width of the bund and mesh to be used for water filtration	P.1 CIBA, Aquaculture Engineering Department, IIT Kanpur (Immediate) P.2- Govt. (1-2 days before floods) Immediate P.3 NaCSA and CIBA (Immediate during crop planning pattern)
Cyclones	• Heavy rain, flood and wind • Farmers access problem • Economic loss	P.1 Farmers should follow seasonal crop pattern (Feb-June) to avoid impacts of cyclones P.2 Construction of flood banks P.3 Disseminating weather forecast P.4 Mangroves as bio-shields (identify suitable species) P.5 BMPs - Liming, oxygen enhancers, less feeding	P.1 CIBA, NaCSA, DoF (Now on regular basis) P.2 Department of Irrigation Every year (summer) mid term P.3 IMD regular basis as and when required P.4 Forest Department Immediate (mid term) P.5 NaCSA, CIBA (Immediate -regular basis)
Seasonal Changes	• Rainfall variation (salinity, pH and DO changes and increased disease problems) • Crop season delays • Temperature variation, (moulting problems, Low/no feeding and slow growth) • Brood stock quality and quantity decline	P.1 Regular monitoring of water quality parameters (Tech Advice) P.2 Preventive measures for disease monitoring-probiotics usage P.3 Pond depth increase, no over feeding, DO increase (Tech advice) P.4 alternate species like seabass, quality seed and feed P.5 BMPs, Maintenance of water level, Induced moulting, Lime P.6 Brood stock bank, SPF	P.1 Farmers through private labs, R&D Institutes(Regular basis) Immediate P.2 CIBA, Labs (Regular basis) P.3 DoF, NaCSA, local feed (Regular basis) companies P.4 CIBA, CMFRI (Short term – 1 to 2 years) NaCSA and CAA P.5 CIBA, NaCSA (Immediate) P.6 RGCA, NFDB (Short term – 1 to 2 years)
Low temperatures	High disease	P.1 Disease surveillance P.2 Feed monitoring	P.1 CIBA (Immediate) P.2 CIBA, DoF, NaCSA (Immediate)
Low tidal movement	Difficulty water exchange	P.1 Improving the pumping efficiency	P.1 Electricity Dept, NaCSA, CIBA (Immediate)

Table 18. Institutional/Policy measures by Policy group

Climate change	Adaptation measures based on priority (P)	Responsible agency for implementing the measures
Flooding	P.1 Crop insurance P.2 Flood alert/flood information P.3 Strengthening of pond bunds P.4 Discourage culture in river bed P.5 Nets around the pond bunds P.6 Free board should be maintained P.7 Financial support for deepening of ponds and to elevate the height of ponds P.8 Evacuation of inhabitations in drains / canals for easy drainage P.9 Support to provide insurance to all small and marginal farmers P.10 Quality seed and feed supply P.11 Awareness about not to use pesticide to save pollution through seepage into ponds. P.12 Vegetation / plantation on ponds bunds – giving awareness to farmers	P.1 Govt. Secretary Agriculture Dept. P.2 District Administration from IMD P.3 DOF/NaCSA P.4 Fisheries dept / MPEDA / NaCSA P.5 NaSCA/DoF/CIBA P.6 DoF/farmer P.7 Do F 9Govt.) P.8 Irrigation Department P.9 Government P.10 Govt./hatcheries/Feed companies/CIBA P.11 NACSA/Pollution Control Board P.12 DOF/NaCSA
Seasonal change / low temperature	P.1 Quality seed P.2 Effective communication system P.3 Announcement of crop calendar - clear cut direction for aquaculture crops (summer / winter) P.4 Three to four weather monitoring stations for each mandal	P.1 Seed Act implementation by DOF P.2 DOF / MPEDA P.3 DoF/NaCSA P.4 District Administration/IMD
Low tidal movement	P.1 Deepening of water bodies P.2 Bank loan reschedule P.3 Maintenance of water level – awareness about water exchange P.4 Time to time clearing of bar mouth P.5 Separate intake and drainage canals P.6 Authority to take care of maintenance of creeks and drains	P.1 Govt. P.2 Govt. and Banks P.3 DOF P.4 Irrigation Department P.5 Irrigation Department P.6 DOF
High temperature	P.1 Strict implementation of quality control / standard norms on hatcheries – (SPF may not affect by high temperature) P.2 Shelter belt plantations and mangrove plantation on bunds P.3 Advance information on weather P.4 Subsidy by Govt. to deepen ponds to increase water level P.5 To maintain at least 1.2 m water depth – should be one of the CAA guidelines	P.1 CAA P.2 Forest Department/DoF P.3 IMD P.4 DoF P.5 CAA guidelines/NaCSA

Climate change	Adaptation measures based on priority (P)	Responsible agency for implementing the measures
Drought / low rainfall	P.1 District level planning for water budgeting for aquaculture P.2 Drought relief measures to be taken up on the lines of agriculture sector including cash compensation P.3 Alternative species that should survive in the low rainfall	P.1 Irrigation/(Agriculture/Fisheries Department P.2 Department of Fisheries P.3 Fisheries Research Institutes
Heavy rainfall	P.1 Activation of groups of small farmers to take up community activities to mitigate loss. P.2 Free board is must	P.1 NaCSA P.2 DoF/Farmer
Cyclone	P.1 Forecast – Advance early warning system P.2 Shelter belt casuraina plantation on the coast – by forest dept	P.1 IMD/District Administration P.2 Forest Department

6.4 Stakeholder Workshop - Plenary session/ Open house discussion

During the last session of the workshop all the participants joined together and the outcome of adaptive measures evolved from the different groups were presented by the facilitators for the benefit of all of the stakeholder participants and further discussions.

Stakeholders suggested that these types of workshops about climate change in relation to shrimp farming should be repeated more often as farmers generally interact among themselves in their local area and not with other farmers outside their area, scientists and government officials. Such meeting provides them an opportunity to express their problems and opinion about climate change to high ranking officials. Government officials in particular felt that it is good to have stakeholder workshops like these as it exposes them to the issues that the farmers are concerned about. During the workshop it was generally expressed that there is a clear need for the development of policy related to climate change adaptation to enhance shrimp farmers' adaptive capacity. Few individual stakeholders expressed their opinions in open house discussion. Since it is an open house, few points were expressed beyond the subject purview of climate change. The important points raised are:

6.4.1 Farmers

- Separate brackishwater aquaculture department is required within the Fisheries Department to have more concentration on shrimp farming activities.
- Need to establish lab/ technical advice system / regular inspection of ponds for proper management in aquaculture.
- Availability of quality seed problem - Govt. should insist on the seed act enforcement on hatcheries for the supply of quality seed.
- Bank loans and insurance are required for aquaculture.
- Consideration of aquaculture on par with agriculture
- Awareness about alternative species and advise on these species during crop holidays
- Power problem needs to be solved Govt. and the supply of electricity should be without any interruption.
- Reduction of input costs
- Due to climate change, crop failures are more and hence farmers are doing continuous stocking and cropping.
- Necessity for the dissemination of information on technology development to farmers.
- Support for the aqua farmers is lacking. There is also no proper extension and assistance given to them.
- Issues on land ownership: Land leases are not available and some farmers are forced to illegally use the area. They are now requesting the government to issue land leases so they can be legal tenants of the land.

6.4.2 Academicians/ Govt. Departments /Scientists/NGOs

- Group farming is required for small and marginal farmers
- Proper inlet / outlet have to be maintained in each farm for avoiding contamination.
- Guidelines about climate change are useful for aquaculture.
- Eco-friendly aquaculture is required.
- Plantations on dykes are required for strengthening the ponds
- Maintenance of drains around the ponds is required.
- Integrated farming system is useful for farming community.
- There is no consolidation of present farming practices and any certification and quality checking on the chemicals being applied.

- Reduction of production cost and mitigation of climate change can be achieved by conversion from diesel to electricity.
- Farmers are advised to deepen the ponds depth and the sediments are to be used to strengthen the pond dikes.
- NaCSA is planning to have discussions with the banks to consider giving loans to aquaculture farmers also. However, issue of loans for some farmers who are illegally using the land will be a problem.

7 Discussion

Brief discussion of results of focus group discussions and the mechanism of climate change impacts of shrimp farming is presented in this session.

7.1 Similarities and differences between coastal and inland shrimp farmers in the perceptions of CC impacts and adaptation

The inland and coastal area shrimp farmers have experienced more or less similar climate change extremes though there was a difference in the order of priority (Table 19). The climate change events such as high temperature, low rainfall and low temperature in coastal area can be categorised under one group (I) which is similar to that seasonal changes in inland area. Heavy rains and floods in inland areas can be matched with floods in coastal area and categorised as group II. Cyclone in both the areas comes under group III followed by low tidal amplitude in coastal area as Group IV.

Table 19.Comparison of climate change events in Inland and shrimp farming areas.

Grouping	Climate extreme events (on priority)		Grouping
	Inland area	Coastal area	
I	1. Floods (ER)	1. High temperature (HR)	I
II	2. Seasonal changes (ER)	2. Floods (HR)	II
	3. Heavy rains (HR)	3. Low/ un-seasonal rain fall (HR)	
III	4. Cyclone (HR)	4. Cyclone (MR)	III
		5. Low tidal amplitude (MR)	IV
		6. Low temperature (MR)	

Risk rating: ER-Extreme risk; HR – High risk; MR – Medium risk

The adaptation measures identified in FGDs for a particular climate change are very similar in inland and coastal shrimp farming areas. In both cases shrimp farming has to be adapted to seasonal changes by following better management practices at farm level. In coastal areas the major adaptive measures are for high temperature as the areas near coast experiences high temperatures and flood protection measures for floods resulting from heavy rainfall and cyclone.

7.2 Explanation of the mechanisms behind how climate change impacts affect shrimp farming

The climate change events affect the shrimp farming in different ways and leads to disease incidence, decrease in production and economic loss or complete failure of crop. The effect of variations in weather parameters on shrimp farming is briefed in this section.

7.2.1 Rainfall and its distribution

Changes in average precipitation, potential increase in seasonal and annual variability and extremes are likely to be the most significant drivers of climate change in shrimp aquaculture in inland areas. Reduced annual rainfall, dry season rainfall, and the resulting growing season length are likely to create impact on shrimp farming and could lead to conflict with other agricultural, industrial and domestic users in water scarce areas.

Variability in the amount of rainfall under different scenarios of monsoon could negatively impact shrimp aquaculture. Timely onset and sudden withdrawal of monsoon causes increase in salinity of water during later stages of culture period. Delay in onset of monsoon leads to high salinity build up, especially in low tidal amplitude areas and conflict with other users for use of freshwater to dilute the high salinity water. Break in monsoon i.e., dry spell conditions for two to three weeks consecutively and early withdrawal of monsoon can lead to salinity build up in creeks and less water availability. The problem of water scarcity and higher salinity is very site-specific with wide variations depending on the tidal amplitude, water current and inflow of freshwater. In Andhra Pradesh the tidal amplitude is relatively low compared to West Bengal and Gujarat. The bar mouth of the various creeks is normally kept open by the outflow of freshwater during monsoon. When there is a failure of monsoon, these bar-mouths may not open and lead to scarcity of water in the creek or backwater. Further, the lack of rains during summer months will lead to an increase in the salinity of the creek beyond the tolerable limits of the cultured shrimps. Some of the negative impacts due to rainfall are:

- Decreases the salinity of brackishwater shrimp ponds, which can affect farm production significantly. High rainfall resulted in a rapid drop in salinity to levels that were lethal for *P. japonicus,* causing mass mortality of the farm crop (Preston et al., 2001).
- The impacts are likely to be felt most strongly by the poor aqua culturists, whose typically smaller ponds go dry more quickly and who may suffer from shortened growing seasons, reduced harvests and a narrower choice of species for culture.
- Changes in suspended sediment and nutrient loads resulting from altered rainfall patterns will affect aquaculture in brackishwater ponds. Elevated nutrient levels can stimulate algal blooms containing toxins that accumulate in the oysters, posing a threat to public health (Nell, 1993).
- Algal blooms, depletion of dissolved oxygen and consequent production losses in inland and coastal ponds, particularly in summer months when water exchange becomes difficult.

7.2.2 Temperature

Increase in mean air temperature will not necessarily equate to increases seen in temperature of aquaculture pond waters. As aquaculture ponds are typically shallow and turbid, solar radiation is likely to be an important influence on temperature (Kutty, 1987). A change in temperature of only a few degrees might mean the difference between a successful aquaculture venture and an unsuccessful one (Pittock, 2003). The variations in pond temperature had pronounced impacts on farm prawn production in Queensland, with maximal growth rates of tiger prawns (*Penaeus monodon*) during sustained periods of warmer pond water (Jackson & Wang 1998). The production efficiency of tropical and sub-tropical species of farmed prawns, such as *P. monodon* and *P. merguiensis* can be increased by a rise in water temperature. Rising temperatures may not only enhance growth rates at existing sites, but also extend the area suitable for farming of these species. On the other hand, an increase in pond water temperature might threaten the viability of farming cooler-water species, such as the penaeid *M. japonicus*, whose production is restricted to a relatively narrow range of latitudes compared to the sub-tropical species (Preston et al., 2001). Increased temperatures will affect pond evaporation rates and the resultant increases in pond salinity could adversely affect less salt-tolerant species. The negative impacts of high temperatures on aquaculture are:

- Higher inland water temperatures in water bodies affect the water quality in source water bodies, worsening dry season mortality, bringing new predators and pathogens, and changing the abundance of food available to fishery species.
- The temperature rise can cause an increase in metabolic rates of shrimp greater than the increase in food supply and thus there can be a negative impact on growth performance.
- Increased water temperatures and other associated physical changes, such as shifts in dissolved oxygen levels, have been linked to increases in the intensity and frequency of disease outbreaks (Goggin & Lester, 1995; Harvell et al., 2002; Vilchis et al., 2005). In source water bodies it will result in more frequent algal blooms in coastal areas (Kent and Poppe, 1998).
- In the areas with low temperatures survival and growth is very poor, restricting farming operations.
- Water temperature also can have a direct effect on survival of larvae and juveniles as well as on the growth of shrimp by acting on physiological processes. Increasing temperatures will have negative impacts on the oxygen transport to tissues. This physiological constraint is likely to cause significant yield reduction.
- High temperatures in summer result in water shortages which would restrict aquaculture and may create conflicts with other users.
- Unequal distribution of temperature with higher temperature near the surface layer and decreasing temperature with depth (water stratification) can result in de-oxygenation of the lower level water and degradation of water quality with the formation of methane, hydrogen sulphide and ammonia.
- Changes in temperature would change plankton community structure. Dinoflagellates have advanced their seasonal peak in response to warming, while diatoms have shown no consistent pattern of change (Edwards and Richardson, 2004).

Changes in temperature can also have positive impacts for aquaculture. Elevated temperatures of coastal waters also could lead to beneficial impacts with respect to growth rate and feed conversion efficiency (Lehtonen, 1996), and increased production.

7.2.3 Extreme climatic events

Floods, droughts, and cyclones are the main extreme natural disasters in tropical Asia. Any increase in the intensity and/or frequency of extreme climatic events can damage aquaculture.

i) Cyclones and floods

The cyclonic storms in May 1990 (AP), November 1991 (AP), Nisha cyclone in November 2008 (Tamil Nadu), Aila cyclone in May 2009 (West Bengal) and Krishna River floods in October 2009 (AP) revealed heavy damage to infrastructure and shrimp stock (CIBA, 1991; CIBA, 1992; Ponniah and Muralidhar, 2009; Muralidhar et al., 2009). The direct impacts due to ensuing flooding are:

- Inundation of the farms almost one meter above bund level
- Erosion of bunds
- Heavy siltation
- Damage to farm buildings, electrical installations, sluices, shutters and screens
- Cut off communications
- Loss of stock
- Loss to feed stocks.

The other associated negative impacts are:

- Changes in salinity of pond water would result in yield reduction.

- Introduction of disease or predators into aquaculture facilities along with the flooded water resulting in crop losses.
- Impacts on wild fish recruitment and stocks in the water bodies

ii) Drought

Consecutive droughts between 2000 and 2002 caused crop failures. In 2002 approximately 40 – 45 % of brackishwater area and 60 % of freshwater area were affected with the severe drought in Krishna District, Andhra Pradesh, where culture was not started. The drop in culture area can be attributed to lack of freshwater and rise in salinity in the source water bodies. The influent drain water with the salinity of 30 – 40 ppt, if taken into a pond, the salinity may increase further to 50-60 ppt within a few days due to evaporation and lead to poor survival and growth of shrimp. Since climate change is expected to affect the availability of freshwater and the flow in rivers, it is essential to forecast the water availability for aquaculture. The concentrations of organic load in the intake water and subsequently outlet water being high the probability of impact of virus and other diseases were proportionately increased (CIBA, unpublished information).

7.2.4 Sea level rise

The sea level rise due to the thermal expansion of oceanic waters with increasing temperature, melting of ice caps and other causes leads to the subsequent inundation that could cause the following negative impacts on shrimp aquaculture.

- Loss of land due to inundation leads to a reduction in the area currently available for aquaculture. However it may result in new areas available for aquaculture but at the expense of other land use types such as paddy fields not able to be used as paddy but able to be used as shrimp culture areas.
- Loss of freshwater fisheries and aquaculture due to reduced freshwater availability.
- Seawater intrusion into freshwater aquifers is an increasing problem with rising sea level (Moore, 1999). Higher sea levels may make groundwater more saline, harming freshwater fisheries, aquaculture and agriculture.
- Loss of coastal ecosystems such as mangroves and salt marshes, which are essential to maintain the wild fish stocks, as well as supplying seed to aquaculture.
- Inundation of inland aquaculture due to increased exposure to waves and storm surges.
- Changes in water management, salinity, and biological activities.

In certain geographical locations, sea water inundation can have positive impacts for aquaculture. Aquaculture diversification due to a shift to brackishwater species due to reduced freshwater availability is a possibility. Increased areas might be suitable for brackishwater culture of high-value species such as shrimp and mud crab. Survey by CIBA revealed that around 829 ha of seawater inundated areas in the Andaman & NICO bar Islands after 2004 tsunami are suitable for brackish water aquaculture (Pillar and Muralidhar, 2006).

7.2.5 Changes in oceanographic variables

Changes in sea-surface temperature (SST), ice cover, ocean circulation, and wave climate which affect the ocean productivity indirectly affects the aquaculture. Changes in precipitation, salinity, temperature, wind, sea level, tides, and freshwater inflows to estuaries are considered likely consequences of climate change on estuarine systems. Climate change could have dramatic impacts on fish production, which would affect the supply of fishmeal and fish oils. The potential for adverse impacts of climate change on global fishmeal production is well illustrated by periodic shortages associated with climate fluctuations such as El Nino (Barlow, 2002).

- Availability of brood stock for some species reducing the seed availability for aquaculture and for some species beneficial for aquaculture.
- Changes in estuarine water quality leading to increased disease occurrence.
- Coastal red tides could affect operations and production of shrimp farming.
- Variations in wind velocity, currents and wave action could have impacts on decreased flushing time and dilution rate in the creeks/estuaries resulting in alternations in water exchanges and waste accumulation affecting the carrying capacity of water bodies.
- Uncertainty also exists regarding changes in dissolved carbon, nutrient delivery and pollutant loading, and their interactions.
- Decrease in the production of fish meal and fish oil for aquaculture feeds.

7.3 Assessment of the plausibility of proposed adaptation measures

Several adaptation measures have been noted which are to be implemented by farmers and other relevant stakeholders during the focus group discussions and stakeholder workshop. Now the question to what extent these measures are reasonable. Sometimes the losses suffered due to climate extremes cannot be ascribed to the events alone because lack of appropriate human adaptation and sometimes maladaptation account for significant losses (Burton et al., 1993). A very strong focus on building general adaptive capacity can help the poor shrimp aquaculture communities to cope with new challenges. With respect to gender issues on climate change adaptation, a recent survey in AP concluded that both men and women report increased stresses due to weather changes over the past 30 years (FAO, 2009). While women often migrate and work as labourers, men, being usually the sole owners of the land, consider themselves to be "farmers" and are less likely to adopt new livelihood strategies. Hence it is essential to increase the adaptive capacity of poor shrimp farmers as they will not be interested to change their livelihood option. First, the farmers should have a commitment to implement the adaptive measures at the farm level (better management practices) and all the Govt. Departments, research organizations and NGOs have to help them in increasing their adaptive capacity. Both Central and State Govt. should make strong policies on climate change with a focus to increase the adaptation capacity of all the stakeholders involved in shrimp farming sector.

Decisions made by Central Government can have a profound effect on the ability of communities to adapt to climate change. Integration of climate change considerations into the policies in aquaculture sector can facilitate adaptation and ensure that they contribute to adaptive capacity from national to local levels. These policies provide opportunities to address climate change as long as the capacities, resources and political will are in place to ensure they are implemented. Depending on the degree of decentralization of decision-making, local-level plans or policies may be important in shaping adaptive capacity of vulnerable communities. It is important to understand these dynamics and how they may affect adaptive capacity at the local government/ community, and individual levels. Further, the process for developing these policies and strategies can provide insights into the level of participation of vulnerable people in establishing these priorities. For example, a detailed survey has to be conducted for de-silting and dredging of the brackishwater creeks, canals and river mouths in each coastal district of AP as this was not done for the last two to three decades leading to heavy siltation, more organic load during summer months, severe outbreak of diseases due to rise in salinity of waters caused by the closure of river mouths near the sea. Further, this also leads to flooding during heavy rains and cyclones. Similarly construction of flood walls, forestation of mangroves, provision of electricity, and equating aquaculture on par with agriculture, all these requires policy measures to be framed by Govt., otherwise the plausibility of adapting then will never been seen.

In order to adopt the scientific adaptive measures reasonably, research has to be carried out in the areas such as, refining and development of adaptive tools to make aquaculture sustainable and productive, planning for uncertainty to take care of extreme weather events, basic research on physiological aspects of shrimp behaviour (feeding metabolism, reproduction, muscle function, cardiac function, toxicity and biochemical genetics aspects), understanding on changes in shrimp yield resulting from climate change.

In order to mitigate climate change impacts and to decrease the emission of green house gases from brackishwater shrimp aquaculture overall comprehensive adaptation approaches are to be in place. Better management practices implementation is one of the adaptation approaches to mitigate climate change impacts at the farm level. Farm run strategies such as exploiting organic matter accumulated in aquatic farming systems to build soil organic matter and carbon in marginal or agricultural land and enhancing in situ primary production, reduced energy use and fuel conservation, direct renewable energy use and enhanced soil, water and waste management to reduce carbon and other greenhouse gas emissions by carbon sequestration in crop lands (Lal et al., 1998; Lal, 2003) can also be applied in aquaculture. Carbon labelling and carbon foot print measurement (CFPM) places more emphasis on greenhouse gas emissions, issuing guidance and standards (Carbon Trust, 2007). Organic certification schemes through carbon labelling means that responsible producers can benefit directly from potential price premiums associated with adopting mitigation and adaptation through low-carbon products (Hammerschlag and Barbour 2003, Lenzen et al., 2007).

8 Conclusion

The use of participatory processes such as facilitated semi-structured focus group discussion and facilitated stakeholder workshop to assess the impacts and adaptation of aquaculture to climate change was a novel technique for the shrimp farmers and stakeholders in Andhra Pradesh. The existing pressures and demand on aquaculture production, and anticipated challenges, will require better multi-scale understanding of the impacts of climate change. Greater climate variability and uncertainty complicate the task of identifying impact pathways and areas of vulnerability (about 43% of the AP coast is under very high-risk and 35% is under high-risk), requiring research to devise and promote coping strategies and improve the adaptability of small scale shrimp farmers, who are socio-economically vulnerable as well.

Research to develop the adaptation strategies and the means to implement them is desperately needed. The researchers and other stakeholders must step up efforts to fill the critical knowledge gaps on climate change impacts, assessment of aquaculture related vulnerability, development of prediction models for different scenarios, refining and development of adaptive tools to make aquaculture sustainable and productive in the face of climate change. Climate change could manifest through extreme events like cyclones and hence a proper understanding of the current coastal zone management practices, such as early warning systems and hazard insurance, could provide useful insights about the potential future adaptation strategies. This will require mainstreaming of cross-sectoral responses into governance policy and frameworks. Links will need to be improved among fisheries, aquaculture and other sectors that share or compete for resources, production processes or market position, in order to manage conflicts and ensure that food security aims can be maintained. Existing management plans for the fisheries and aquaculture sectors, coastal zones and watersheds need to be reviewed and, if needed, further developed to ensure they cover potential climate change impacts, mitigations and adaptation responses.

9 References

Anonymous. 2005. Concept paper on revival of shrimp aquaculture in Krishna District. Project document for a follow up of the FAO assisted project TCP/IND/2902(A) on Health Management of shrimp aquaculture in Andhra Pradesh.

Coastal Aquaculture Authority. 2001. Shrimp Aquaculture and the Environment: An Environment Impact Assessment Report submitted to the Supreme Court of India, Aquaculture Authority, Govt. of India, p.114. (http://aquaculture.tn.nic.in/shrimpfarming.html).

Barlow, S.M. 2002. The world market overview of fish meal and fish oil. http://www.iffo.org.uk/tech/alaska.htm.

Baskaran R (2004) Coastal erosion. Curr Sci 86:25

Bastia R, Nayak PK (2006) Tectono stratigraphy and depositional patterns in Krishna offshore basin, Bay of Bengal. Lead Edge (Tulsa Okla) 25:839–845 doi:10.1190/1.2221361

Burton, I., R.W. Kates and G.F. White, 1993. *The Environment as Hazard,* Second Edition, Gullford Press, New York.

Carbon Trust, 2007. Carbon footprint measurement methodology. Version 1.3. Carbon Trust, London, 26 p.

Chadha RK, Latha G, Yeh H et al (2005) The tsunami of the great Sumatra earthquake of M.9.0 on 26 December 2004—impact on the east coast of India. Curr Sci 88:1297–1301

CIBA. 1991. Annual Report 1990-91. (K.Alagarswami and K.N.Krishnamurthy, editors). Central Institute of Brackishwater Aquaculture, Chennai, 45 p.

CIBA. 1992. Annual Report 1991-92. (K.Alagarswami and K.N.Krishnamurthy, editors). Central Institute of Brackishwater Aquaculture, Chennai, 40 p.

CIBA. 1996. Comprehensive Survey of Impact Assessment of Shrimp Farms in Nellore District. Mimeo., Central Institute of Brackishwater Aquaculture, Chennai.

CWC. 2001. Water and related statistics. Report of the Ministry of Water Resources, Central Water Commission, New Delhi.

De, U.S. and R.K. Mukhopadhyay. 1998. Severe heat wave over the Indian subcontinent in 1998, in perspective of global climate. Current science 75 (12): 1308-1311.

Edwards, M. and A.J. Richardson. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430: 881-884.

FAO, 2009. Does gender make a difference in dealing with climate shifts? Research results from Andhra Pradesh, India. Gender, Equity and Rural Employment Division Economic and Social Development Department Food and Agriculture Organization of the United Nations 00153, Rome, Italy.

Goggin, C.L. and R.J.G. Lester. 1995. *Perkinsus*, a protistan parasite of abalone in Australia - review. Marine and Freshwater Research 46: 639-646.

GOI, 2006. Hand Book on Fisheries Statistics, 2006. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Govt. of India.

Gupta, S.K and R.D. Deshpande. 2004. Water for India in 2050: first-order assessment of available options. Current Science 86(9): 1216–1224.

Hammerschlag, R and W. Barbour. 2003. "Life-Cycle Assessment and Indirect Emission Reductions: Issues Associated with Ownership and Trading". Institute for Lifecycle Environmental Assessment (ILEA), Seattle, Washington, USA, May 2003.

Harvell, C.D., C.E. Mitchell., J.R. Ward., S.Altizer., A.P. Dobson., R.S Ostfeld. and M.D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. Science 296: 2158-2162.

Hema Malini B, Nageswara Rao K (2004) Coastal erosion and habitat loss along the Godavari delta front – a fallout of dam construction (?). Curr Sci 87:1232–1236

IPCC. 2007. Climate Change 2007: Mitigation and Climate Change. Contribution of Working Group III to the Forth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policy Makers. http://www.ipcc.ch.

Jackson, C.J. and Y.G. Wang. 1998. Modeling growth rate of *Penaeus monodon* Fabricus in intensively managed ponds: effects of temperature, pond age and stocking density. Aquaculture Research 29: 27-36.

Kent, M.L. and T.T. Poppe. 1998. Diseases of Seawater Netpen-Reared Salmonid Fishes. Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, 137 pp

Kripalani, R.H., S.R. Inamdar. and N.A. Sontakke. 1996. Rainfall variability over Bangladesh and Nepal: comparison and connection with features over India. International Journal of Climatology 16: 689–703.

Kutty. 1987. Site selection for aquaculture: Physical features of water. United nations development program. Food and Agricultural Organization of the United Nations. Nigerian Institute for Oceanography and Marine Research. Project RAF/82/009.

Lal, R. 2003. Global potential of soil carbon sequestration to mitigate the greenhouse effect. Crit. Rev. Plant Sci. 22: 151–184,

Lal, R., J.M. Kimble., R.F. Follett. and C.V. Cole. 1998. The potential of US cropland to sequester carbon and mitigate the greenhouse effect. Ann. Arbour Press, Chelsea, Michigan.

Lehtonen, H. 1996. Potential effects of global warming on northern European freshwater fish and fisheries. Fisheries Management and Ecology 3: 59-71.

Lenzen, M., Murray, J., Sack, F and Wiedmann, T. 2007. Shared producer and consumer responsibility - Theory and practice. Ecological Economics, 61(1): 27-42.

Mirza, M.Q. and N.J. Ericksen, 1996. Impact of water control projects on fisheries resources in Bangladesh. Enviornmental Management 20(4): 527–539.

Moore, W.S. 1999. The subterranean estuary: a reaction zone of ground water and sea water. Marine Chemistry 65: 111-125.

MPEDA, 2006. Action plan for development of export oriented aquaculture in maritime states of India. MPEDA, Cochin, India pp.72.

Muralidhar,M., B.P.Gupta., M.Jayanthi, M.Krishnan and A.G.Ponniah, 2009. Impact of extreme climatic events on brackish water aquaculture. In: Marine Ecosystems Challenges and Opportunities, Book of Abstracts (Ed. E.Vivekanandan et al), Marine Biological Association of India, February 9-12, 2009, Cochin, CCO 03, pp. 249-250.

NaCSA. 2009a. Agenda for the 8th Governing Council Meeting presented at MPEDA, HO, Cochin on 30/09/09. NaCSA, pp.

NaCSA. 2009b. Agenda for the Third Annual General Body Meeting –Annual report 2008-09 presented at MPEDA, HO, Cochin on 30/09/09. NaCSA, pp.

Nageswara Rao K, Ashokvardhan D, Subraelu P (2007) Coastal Topography and Tsunami Impact: GIS/GPS-based Mobile Mapping of the coastal sectors affected by 2004-tsunami in Krishna–Godavari delta region. East Geogr 13:67–74

Nageswara Rao., K P. Subraelu, T. Venkateswara Rao, B. Hema Malini, R. Ratheesh, S. Bhattacharya, A. S. Rajawat and Ajai. (2008). Sea-level rise and coastal vulnerability: an assessment of Andhra Pradesh coast, India through remote sensing and GIS. J. Coast Conserv. 12:195–207

Nell, J.A. 1993. Farming the Sydney Rock Oyster (*Saccostrea commercialis*) in Australia. Reviews in Fisheries Science 1: 97-120.

Nicholls R. J. and. Lowe, J. A. 2004. Benefits of mitigation of climate change for coastal areas. Global Environmental Change Part A 14 (3): 229-244.

Nicholls, R.J. 1998. Assessing erosion of sandy beaches due to sea-level rise. Pages 71-76 in J.G. Maund, and M. Eddleston, editors. Geohazard in Engineering Geology Engineering Geology Special Publications, Geological Society, London, United Kingdom.

Nicholls, R.J. and J. Branson. 1998. Coastal resilience and planning for an uncertain future: an introduction. Geographical Journal 164(3): 255-258.

Nicholls, R.J. and Mimura, N. 1998: Regional issues raised by sea-level rise and their policy implications. Climate Research 11(1): 5-18.

Nicholls, R.J., F.M.J. Hoozemans. and M. Marchand. 1999. Increasing flood risk and wetland losses due to sea-level rise: regional and global analyses. Global Environmental Change 9: S69-S87.

Pendleton EA, Thieler ER, Williams SJ (2004) Coastal vulnerability assessment of Cape Hettaras National Seashore (CAHA) to sea level rise. USGS Open File Report 2004-1064. Available from http://pubs.usgs.gov/of/2004/1064/images/pdf/caha.pdf

Pillai, S.M, and M. Muralidhar. 2006. Survey and demarcation of seawater inundated areas for eco-friendly aquaculture in Andaman and Nicobar Islands' Report submitted to Andaman and Nicobar Administration, Port Blair, Central Institute of Brackishwater Aquaculture, Chennai, 69 p.

Pittock, B., editor. 2003. Climate Change: an Australian guide to the science and potential impacts. ACT, Australian Greenhouse Office, Canberra.

Ponniah, A.G and Muralidhar, M. 2009. Research requirements to understand impact of climate change on Brackishwater aquaculture and develop adaptive measures. In: Proceedings of 96th Session of the Indian Science Congress, Part II: Session of Animal Veterinary and Fisheries Sciences, January 3-7, 2009, pp. 46-47.

Preston, N.P., C.J. Jackson, P. Thompson., M. Austin., M.A. Burford. and P.C. Rothlisberg. 2001. Prawn farm effluent: Composition, origin and treatment. Fisheries Research and Development Corporation, Australia, Final Report, Project No. 95/162.

Rosenzweig,C., D. Karoly., M. Vicarelli., P.Neofotis., Q. Wu., G.Casassa., A.Menzel., T.L. Root., N. Estrella., B. Seguin., P.Tryjanowski., C. Liu., S. Rawlins. and A. Imeson. 2008. Attributing physical and biological impacts to anthropogenic climate change. Nature 453: 353-357

Singh, N. and N. A. Sontakke. 2002. On climatic fluctuations and environmental changes of the Indo-Gangetic plains, India. Climatic Change 52: 287–313.

Surendran, V., Madhusudhan Reddy, K. and Subba Rao, V. 1991. Semi-intensive shrimp farming-TASPARC's experience at Nellore. Fishing Chimes, February 1991: 23–29.

Umesh, N.R, A.B.Chandra Mohan., G.Ravibabu., P.A.Padiyar., M.J.Phillips., C.V.Mohan and B.Vishnu Bhat. 2009. Shrimp farmers in India: Empowering small-scale farmers through a cluster-based approach. (In: Success stories in Asian aquaculture ed. Sena S. De Silva and F.Brian Davy), Network of Aquaculture Centers in Asia-Pacific, Springer Publication, UK pp. 41-66

Unnikrishnan AS, Rup Kumar K, Fernandes SE et al (2006) Sea level changes along the Indian coast: observations and projections. Curr Sci 90:362–368

Unnikrishnan AS, Shankar D (2007) Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? Global Planet Change 57:301–307 doi:10.1016/j.gloplacha.2006.11.029

Vilchis, L.I., M.J. Tegner., J.D. Moore., J.D. Friedman., C.S. Friedman., K.L. Riser., T.T. Robbins. and P.K. Dayton, 2005. Ocean warming effects on growth reproduction and survivorship of southern California abalone. Ecological Applications 15:469-480.

Webster, P.J., V.O. Magana., T.N. Palmer., J. Shukla., R.A. Tomas., M. Yanagi. and T. Yasunari. 1998. Monsoons: process, predictability and the prospects for prediction. Journal of Geophysical Research 103 (C7): 14451–14510.

Yadava.Y.S. 2002. Shrimp farming In India: Lessons and challenges in Sustainable Development', Aquaculture Authority News, 1(1): 1-4.

10 Appendices

Appendix -1

CLIMATOLOGICAL TABLE
PERIOD: 1951-1980

Month	Mean Temperature (^oC)		Mean Total Rainfall (mm)	Mean Number of Rainy Days	Mean Number of days with			
	Daily Minimum	Daily Maximum			Hail	Thunder	Fog	Squall
Jan	18.7	30	0.9	0.1	0	0	2	0
Feb	20.1	32.7	5.3	0.4	0	0.4	2.3	0
Mar	22.4	35.4	9.6	0.5	0	0.9	2.1	0
Apr	25.5	37.4	14.3	1	0	2.9	0.2	0
May	27.5	39.8	51.3	3.1	0	6.2	0	0.1
Jun	27	37.2	131.9	7.6	0	7.1	0	0
Jul	25.4	33.2	218.4	12.6	0	4.7	0	0.1
Aug	25.1	32.4	185.6	11.5	0	4.9	0	0
Sep	25.1	32.6	163.5	8.8	0	8.2	0.2	0
Oct	24	31.8	142.6	7.1	0	7.6	0.3	0
Nov	21.3	30.7	51.3	2.8	0	1.6	0.1	0
Dec	19.1	29.6	6.7	0.6	0	0	0.6	0
Annual	23.4	33.6	998.2	56.1	0	44.5	7.8	0.2

Source: IMD, Vijayawada

Appendix - 2

Aqua Climate - Focus Group Discussion (FGD) with shrimp farmers

3rd December 2009

Krishna District, Andhra Pradesh

Inland area – Chinnapuram   Coastal area - Gullalamoda

Programme Schedule

Time	Activity
10.00	Registration of participants
10.30	Brief introduction to the project/focus group objectives by Project co-ordinators
10.40	Introductions and Grouping of participants
10.50	Farmer perception on climate change
11.10	Impact of climate change on shrimp farming
11.30	Economic Impact
	Tea break
12.00	Risk assessment
13.00	Solution, responsible agencies and timeline (What measures?, How?, Who? When?)
14.00	Lunch
15.00	Seasonal and Crop calendar
15.45	Discussion
16.30	Closing

Appendix - 3

Aqua Climate - Stakeholders Workshop

4th December 2009, Hotel Ilapuram, Vijayawada

Programme Schedule

Time	Activity
9.00	Registration
9.20	Welcome and Introductions of all the participants
9.30	Brief Presentation of the Project - Dr. Nigel William Abery, Coordinator, Aqua Climate Project, NACA
9.40	Workshop Objectives - Dr. Udaya Sekhar Nagothu, BIOFORSK
9.50	Brief Remarks
	Dr.T.C.Santiago, HOD, AAH&ED, CIBA
	G.Rathina Raj, Deputy Director, MPEDA
	Dr. (Mrs.) B.Chamundeswari Devi, Principal, CoF, Nellore
10.15	The status of shrimp culture in Andhra Pradesh with special reference to study area - Sh.N.R.Umesh, NaCSA
10.25	Climate Change Impacts on shrimp aquaculture – Focus on extreme events (Indian scenario) – Dr.M.Muralidhar, CIBA and National Coordinator
10.35	Climate change - Adaptation for sustainability – Dr.M.Kumaran, CIBA and National co-ordinators
10.45	Presentation of Focus Group Discussions
10.55	**Coffee/Tea break**
11.05	Workshop Mechanics and Groupings
	Theme 1: Farmers and other input group perceptions
	Theme 2: Scientists perception
	Theme 3: Institutions response
11.30	Discussions among the groups
13.15	Group photographs
13:30	**Lunch**
14.30	Discussion among the groups and presentations
16.00	**Coffee/Tea break**
16.30	Open session
17.00	Closing