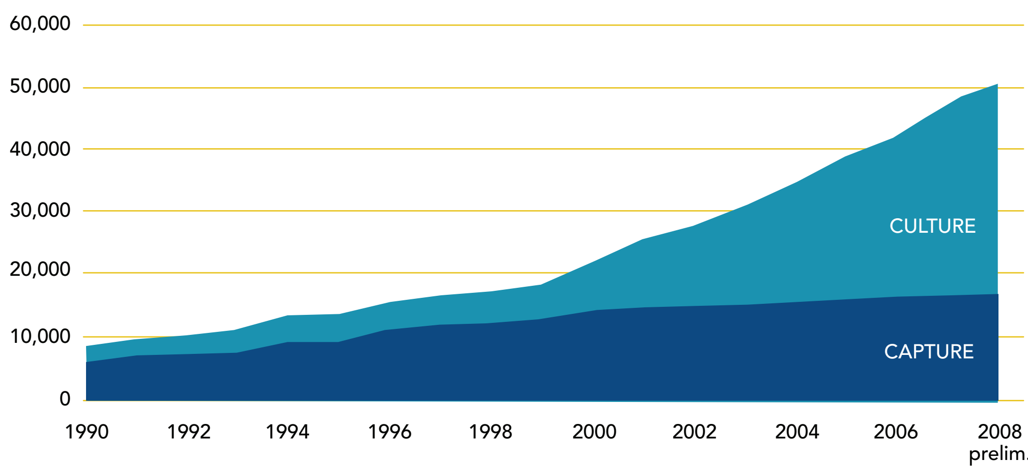
Aquaculture

The Growth of Aquaculture in Vietnam

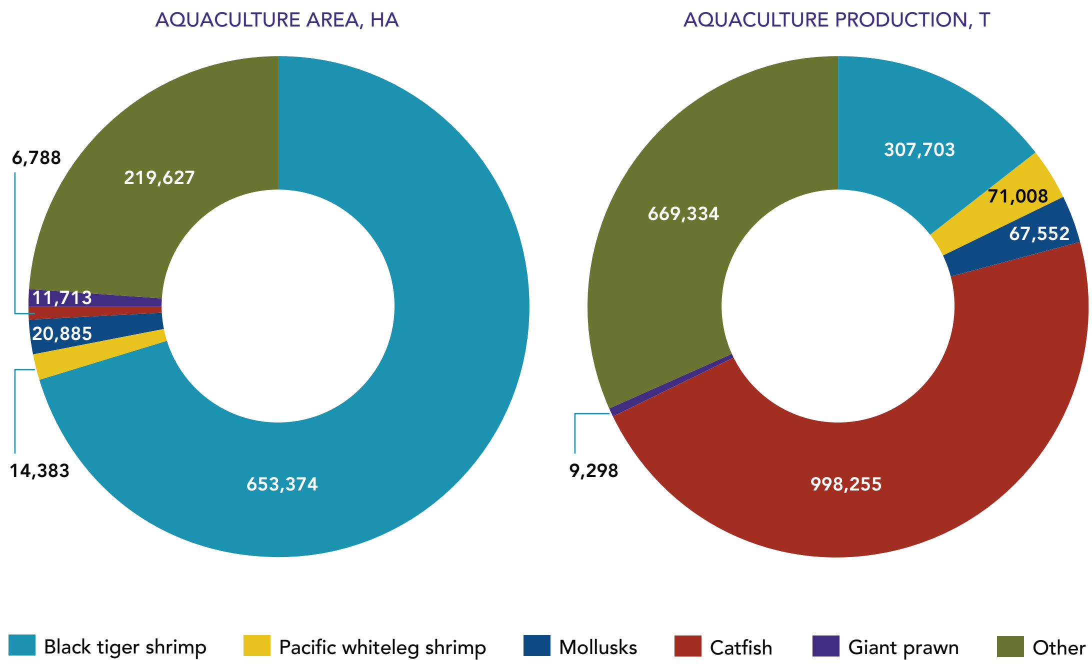
Given Vietnam's long coastline, capture fisheries have always been important as a source of food and incomes. With slower growth of capture fisheries, aquaculture has overtaken capture fisheries in both the quantity and value of production (Figure 3). In 2008, aquaculture production was valued at 33 trillion VNĐ, accounting for 6.6 percent of the national GDP, up from 2.2 percent a decade ago. Over the same period, capture fisheries' share of GDP fell from 5.0 percent to 3.6 percent (Trong 2008). The rapid growth of the sector has been a major source of agricultural diversification over the past decade. It is a direct result of adapting operating practices together with a focus on the production of exportable species at increased levels of intensification. The EACC sector study on

FIGURE 3 VALUE OF PRODUCTION FROM CAPTURE FISHERIES AND AQUACULTURE (VNĐ BILLION AT CONSTANT 1994 PRICES)



Source: General Statistical Office of Vietnam, 2009

FIGURE 4 **AQUACULTURE AREA AND PRODUCTION IN VIETNAM'S SOUTHERN PROVINCES, 2009**



Source: VASEP (2010)

aquaculture (Kam et al. 2010) looked at the economics of adaptation to climate change for some aquaculture products and for some areas.

Aquaculture in Vietnam is dominated by brackish-water and freshwater production systems. Shrimp dominates the brackish-water aquaculture production, accounting for 98 percent of the production volume, while fish accounted for 99 percent of freshwater production in 2005. Estimates by the Department of Aquacultureof the Ministry of Agriculture and Rural Development (MARD) put the 2009 aquaculture area in the southern provinces (from Da Nang to Ca Mau) at 927,000 ha with total production of 2.1 million tons, accounting for 79 percent of the country's total aquaculture area and 80 percent of the total aquaculture output (VASEP 2010). Pond culture of brackish-water shrimp dominates in terms of farm area (71 percent of all aquaculture area is used for shrimp production), while freshwater catfish farming accounts for 47 percent of total aquaculture production by weight (Figure 4).

The regional distribution of cultured shrimp and fish are reasonably representative of the geographical differences in the dominance of brackish-water and freshwater aquaculture production respectively. The Mekong River Delta accounts for about 80 percent of the country's total shrimp production (which includes brackish-water shrimp and freshwater prawns), while the coastal provinces in central Vietnam account for about 15 percent. The Mekong River Delta has also increased its share of the country's cultured fish production from 67 percent in 2005 to an estimated 75 percent in 2008, mainly due to the expansion of the catfish industry. Freshwater catfish production now dominates cultured fish production in the Mekong River Delta, but there are also many other freshwater and marine fish species that are cultured throughout the country. The Red River Delta region ranks second in cultured fish production, but its share declined from about 20 percent to 15 percent from 2005 to 2008.

In the Mekong River Delta, striped catfish are grown primarily in ponds with earth walls that are sited adjacent to rivers to permit a high level of water exchange between river and ponds. It is an air-breathing species that can tolerate low levels of dissolved oxygen—that is, highly polluted water—and high stocking rates, so it can be grown in locations where the water is not suitable for other uses. Catfish cultivation is mostly a small-scale activity. The typical pond has an area of 0.4 ha, and less than 10 percent of operators have more than four ponds. Extensive shrimp production takes place in large coastal ponds relying upon tidal water exchange but stocked from hatcheries, with the use of fertilizers to promote the growth of natural organisms to feed the shrimp. Semi-intensive or intensive production methods use smaller ponds and higher stocking rates, relying upon water pumps and aeration to maintain water quality as well as a variety of formulated feedstuffs. The most intensive production methods require substantial inputs of capital and skilled labor.

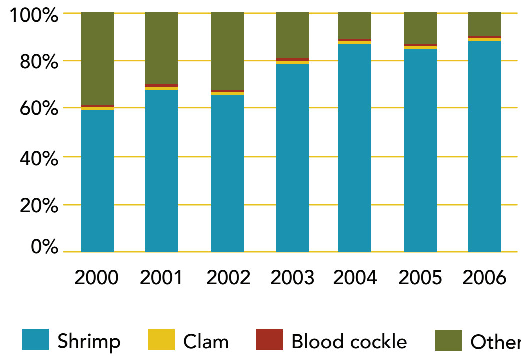
In summary,

- Aquaculture in Vietnam has grown rapidly in the course of the last decade and has overtaken capture fisheries in terms of growth of the sector.
- The aquaculture sector is dominated by shrimp and catfish.
- Geographically, the Mekong River Delta accounts for the largest share of the sector's activities.

Hence, this study focuses on freshwater catfish and brackish-water shrimp in the Mekong River Delta (Figure 5).

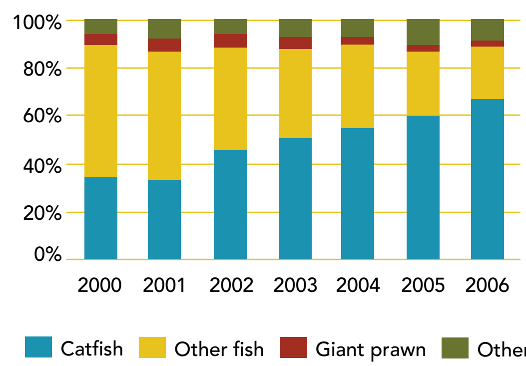
FIGURE 5 VALUE OF (A) BRACKISH WATER AND (B) CATFISH PRODUCED IN THE MEKONG RIVER DELTA

BRACKISH WATER AND MARINE PRODUCTION VALUE



	2000	2001	2002	2003	2004	2005	2006
Other	3227	3852	4917	3228	2223	3028	2436
Blood cockle	18	18	23	24	56	123	160
Clam	133	226	248	306	270	278	342
Shrimp	4964	8759	10133	13592	17790	19700	23367

FRESHWATER PRODUCTION VALUE



	2000	2001	2002	2003	2004	2005	2006
Other	105	143	150	218	367	721	869
Giant prawn	73	98	133	168	155	178	270
Other fish	941	1021	1034	1144	1783	1811	2216
Catfish	595	640	1124	1612	2841	4209	6825

Note: Tabulated values are in billion VNĐ.
Source: Research Institute of Aquaculture No.2 (RIA2).

A recent strategy document (MARD 2009) provides targets for fisheries production up to 2020. The production target for aquaculture is 4.5 million metric tons in 2020 (Table 24). It estimated that about 1.3 million ha of water bodies will be exploited for aquaculture activities, of which there are 0.6 million ha of freshwater area and 0.7 million ha of brackish-water and marine areas. A second plan approved by MARD focuses exclusively on catfish production. From 2010 to 2020, the total area under catfish culture is expected to increase by 4.2 percent per year, reaching 13,000 ha by 2020. Export turnover is expected to grow at 5.9 percent per year, reaching $1.85 billion, which will account for 45–50 percent of the projected aquaculture exports of $5.0–$5.5 billion.

The Impact of Climate Change on Aquaculture

Climate change will affect the aquaculture sector through a number of direct and indirect pathways. Examples of potential impacts are illustrated in Figure 6. The direct impact of sea level rise may be particularly important as increased flooding and salinity intrusion will affect coastal aquaculture installations, especially ponds that are located right along the coast. Higher tides will obstruct river discharge into the sea and exacerbate flooding further inland. Any increase in the intensity and frequency of extreme climatic events such as storms may affect aquaculture production by damaging production assets and transport infrastructure required for access to markets.

Vulnerability of aquaculture in the Mekong River Delta. A vulnerability analysis of aquaculture in the Mekong River Delta focusing on the shrimp and catfish industry was carried out using an approach that follows the general IPCC conceptual framework. Four production systems were identified, two for catfish and two for shrimp:

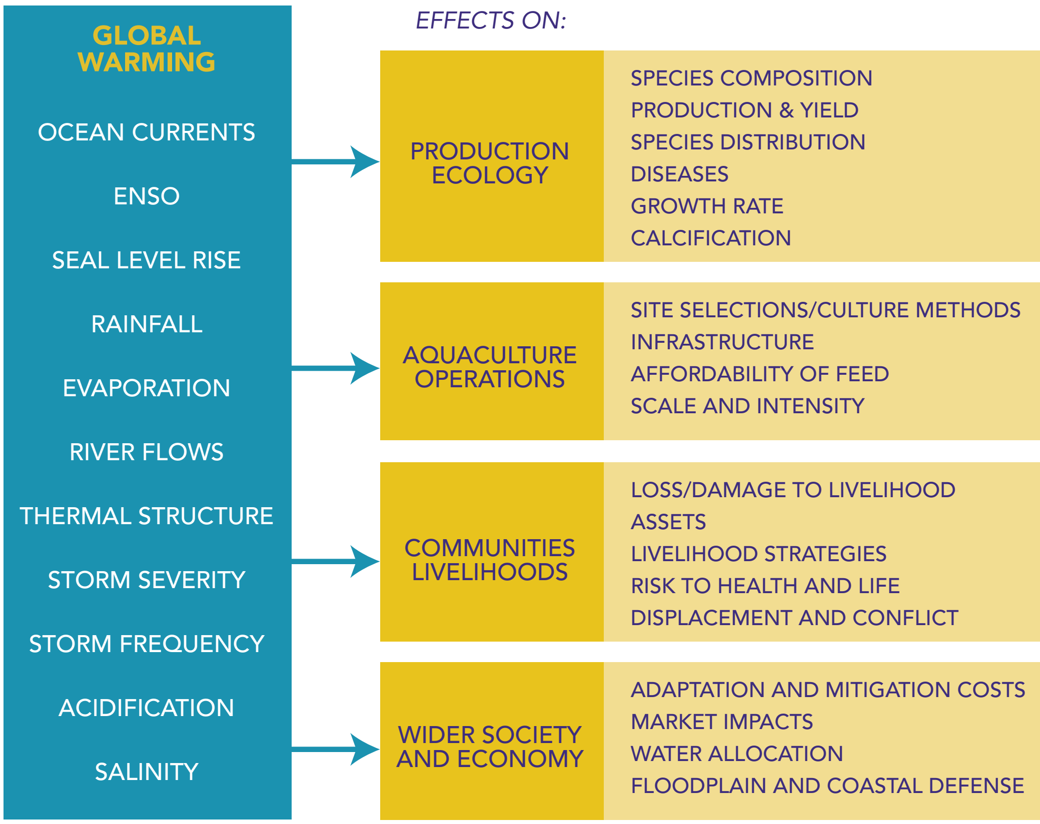
- Catfish (I).—pond culture of the tra catfish (*Pangasianodon hypophthalmus*) in inland

TABLE 24 AQUACULTURE DEVELOPMENT TARGETS UP TO 2020

		Targets for:		
		2010	*2015*	*2020*
Total production	000 tons	**2,600**	**3,650**	**4,500**
Brackish-water shrimp	000 tons	400	550	700
Catfish	000 tons	1,250	1,800	2,000
Mollusk	000 tons	200	250	300
Marine fish	000 tons	50	150	200
Tilapia	000 tons	70	100	150
Sea weed	000 tons	75	100	150
Freshwater prawn (Macrobrachium)	000 tons	20	40	60
Other species	000 tons	35	60	90
Traditional fish	000 tons	500	600	850
Export turnover	billion US$	**2.8**	**3.5–4.0**	**5.0–5.5**
Labor	000 people	**2,800**	**3,000**	**3,000**

Source: MARD (2009).

FIGURE 6 GLOBAL WARMING AND FISHERIES/AQUACULTURE: POTENTIAL IMPACTS



Source: Based on Badjeck et al. (2009).

provinces of An Giang, Dong Thap, Cantho and Vinh Long.

- Catfish (C)—pond culture of tra catfish in coastal MRD provinces of Soc Trang and Ben Tre: the movement of freshwater catfish culture towards the coast began in 2002.

- Shrimp (Ext)—the black tiger shrimp (*Peneaus monodon*) cultured at improved extensive scale mainly in Ca Mau province in the Mekong River Delta.

- Shrimp (SII)—*P. monodon* cultured at semi-intensive/intensive scale in most other coastal provinces of the Delta (and also in Central Vietnam and the Red River Delta).

To assess vulnerability, a combination of qualitative and quantitative methods was used. At Step 1, the exposure, sensitivity, and adaptive capacity of production systems were assessed. At Step 2, secondary data and expert knowledge were used to identify exposure and sensitivity at the farm level. At Step 3, geographical information system (GIS) methods were used to map the potential impacts of sea level rise on catfish and shrimp farms. Finally, at Step 4 the capacity of the catfish and shrimp industries to adapt to change was investigated. The vulnerability analysis produced the following results.

TABLE 25 MAIN SALINITY AND TEMPERATURE REQUIREMENTS FOR CATFISH AND SHRIMP

	Catfish	*Shrimp*
To in ponds (oC)	Optimum range for channel catfish growth is 28–30°C (Hargreaves and Tucker 2003)	29.8 ± 1.0 °C (Duong, N.D., 2006) Morning: 28.3 ± 0.5 °C Afternoon: 30.5 ± 0.5 °C
Salinity tolerance (ppt)	Channel catfish can survive and grow in *slightly* salty water (Buttner, n.d)	Range 15–30 ppt; optimum growth 25 ppt. Survival rates not significantly affected by salinity in the range 10–35 ppt

Note: ppt = parts per thousand.

Exposure. Lower rainfall during the dry season coupled with increased air temperature will result in higher water losses from ponds, especially the larger extensive-scale shrimp ponds, hence increasing water salinity in the ponds. This may require the addition of freshwater to ponds during the dry season, when there will likely be competing demands for freshwater from other sectors (agricultural, industrial, and domestic).

In general, the effects of projected changes in localized rainfall on water availability for aquaculture ponds are not likely to be as significant as those of changes in sea level and upstream hydropower development in the Mekong Basin. Projections of climate-related changes in mean annual flow in the Mekong River range from 5 percent (Hoanh et al. 2003) to 20 percent (Eastham et al. 2008). In comparison, planned large hydropower projects in the Mekong are projected to increase dry-season flows by 10–50 percent and decrease wet season flows by 6–16 percent (Hang and Lennaerts 2008).

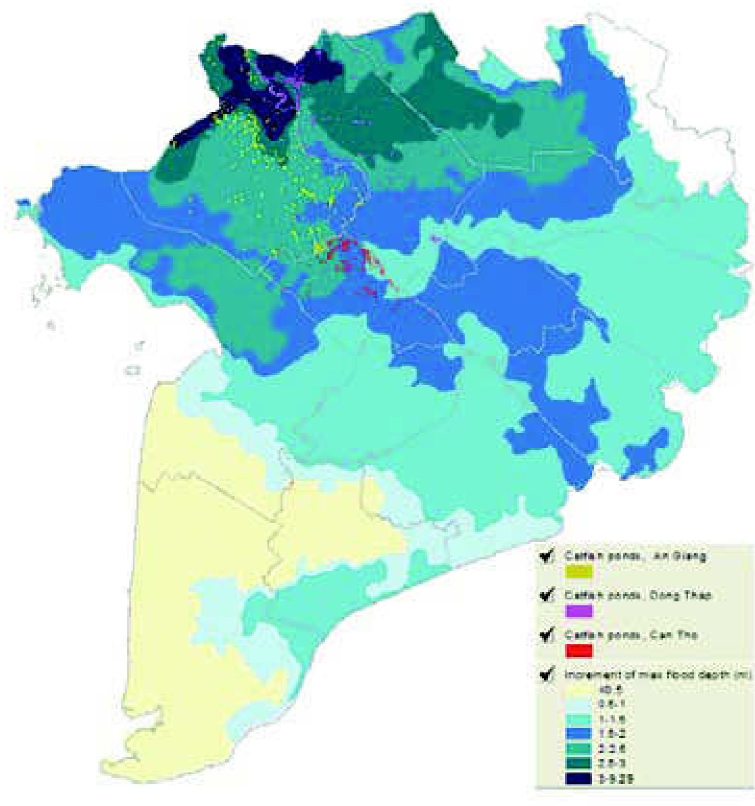
Sensitivity. Catfish and shrimp species have different physiological characteristics, especially in terms of salinity tolerance, with catfish being able to tolerate only slightly salty water (Table 25). Effects of temperature rise and salinity increase on cultured species in the Mekong River Delta are still not well-studied and data are scant on maximum salinity thresholds.

The increased temperature would be within the tolerance range of the main cultured species— particularly the river catfish—that perform well in high water temperatures of around 30°C.[10] The main effect of temperature rise is increased metabolic rates, which can enhance growth rates provided that feeding is correspondingly increased, hence incurring increased cost but reduced time to grow to the preferred size. Another effect is increased organic decomposition rates, which may lead to fouling of the water, particularly in closed culture systems such as ponds. Decreased dissolved oxygen may require increased aeration, particularly in intensive culture of shrimp, which are more sensitive to reduced oxygenation than catfish. River catfish can tolerate poor water quality, including high organic matter or low dissolved oxygen levels. It is important to note that temperature responses are species specific. While some species will be adversely affected, others are better adapted to high temperature and possess a wide thermal tolerance zone—such as the catfish *H. brachysoma*—and could be introduced in tropical freshwaters (Dalvia et al. 2009).

Sea level rise will gradually impact marine and brackish aquaculture with saltwater intrusion, requiring the farming of species that tolerate high salinity. Increasing extremes of weather patterns and storms will be another hazard to coastal industries. Storm surges, waves, and coastal erosion could have a larger effect than the rise in mean high water level (2WE Associates Consulting Ltd.

10 http://www.richardsbrothersseafoods.com.au/basa_farming.htm.

FIGURE 7 AREAS IN AN GIANG, DONG THAP, AND CAN THO PROVINCES SUBJECTED TO INCREMENTS OF MAXIMUM FLOODING DEPTHS FOR 50-CM SLR SCENARIO



2000). There is already evidence of coastal erosion as a result of damages to sea dikes in the Cau Mau Province.

Potential impacts: flooding. Extensive shrimp and inland catfish farming are particularly sensitive to flooding. The catfish-rearing areas of An Giang, Dong Thap, and Can Tho are most likely to be affected by increased flooding during the rainy season as a result of a combination of sea level rise and changes in rainfall patterns. Figure 7 illustrates the geographical pattern of projected increases in maximum flood levels during the rainy season for a 50-cm SLR scenario. The greatest increments in flooding depth are projected to occur in the inland provinces, which already experience floods from the discharge of the Mekong River yearly during the rainy season and where catfish farmers already have experience in dealing with these seasonal floods. Table 26 provides the estimates of areas of catfish ponds that will be affected by successive increments of maximum flooding depths during the rainy season.

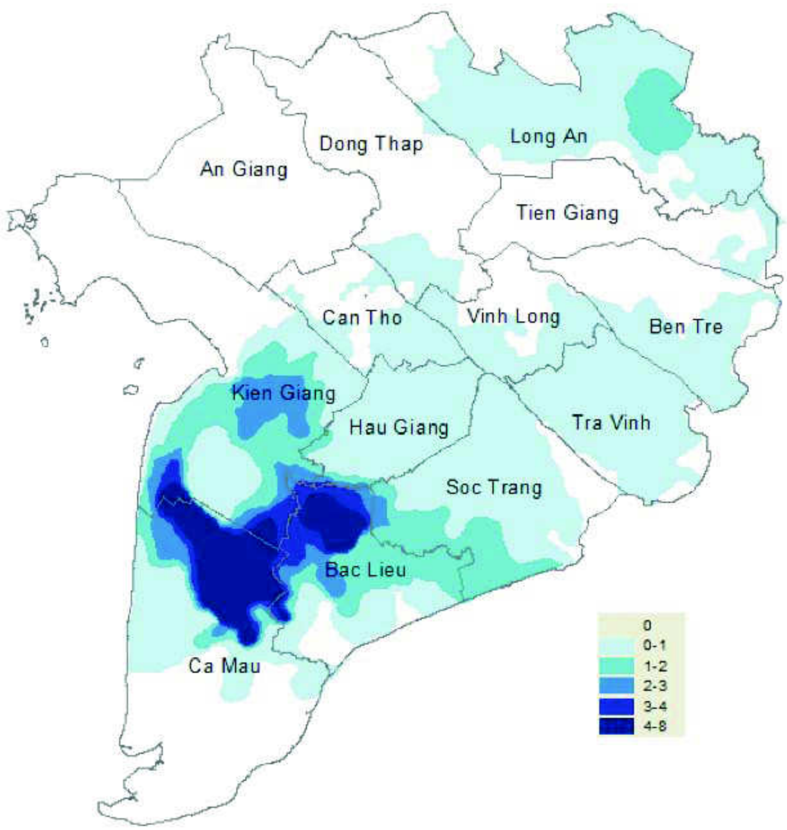
An increase in flooding depth directly due to sea-level rise will be experienced along the coastal strip facing the South China Sea that is not protected by salinity control systems. This is most evident south of the national road 1 joining the towns of Bac Lieu and Ca Mau.

Potential impacts: salinity. Salinity intrusion is especially important for shrimp and coastal catfish aquaculture. The brackish-water shrimp areas in

TABLE 26 ESTIMATES OF CATFISH POND AREA (HA) THAT WILL BE SUBJECTED TO INCREMENTS OF MAXIMUM FLOODING DEPTHS IN THE RAINY SEASON UNDER 50-CM SLR SCENARIO

Increment of max flood depth (m)	*Affected catfish pond area*					
	An Giang		*Dong Thap*		*Can Tho*	
	ha	*%*	*ha*	*%*	*ha*	*%*
<0.5						
0.5–1						
1–1.5			178	13	273	26
1.5–2	163	8	89	6	509	48
2–2.5	1,236	62	211	15	286	27
2.5–3	394	20	497	36		
> 3	210	10	402	29		
Total	2,003	100	1,376	100	1,068	100

FIGURE 8 AREAS SUBJECTED TO INCREMENTS OF MAXIMUM WATER SALINITY OR 50-CM SLR SCENARIO



the coastal provinces stretching from Tra Vinh to Ca Mau are likely to be affected by increased salinity intrusion during the dry season, especially where the shrimp ponds are outside of the areas protected by the coastal embankments and water control sluices. Even though the salinity tolerance of black tiger shrimp can be as high as 35–40 ppt, this tolerance is limited by disease problems.

Figure 8 shows where increments in maximum water salinity under the 50-cm SLR scenario are projected to occur. The greatest increments in maximum salinity are expected to occur around the area where Ca Mau, Bac Lieu, and Kien Giang provinces meet. The shrimp ponds in this area would be subjected to increments of maximum salinity exceeding 2 ppt in the dry season. Increased water salinity, particularly in the dry season, would require additional pumping of freshwater to maintain the required salinity levels for brackish-water shrimp culture. For most other parts of the delta, which are already protected from salinity intrusion by existing water control infrastructure, increments in maximum salinity are relatively smaller, not exceeding 1 ppt. Where catfish rearing has expanded toward the coast, in Vinh Long and Ben Tre provinces, it is possible that the ponds may be exposed to slightly higher salinity levels.

Table 27 shows the types of agricultural and aquaculture land use that may experience increases in maximum salinity levels exceeding 4 ppt under the 50-cm SLR scenario. Substantial areas of irrigated and rainfed rice or rice-aquaculture may be affected in this way. While this would be bad for rice production, it represents an opportunity to extend either the period or the area of brackish-water aquaculture in the Mekong River Delta.

TABLE 27 LAND USE TYPES THAT WILL BE SUBJECTED TO > 4 PPT MAXIMUM SALINITY INTRUSION IN THE DRY SEASON UNDER 50-CM SLR SCENARIO

Land use category	*Area (000 ha)*
Irrigated rice	159
Mangrove	66
Mangrove + shrimp pond	77
Rainfed rice	190
Rice-aquaculture	83
Shrimp pond	384

Economic Analysis of Adaptation

The economic analysis of adaption to climate change in aquaculture focuses on the two main export-oriented activities in Vietnam—freshwater catfish (in particular the tra catfish, *Pangasianodon hypophthalmus*) and brackish-water shrimp (in particular the black tiger shrimp, *Peneaus monodon*). For catfish, the analysis focused on the pond culture system, since about 95 percent of catfish are now cultured in ponds. For shrimp, the economics of production focused on the black tiger shrimp, which is the dominant species, although the Pacific white leg shrimp (*Litopenaeus vannamei*) has recently been introduced into the Mekong River Delta. The classification of production systems used in the vulnerability analysis is retained in considering adaptation.

The main steps in the economic analysis are shown in Figure 9. Steps 1 to 3 were conducted at the farm level for the four production systems. Adaptation measures undertaken at the farm level in response to the impact of climate change are mainly autonomous in nature. For Step 4, the analysis was conducted at the industry level for the Mekong River Delta to estimate the overall costs of adaptation measures. Step 5 deals with planned adaptation measures undertaken beyond individual farms, and are mainly government-initiated and funded. Many of these planned adaptation measures, such as building protective sea and river dikes, will serve various purposes, of which adaptation for the aquaculture sector is only one.

FIGURE 9 STEPS IN THE ECONOMIC ANALYSIS

STEP ONE	FARM-LEVEL COSTS AND EARNINGS FOR FOUR PRODUCTION SYSTEMS (TWO CATFISH, TWO SHRIMP)
STEP TWO	EXPERT ELICITATION: CHANGE IN LAST TEN YEARS, PERCEPTIONS FOR THE NEXT TEN YEARS AND ATTRIBUTION TO CLIMATE CHANGE IMPACTS
STEP THREE	DIRECT COSTS PLUS **AUTONOMOUS ADAPTATION** COSTS, AND BENEFITS, AT FARM LEVEL FOR THE NEXT TEN YEARS AND BEYOND TO 2050
STEP FOUR	SCALE UP TO INDUSTRY LEVEL TO ASSESS COST IMPLICATIONS FOR AQUACULTURE
STEP FIVE	BENEFITS TO FARMERS DUE TO **PLANNED ADAPTATION** MEASURES UNDERTAKEN BY THE GOVERNMENT

The economic impact of climate change at the farm level. The results generated at Steps 1 and 2 of the analysis must be interpreted very carefully. They are not projections for the future profitability of different aquaculture systems. Instead they are intended to provide a baseline for assessing (a) the net impact of climate change on future profitability, and (b) the viability of various options for autonomous and planned adaptation to offset the impact of climate change. The baselines for the next decade to 2020 reflect general perceptions about changes to the catfish and shrimp sectors in the near future. For the period after 2020, the baseline relies on fairly simple extrapolation of long trends. In reality, there is a large amount of uncertainty about demand for seafood, input prices, and other costs of production. Thus, the only relevance of the baseline is to provide a starting point for the analysis of climate change.

Catfish. The direct impact of climate change on net income from both inland and coastal catfish farming is strongly negative. Without adaptation, the net income from inland catfish production may fall by 3,000 million VNĐ per ha in 2020 as a consequence of climate change. This reduction may nearly treble by 2050 (Figure 10). If this analysis of the impact of climate change is even roughly correct, autonomous and planned adaptation is critical for the future success of the industry.

Shrimp. The direct impact of climate change on net income from both extensive and (semi-) intensive shrimp farming is negative, more strongly so for extensive farming. Without adaptation, the net income from (semi-)intensive shrimp production may fall by 130 million VNĐ per ha in 2020. This reduction may increase to 950 million VNĐ in 2050 (Figure 11). Again, adaptation to climate change is critical for the future success of the industry.

Autonomous adaptation. The primary options for autonomous adaptation whose costs can be estimated are (a) the replacement or upgrading of pond dikes to reduce the extent of flooding and saline intrusion, and (b) additional expenditures on electricity and fuel to maintain water levels and salinity in ponds. However, these are only part of what is likely to be a much larger response to climate change. A combination of selective breeding programs with changes in farming practices should permit the farming of catfish species that can tolerate higher levels of salinity. Funding the breeding programs would fall to the government as an aspect of planned adaptation, but the adoption of different species and the modification of farming practices will fall to those responsible for managing aquaculture operations.

It is important to recognize that autonomous adaptation will not take place in isolation from other changes. The scale of the aquaculture sector has increased more than 5 times over the last decade. If it is to continue to grow, it will face a variety of challenges that will require changes in farming practices, marketing, investment , and many other activities. Autonomous adaptation should be seen as one aspect of a much broader process by which the sector reaches maturity after a period of quite exceptional growth. While some of the specific costs of autonomous adaptation may be identified for analytical purposes, the reality will be one of continuing change in response to a wide variety of economic, physical, and climatic factors, in which the specific role of adaptation to a changing climate may be difficult to distinguish from other factors.

FIGURE 10 REDUCTION IN NET INCOME FROM CATFISH FARMING DUE TO CLIMATE CHANGE WITHOUT ADAPTATION (VNĐ MILLION PER HA)

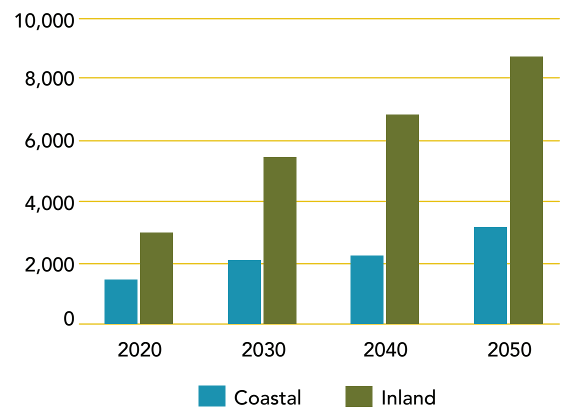
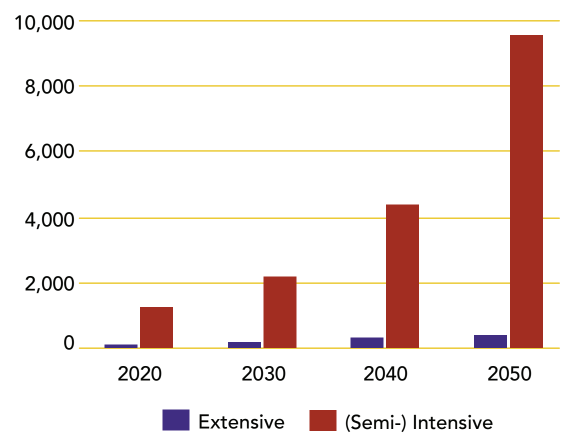


FIGURE 11 REDUCTION IN NET INCOME FROM SHRIMP FARMING DUE TO CLIMATE CHANGE WITHOUT ADAPTATION (VNĐ MILLION PER HA)



Catfish. On current trends, catfish farming faces an uncertain future because gross revenues may not keep pace with the increase in input costs, particularly for feed, which constitutes the largest cost. Only the most efficient and adaptable farmers may be able to survive such a squeeze on farming margins, which are currently in the 3–5 percent range. The additional costs of adapting to climate change will intensify this squeeze, but they will also reinforce the benefits of "no regrets" strategies, which will increase margins and enable operators to underwrite the costs of adaptation. Such strategies include:

- Improving feed conversion ratios by the development and adoption of better practices, including breeding, feed formulation, and disease control.

- Consolidation of the value chain by vertical integration. Transferring the very high margin from retailers in importing countries and export processing companies to farmers either through actions by the companies and/or the retailers—that is, market responses to maintain the supply to meet growth in demand—or by government intervention will increase both the incentive and capacity of aquaculture operators to adapt to climate change.

The catfish industry is more heavily capitalized than the shrimp industry, making restructuring of the sector and quick response from medium- or large-scale farmers to salinity intrusion and floods possible with the right market (demand) and government incentives. To the extent that dike construction to mitigate river and coastal flooding or saline intrusion provides ancillary benefits to agriculture and other sectors, then adaptation costs borne by the aquaculture sector could be significantly lower. At the moment, however, there appears to be no mechanism for either assessing or sharing the joint benefits of such infrastructure. This is a matter that deserves further investigation and consideration in the future.

Shrimp. Current trends for shrimp production are not as unfavorable as those for catfish farming. Having had a longer history, the shrimp industry is relatively better established and more stable. The extensive shrimp system is less profitable but has a lower impact on the environment, so it may be particularly important for small-scale farmers.

Overall, it is likely that inland catfish farmers will experience the highest costs in adapting to the increased risks of floods and salinity intrusion. While costs for shrimp systems overall are likely to be lower, the cost of water pumping in semi-intensive/intensive systems will increase significantly. Water exchange and pumping of water is not practiced in extensive systems to the same high level as with semi-intensive/intensive systems for all systems. Since the industry is both capital-intensive and growing rapidly, adaptation is likely to be autonomous with the costs borne by operators. The total cost of adaptation is estimated at an average of $130 million per year from 2010–50, which is equivalent to 2.4 percent of total costs.