Sustainable Growth Strategies for Indian Shrimp Industry: A Multiple Perspective

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1. Introduction

The Indian Shrimp Industry plays an important role in the Indian economy, generating annual foreign exchange of US$ 1,000 million during 2006–07 (MPEDA, 2007), enhancing the farm employment by 2–15%, and contributing handsomely to the economic development in the coastal regions (Vasudevappa and Seenappa, 2002, Walker and Mohan, 2009). However, the Industry has shown a peculiar growth of fast rise (1990–1994), sudden decline (1995–1997), slow revamp (1998–2004), and re-decline (2005–2009) in terms of production, export, area under cultivation, and yield (Figure 1). The fluctuating growth behaviour of the Industry has generated various unintended issues like social allegation against shrimp farming, environmental degradation, economic loss to investors, and uncertainty in cash flows of producers (Vasudevappa and Seenappa, 2002). The persistent production uncertainty of the contemporary periods is a challenge for the Industry's sustainability. Keeping in view the Industry's sustainability in the future, the current research was carried out to design candidate strategies for the Industry by using popular methods of Porter's Five Forces Model and Delphi survey, testing them in a system dynamics model framework to generate various scenarios, and recommending viable sustainable growth strategies for the Industry.

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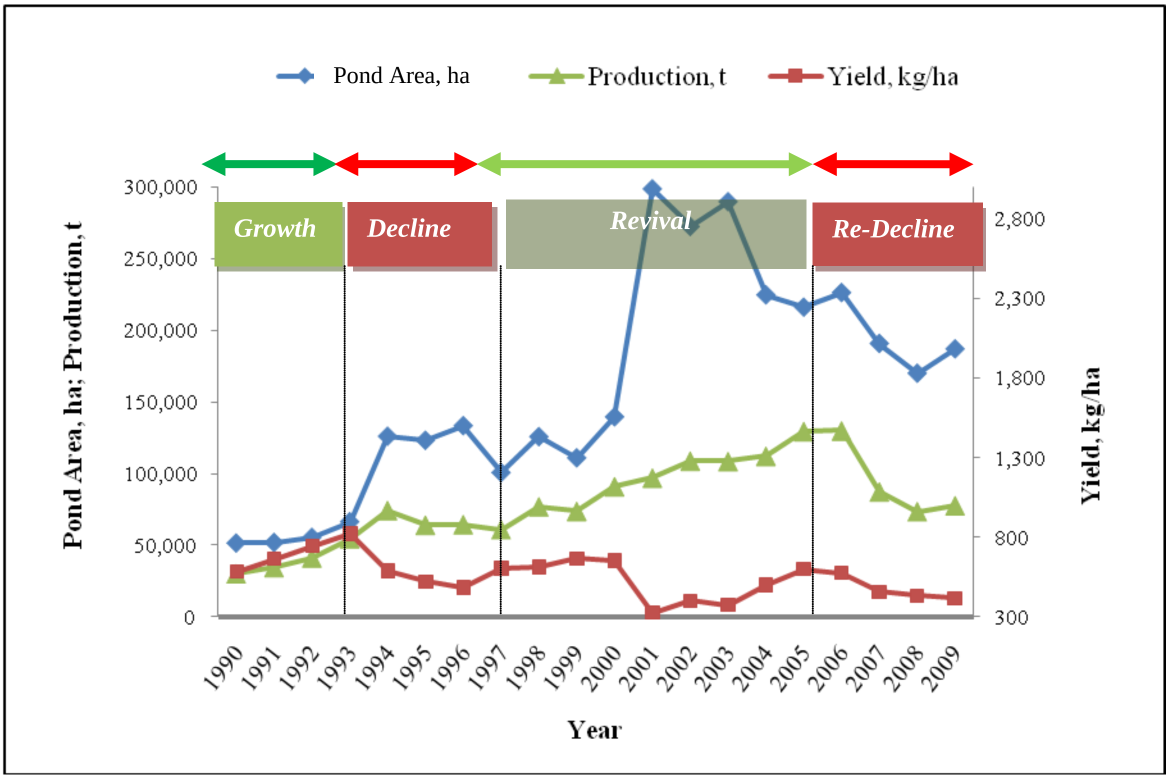

Figure 1: Growth of Indian Shrimp Industry (Pond Area, Production, and Yield)

(Source: Ganapathy and Viswakumar, 2001; Muralidhar *et al.*, 2010, Seafood Export Journal, 2009)

2. Methodology

Designing and planning for strategy have been widely discussed in strategic planning literature (for example, Chakravarthy, 1987; Mintzberg, 1993; McKiernan and Morris, 1994; McDonald, 1996; Wright, 1996; Hopkins and Hopkins, 1997; Proctor, 1997; Hewlette, 1999; O'Regan and Ghobadian, 2002). According to Chakravarthy (1987)**,** centralized involvement of different units of an organization and decentralized adoption of innovations by these units are essential components in an effective strategic planning process. However, small and medium firms fail to envision a holistic approach in the strategic planning process (McKiernan and Morris, 1994). Many strategic plans have failed in the implementation stage. Such failures are reported due to the lack of a formal strategic planning process (O'Regan and Ghobadian, 2002). For setting of goals, a centralized top-down approach has to be followed in the organization involving people of different units in the organization. Hamel and Prahalad (1989) have suggested that the engagement of stakeholders of the organization is necessary in order to analyze the challenges, set the goals and review the outcomes. Stave (2002) cited how use of system dynamics, through group model building process, can ensure the participation of stakeholders in taking environmental related decisions. The participation of stakeholders and use of system dynamics help in defining the problems, understanding their causes, and focusing on policy levers. In the context of aquaculture industries, Sevaly (2001) has specifically remarked that the involvement of stakeholders in strategy-making, planning, and management would lead to more realistic and effective strategies and improve their implementation. Linstone and Turoff (2002) are of the view that Delphi survey, a method of structuring a group communication process, which can involve the group as a whole in decision and strategy making process. Delphi survey has been used for setting goals, finding problems, forecasting, developing system models, *etc.* A theoretical background of the strategy making process defines five distinct approaches to strategy formulation (Babuto, 2002). They are: *autocratic*, *transformational*, *rational*, *learning*, and *political* approaches. A synthesis of these five approaches in addition with considering the role of top manager, understanding the environmental factors, and aligning the organizational goals would lead to an efficient strategy making process for designing strategies for organizations and industries.

We followed a three-prong approach to develop candidate strategies for the Indian Shrimp Industry that represents a judicious synthesis of *transformational*, *rational*, *learning*, and *political* approaches. First, a list of candidate strategies was developed through *Industry Analysis* using *Porter's Five Forces* model. Second, using the *Delphi* survey methodology, we developed a second list of candidate strategies through the participation of 40 stakeholders of the Industry. Third, the third list of the strategies was developed by analyzing the past behavior of the Industry in a *System Archetypical* framework. This three-way approach to the strategy formulation has helped us in analyzing the Industry from a macro-perspective, ensuring the participation of stakeholders in the strategy formulation, and capturing the dynamic characteristics among the critical factors of the Industry, and in generating a comprehensive strategy set (Figure 2).

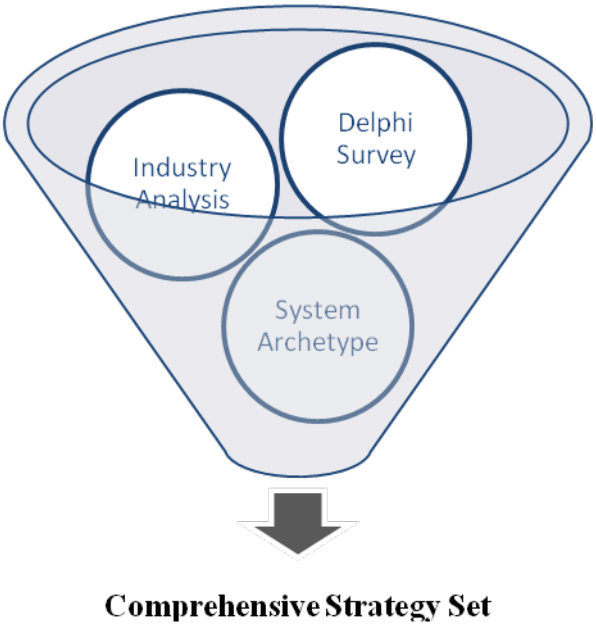

Figure 2: A Framework for Comprehensive Strategy Formulation

3. Candidate Strategies

A candidate strategy is defined as an action or a set of actions that, when implemented, can help in achieving a desired organizational objective. Three sets of such candidate strategies have been developed using the above-mentioned approach.

3.1. Strategy Formulation Using Industry Analysis

The Industry analysis using *Porter's Five Forces* model (Porter 2008) is widely used to develop strategies for organizations and industries. We have used the same model to develop a first list of candidate strategies for the Industry. Using such a five-force framework, the contemporary position of the Industry is evaluated vis-á-vis its competitors in respect of the five forces—*bargaining power of suppliers, bargaining power of customers, threat of new entrants, threat of substitutions,* and *degree of rivalry.* A Porter's Five Forces model portraying the competitive position of the Industry is presented in Figure 3.

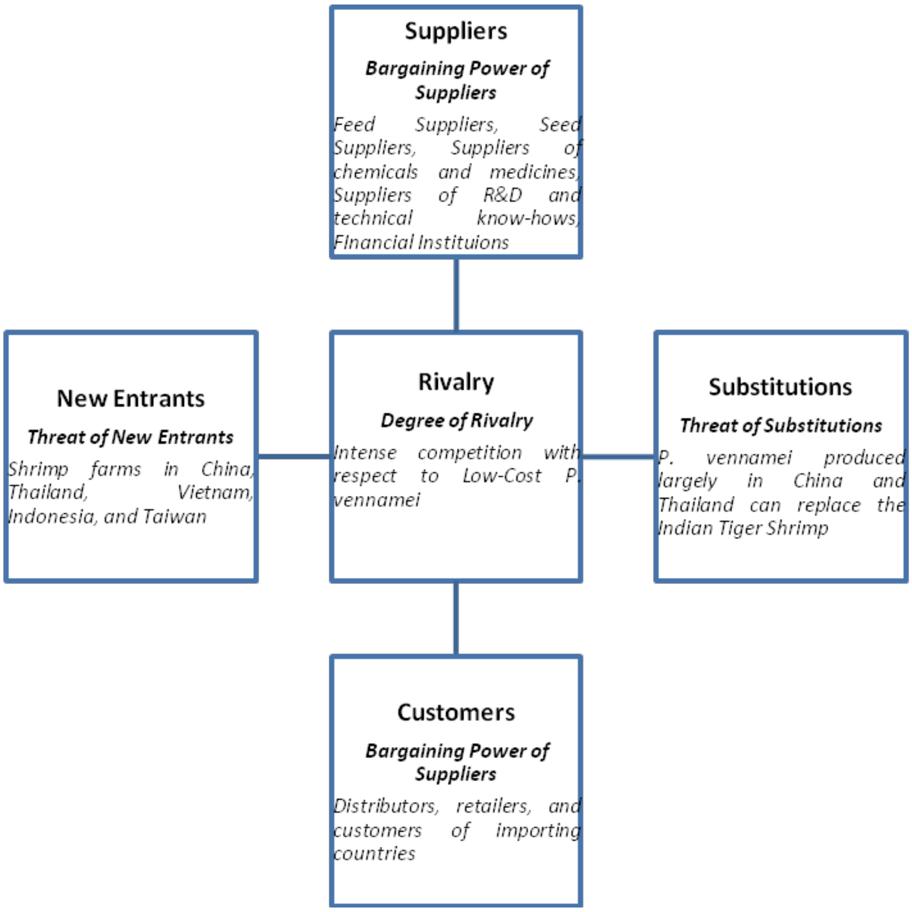

Figure 3: Porter's Five Forces Model of the Industry

The contemporary position of the Industry vis-á-vis its probable competitors was analyzed and a list of candidate strategies was developed so that they would enhance the competitiveness of the Industry by countering five competitive forces. The strategies call for: (1) adopting group approach to shrimp farming, (2) ensuring financial readiness and security to the producers, (3) producing and exporting Value-Added Products of shrimp, (4) increasing transparency and efficiency of value-chain, (5) aggressive marketing of Indian shrimp in the export markets, (6) technological applications across the Industry's operations, (7) producing shrimp brood-stock in laboratory, (8) field-testing and adopting P. *vennamei* species in the Indian conditions, (9) exclusively zoning area for shrimp farming, and (10) providing institutional support to shrimp farming.

3.2. Strategy Formulation Using Delphi Survey

When the boundary of a strategy-making process encompasses more than one sector, or the organization belongs to a class of un-organized small scale enterprises, or when the performance of the enterprises is influenced by natural phenomena and frequent government interventions, strategic planning becomes a challenging process. Indian Shrimp Industry presents such a case, where various stakeholders from different sectors of the Industry need to be pulled to participate in a strategic planning process. To ensure their participation in the strategy making process, we conducted a Delphi survey. Forty individuals drawn from different shrimp producing states of the country with various domain expertise (like farmers, processing house owners, exporters, scientists, NGOs, and government officials) participated in the survey.

The survey was conducted in two-phases. In the first phase, the survey participants were asked to elicit the long-term *goals* and short-term *objectives* the Industry should aim at, and the appropriate *strategies* the Industry should follow to achieve them. In the second phase, they were asked to rate the *desirability* and *feasibility* of meeting the *goals* and the *objectives* of the Industry, and *effectiveness* and implementation *feasibility* of the *strategies* to achieve the desired *goals* and *objectives.* The consensus of opinions of the participants on the above-stated criteria were mathematically derived, which enabled us to generate a second list of candidate strategies suitably aligned with the *goals* and *objectives.* Such a way of generating candidate strategies was advantageous in two ways: (1) encompassing wide sources of opinions of stakeholders from various domains and (2) ensuring the alignment of candidate strategies with the *goals* and *objectives* of the Industry.

The second list of strategies helped us to conclude the following:

1. Farmers must be adequately trained on modern methods relevant to operations and management of shrimp production, processing, and marketing.
2. Sufficient innovation on the Industry has to be done through investment in R&D.
3. There has to be strict enforcement of quality regulations on the shrimp production and shrimp processing processes.
4. The Industry should adopt P. *vennamei* as a substitute for the P. *monodon* (Indian Black Tiger shrimp).

3.3. Strategy Formulation Using System Archetype

In order to test the viability and effectiveness of the candidate strategies derived from the Industry analysis and the Delphi survey, they were further analyzed in a *System Archetypical* framework of the Industry. The archetype was built based on the generic archetype structures proposed by Wolstenholme (2003; 2004). The system archetypical structure depicts the dynamic relationships among the key factors of the Industry and verifies the Industry's past growth behaviour and hence becomes trustworthy for designing sustainable strategies for the future. The Industry archetype consists of three broad feedback loops, namely *Acting, Limiting,* and *Learning* loops, acting independently in three hypothetical sectors of the Industry—Production, Environmental, and Institutional. The archetypical structure of the Industry is shown in Figure 4. The dotted lines connecting the *Production* sector and the *Institutional* sector and connecting the *Environmental* sector and the *Production* sector are two causal links, defined here as sustainable links (S-Links) that are necessary to avoid the unintended consequences of the strategies.

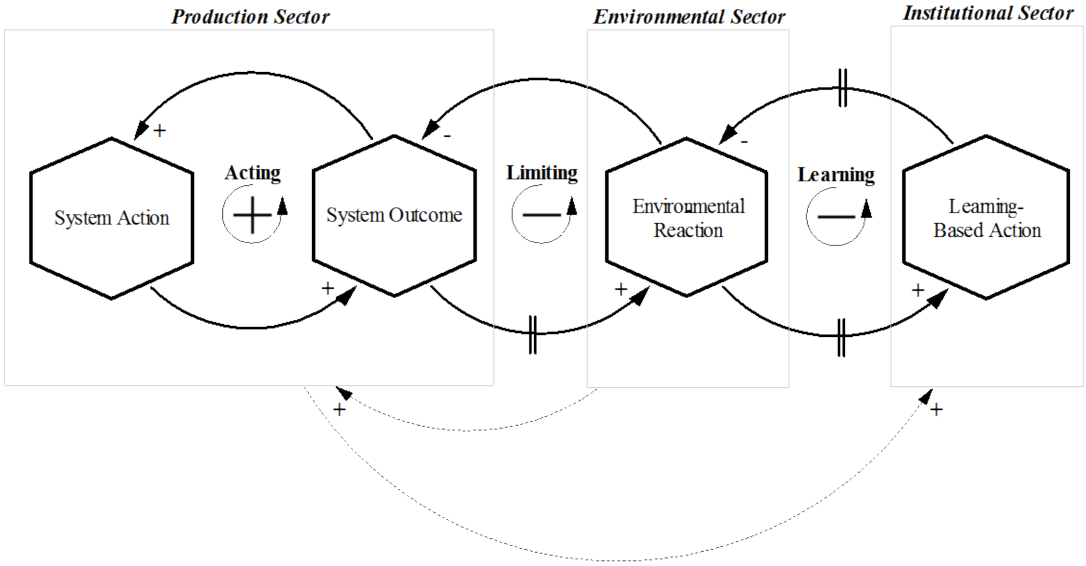

Figure 4: Framework of Three-Loop Archetype for the Industry

The key factors pertaining to the *Production* sector are: *Yield* (kg/ha), *Intensity* of culture (shrimp/ha), and *Area under Cultivation* (ha). The amount of shrimp production (kg) in the Production sector is the Industry outcome that generates profits for the producers and motivates them to continue cultivation in the *Production* sector generating the *Acting* feedback loop to work. *Area under Cultivation* and the *Intensity* of culture, the other two outcomes of the Production sector, also generate pollution that accumulate in the *Environmental* sector of the Industry. When the accumulation pollution crosses the limiting conditions, the production of shrimp in the *Production* sector is negatively affected. This dynamic interaction between the *Production* and the *Environmental* sectors gives rise to a negative feedback loop defined as the *Limiting* Loop that opposes the growing action of the *Acting* Loop, limits the growth of the Industry in the late nineties, and causes production crash and overall decline of the Industry. The experiential learning of the actors in the *Institutional* sector (Government) from the growth and decline behaviour of the Industry help them to take measures to contain or even reduce the level of pollution in the *Environmental* sector. Thus, a balancing feedback loop is created between *Environmental* and *Institutional* sector, defined as *Learning* Loop, that helps in reducing the level of pollution elements and prevent it reaching the critical point. A detailed causal model representing the Industry's archetype is presented in Figure 5.

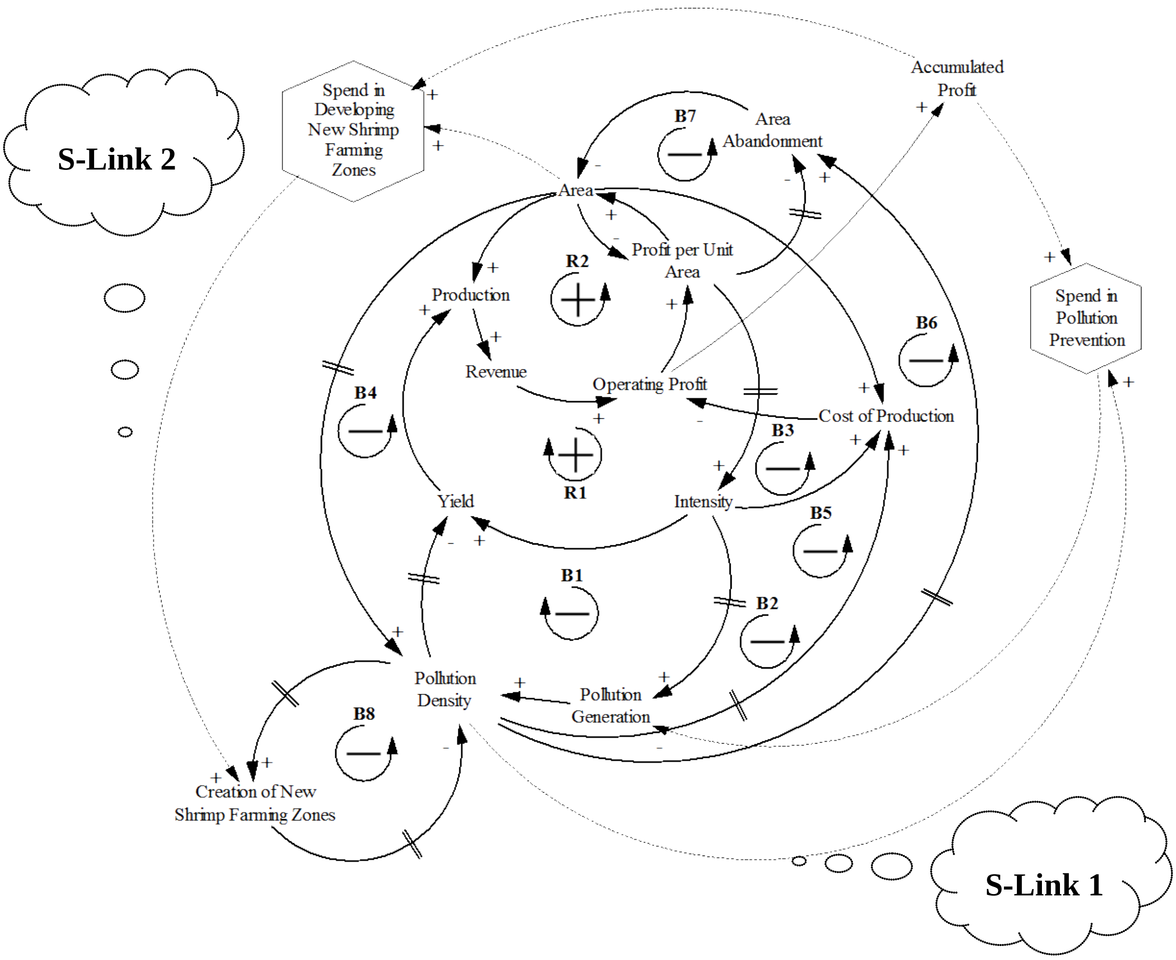

Figure 5: Three-Loop Archetype of the Industry with Its S-Links

In Figure 5 the positive feedback loops, R1 and R2, belong to the class of the *Acting* Loop (Figure 4). Handsome profit derived from shrimp farming excites the producers in increasing *Intensity* of culture and getting higher *Yield* and profit per unit area (R1 loop). A notable assumption here is that most of the shrimp produced are exported with considerable profit margin at the farm site itself due to the huge demand of shrimp in the export market (countries like US, EU, and Japan). Shrimp export generates foreign money for the country that influences the Government to initiate various promotional actions like providing land lease, providing subsidy, supporting with technical know-hows, organizing meetings and seminars, exempting/reducing export duties from shrimp, *etc.*, which increase the *Area* under shrimp cultivation, thus initiating the R2 loop.. During the initial growth period of the Industry (1990–1994) both the R1 and R2 loops were driving the growth of the Industry.

The limit to growth of the Industry started as the family of *Limiting* loops became stronger against the growing actions of the *Limiting* Loops. The feedback loops, B1, B2, B3, B4, and B5 belong to the family of the *Limiting* Loops. The B1 balancing loop starts as the pollution elements are generated due to *Intensity* of culture, which, after a certain time delay, reduces *Yield.* The producers' investment in pollution prevention activities reduces the *Profit per Unit Area* creating the B2 balancing loop. The variable cost of production increases in a non-linear fashion as the intensity level of culture increases, which creates the B3 balancing loop trying to balance *Profit per Unit Area.* As the *Area* under shrimp cultivation increases more farms are clustered in a particular geographical area, discharging more pollutants to the nearby water sources. Water intake from those polluted water sources increases the pollution level in a farm which, in turn, reduces yield, creating the B4 and B5 balancing loops that try to reduce the expansion of the Industry.

The domino effect of the *Limiting* Loops generates two balancing feedback loops, B6 and B7, and causes abandonment of polluted shrimp farms and withdrawal of producers from the shrimp culture business due to low yield and declining profit margin. These domino loops were responsible for the decline of the Industry during 1994–1997.

The growth and decline behaviour created by the successive actions of the *Acting* Loops and the *Limiting* Loops acted as an eye opener for the policy makers. Appealed by the unintended consequences of the growth and subsequent decline behaviour of the Industry, they initiated various damage controlling actions like creating new shrimp farming zones so that clustering of shrimp farms could be avoided. This actions by the policy makers are explained by the B8 feedback loop, defined as the *Learning* Loop. The B8 loop reduces the pollution intensity level of the Industry and pulling the Industry to the normal state after 1997.

From a systemic analysis of the Industry's past growth we understood that the successive growth-decline-revival behaviour of the Industry was due to: (1) Overexpansion and inability of the policy makers to foresee the negative effect of it and (2) Time delay in learning by the policy makers and taking subsequent revival actions. In order to avoid repetition of such phenomenon in the future we have proposed two S-Links (Sustainable Links as shown by dotted lines in Figure 5).

The links carry out the following functions:

1. Use the signals from the *Environmental Sector* to the *Production Sector* in order to take simultaneous actions for growth of *intended consequences* in *Production Sector* and for minimizing the *unintended consequences* in the *Environmental Sector*; and

2. Connect the signals of *outcomes* in *Production Sector* to the *actions* in the *Institutional Sector* in order to synchronize the actions in both *Production* and *Institutional Sectors.*

The Industry archetype represents the causal structure of the Industry. It can be used as an instrument to design future sustainable strategies. The first S-link helps the actors in taking various actions to reduce the generation of *pollution* in the *Environment* sector. The second S-link reflects the *learning-based strategic actions* by the actors in the *Institutional* sector to reduce generation of pollution in the Environment sector.

S-Link 1 connects the *profit per unit area* to the *pollution generation* through the "*spend in pollution prevention*". Based on this link, we propose the following sustainable strategies for the actors in *Production* sector:

1. Invest a fraction of the *profit per unit area* in adopting various pollution prevention strategies.

2. Contribute a fraction of the *profit per unit area* towards the development of R&D for minimizing pollution generation during shrimp production processes.

S-Link 2 passes a positive signal from the *pollution density* to the *creation of new shrimp farming zones.* Based on this link, we propose the following sustainable strategies for the *actors* in the *Institutional* sector:

1. Explore and develop new shrimp farming zones for expansion.
2. Follow a stringent license and renewal-of-license strategy for the new producers and the old producers respectively.
3. Regulate and control the rapid development of shrimp farms in every shrimp-farming zone.

4 Strategy Formulation

The strategies derived in the previous sections are collated into four pure *functional* sets based on their intent: (1) *Production Strategy,* (2) *Environmental Strategy,* (3) *Financial Strategy,* and (4) *Marketing Strategy* sets. The individual strategies of each strategy set are presented in Figure 6 through Figure 9. The *Production Strategy* set improves *Yield* and *Area under Cultivatio;*. The *Environmental Strategy* set reduces the negative effect of shrimp farming on environment; the *Financial Strategy* set improves the profitability of the shrimp farming business, and the *Market Strategy* set improves the marketing aspects of the Industry.

In order to test the effectiveness of each pure functional strategy groups on the behaviour of the Industry, a system dynamics model of the Industry was developed based on the system archetypical structure (Figure 5).

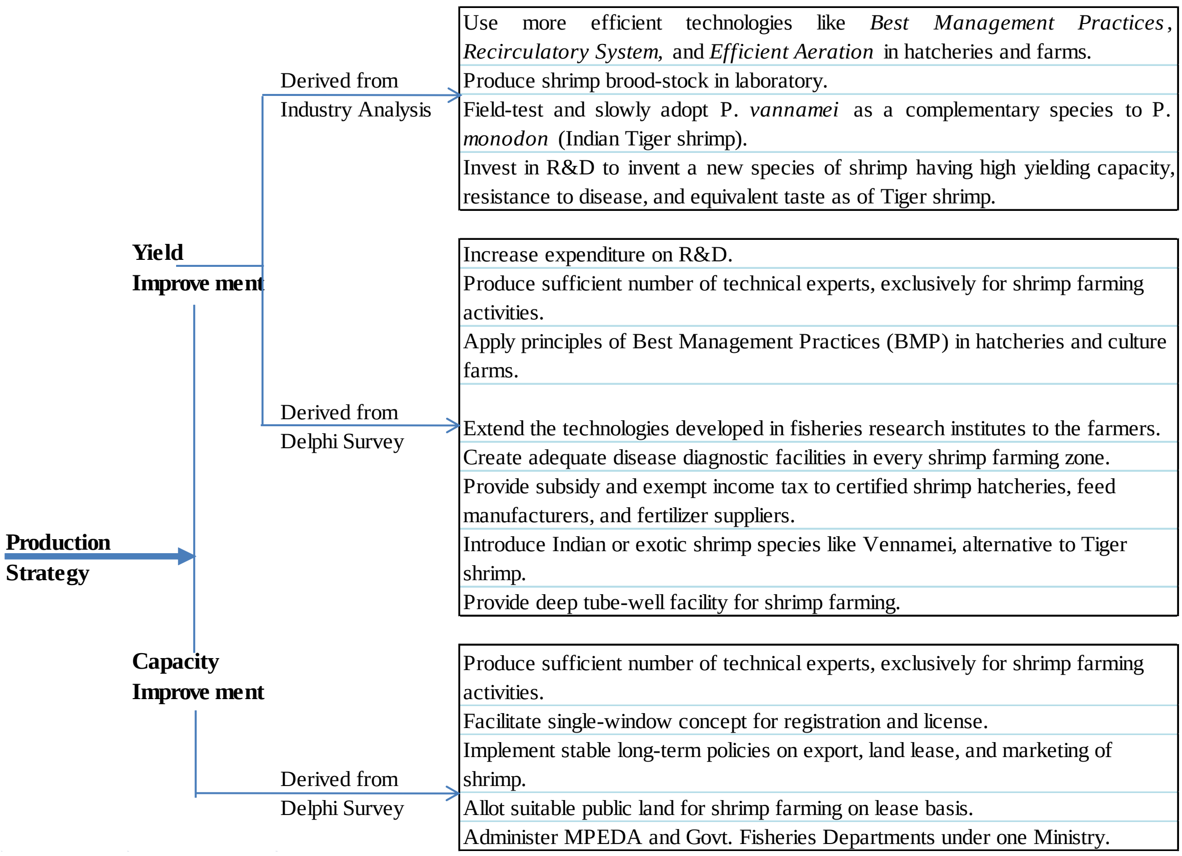

Figure 6: Production Strategy Set and Its Individual Strategies

Environmental Strategy

Derived from Industry Analysis

- Use more efficient technologies like *Best Management Practices*, *Recirculatory System*, and *Efficient Aeration* in hatcheries and farms.
- Promote *organic* shrimp farms.
- Adopt *group approach* to shrimp farming and form shrimp farmers' co-operatives and aqua-clubs.

Derived from Delphi Survey

- Increase expenditure on R&D.
- Educate farmers with advanced technologies for reducing environmental impact
- Apply principles of Best Management Practices (BMP) in hatcheries and culture farms.
- Extend the technologies developed in fisheries research institutes to the farmers.

Figure 7: Environmental Strategy Set and Its Individual Strategies

Financial Strategy

Derived from Industry Analysis

- Share true price of shrimp and maintain proper co-ordination among the players of the value chain.
- Reduce middle-men effect across the value-chain of shrimp.
- Produce and export of Value-Added Products of Indian Tiger shrimp.
- Create the domestic market for the Indian Tiger shrimp.
- Supplying Indian Tiger shrimp to other countries and places, where shrimp supply from other countries are not there.
- Adopt *group approach* to shrimp farming and form shrimp farmers' co-operatives and aqua-clubs.
- Provide insurance against the crop failure.
- Provide short-term credit through banks.

Derived from Delphi Survey

- Provide adequate financial support to shrimp farming as it is provided to agriculture.
- Provide price information to farmers.
- Invite FDI and private companies to value-added production sector.
- Reduce number of intermediaries in shrimp supply chain.
- Distribute low cost inputs such as feed, seed, fertilizer, water, energy, etc. through co-operatives.
- Provide 50% subsidy for investment in value-added production firms.
- Facilitate buy-back arrangement at farm site through MPEDA or large exporters.
- Invite other corporate firms in India to set up/invest in value-added shrimp production firms

Figure 8: Financial Strategy Set and Its Individual Strategies

Marketing Strategy

Derived from Industry Analysis

- Position Indian Black Tiger shrimp separately through advertising it as a high-valued product (for its taste and quality) and create a high-end customer base.
- Implement product tracking system across the value chain.
- Identify and register the suppliers of drugs and chemicals.

Derived from Delphi Survey

- Set up a distribution chain, like cold-chain facilities, for domestic market.
- Promote non-traditional export markets other than US, EU, and Japan.
- Implement stable long-term policies on export, land lease, and marketing of shrimp.
- Invite FDI and private companies to value-added production sector.
- Pursue aggressive marketing of Indian shrimp at export market.
- Label the shrimp product along its value-chain, starting from farm-site.
- Intensify efforts to finalize international agreement on world shrimp price and country-export quota.
- Supply shrimp at a cheaper rate to domestic market.

Figure 9: Marketing Strategy Set and Its Individual Strategies

5 System Dynamics (SD) Model of the Industry

The Industry archetype discussed earlier captures the feedback relationships among the key factors of the Indian Shrimp Industry. A system dynamics model is now developed for the shrimp industry on the basis of these fundamental feedback relationships.

5.1. *Model Objectives*

The basic objectives of the model are as follows:

1. Explain the dynamic behavior of the Industry during the *growth, decline,* and *revival* phases.
2. Identify the parameters to the changes in which the Industry behavior is very sensitive.
3. Experiment with the model to evaluate the *effectiveness* of the candidate strategies.
4. Design robust strategies for sustainable growth of the Industry.

5.2. Problem Identification

The unstable growth behaviour of the Shrimp Industry in the past reflects the problem the Industry is facing. Figure 1 that depicted the the *growth-decline-revival-and-re-decline* phases of the Industry's past growth is the reference mode of the model.. *Pond Area, Production*, and *Yield,* whose behaviours are shown in Figure 1, are the considered as the *key variables* of the model.

5.3. Model Boundary

The model was built on the basis of the causal model of the Industry derived in the Section 3.3. The variables included in the model have both long- and short-term implications. The variables like *Yield*, *Intensity,* and short-term profit indicators have short-term implications, whereas *Accumulated Pollution, Area under Cultivation*, Long-term profit indicators, and number of shrimp farming zones have long-term importance. All these variables pertain to the *farm domain* of the Industry. It is assumed that all the shrimp produced are either exported or sold in the domestic market.

The model is divided into three major sectors, namely *Production, Environmental,* and *Institutional*. The *Production* sector consists of two sub-sectors: *Culture* and *Capacity.* The *Culture* sub-sector models *Yield*, and the *Capacity* sub-sector models *Area under Culture.* The *sectoral overview diagram* of the Industry is presented in Figure 10.

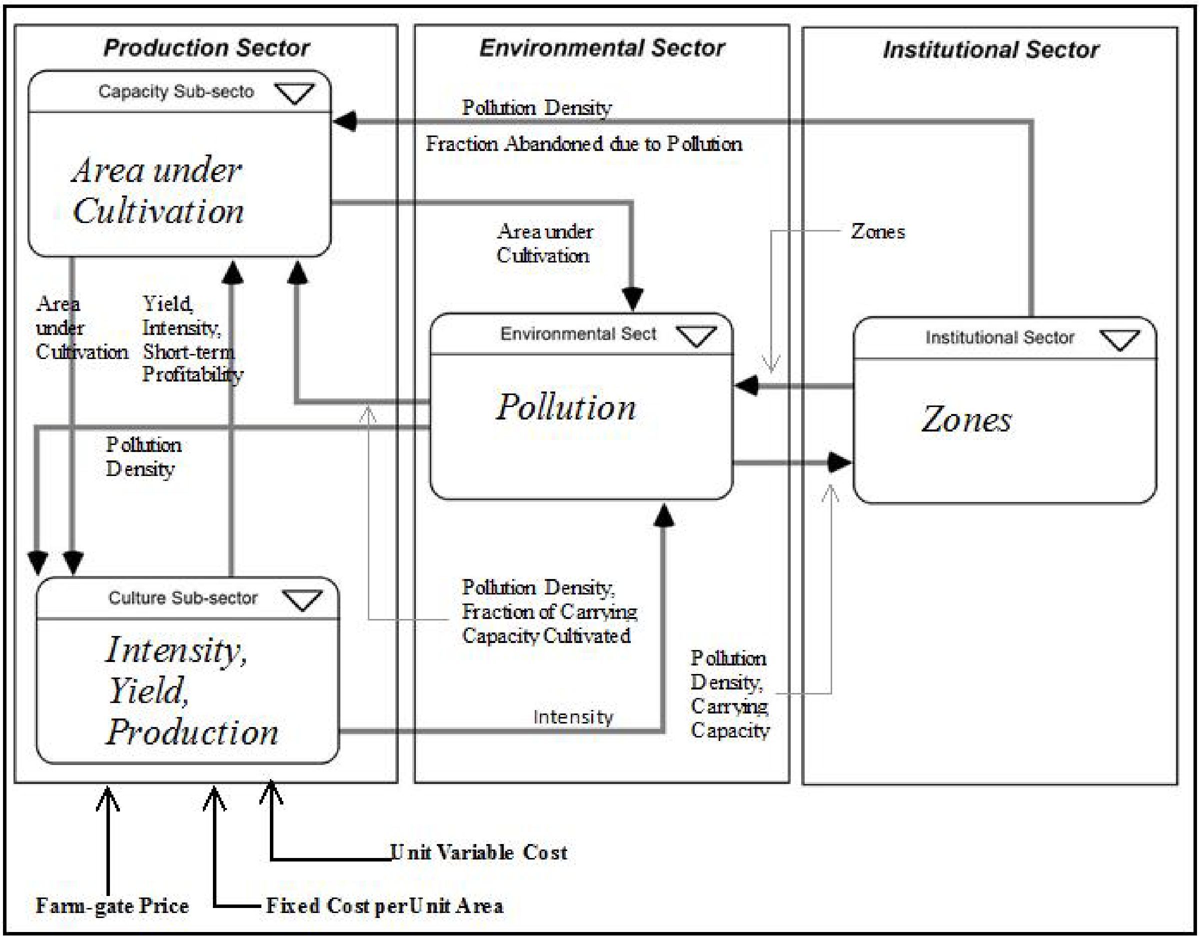

Figure 10: STELLA 5.0 Software Generated Sectoral Diagram of the Industry

The *sectoral overview diagram* displays interconnections among the sectors through physical and information flows. The physical flows include the flow of *pollutants* between the *Production* sector and the *Environmental* sector, the flow of shrimp from the *Culture* sub-sector to the *market domain* and the flow of money and price information from the *market domain*, to the *Capacity* sub-sector. The *pollution* information flows from the *Environmental* sector to the *Institutional* sector. The *pollution* information flow helps the actors in the *Institutional* sector to extend shrimp farming activities to newer zones in order to avoid clustering of farms in a particular zone. Information on zonal diversity is used in the *Production* sector to compute annual shrimp production.

5.4. *Model Structure*

The stock-flow structure of the SD model is built on the STELLA 5.0 software platform. The current section presents the decision structure diagram of each sector representing the major *level* and *rate* variables and their dynamics.

5.4.1 Structure of the Production Sector

Capacity Sub-sector

The *Capacity* sub-sector (Figure 11) deals with the dynamics of total pond area under cultivation. Investment in developing new shrimp farms is a long-term decision of the producers and the new investors. The decision regarding the new area development depends upon the long-term profit expectation from the shrimp business. Figure 11 explains the major variables defining the flow rates that control *Area under Cultivation.*

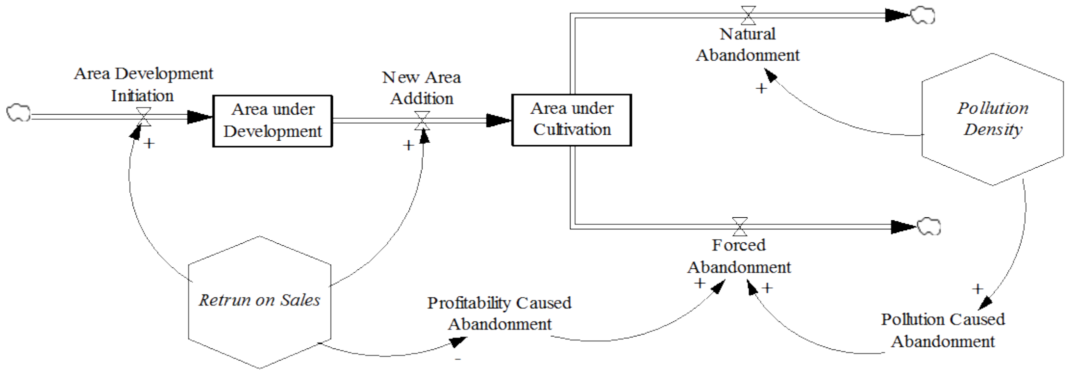

Figure 11: Decision Structure Diagram of *Capacity* sub-sector

There are four rate variables and two level variables in the *Capacity* sub-sector. *Area Development Initiation* and *New Area Addition* control the increase rate of *Area under Development* and *Area under Cultivation* respectively and are dependent on *Return on Sales*, an indicator for long-term profitability. As *Return on Sales* increases, new producers join the shrimp culture business and old producers expand their activities. In both the cases new ponds are constructed and hence *Area under Cultivation* increases. Flow rates, *Natural Abandonment* and *Forced Abandonment*, reduce *Area under Cultivation. Natural Abandonment* is dependent on *Pollution Density.* The *Pollution* density represents the concentration of pollutants in the shrimp farms. Intense pollution level in the pond ecosystem reduces the productivity of the ponds making them unfit for the shrimp production.

Forced Abandonment is caused by *Return on Sales* and *Pollution Density*. When *Return on Sales* falls because of a fall in the market price or a rise in the cost of production, the producers quit shrimp culture business, thus reducing the level of *Area under Cultivation.* Also, as the pollution level of the Industry increases, the Government enforces stringent regulations because of which producers often quit shrimp farming (*Forced Abandonment* rate).

Culture Sub-sector

The dynamics of *Yield* depends on two variables: Intensity and Pollution Density. Figure 12 presents the decision structure diagram of the *Culture* sub-sector. *Intensity* of culture (Number of shrimps to be cultured in a pond) is a decision taken by the producers based on their short-term profit expectation (*Ratio of Contribution Margin to Sales*) from the shrimp production business.

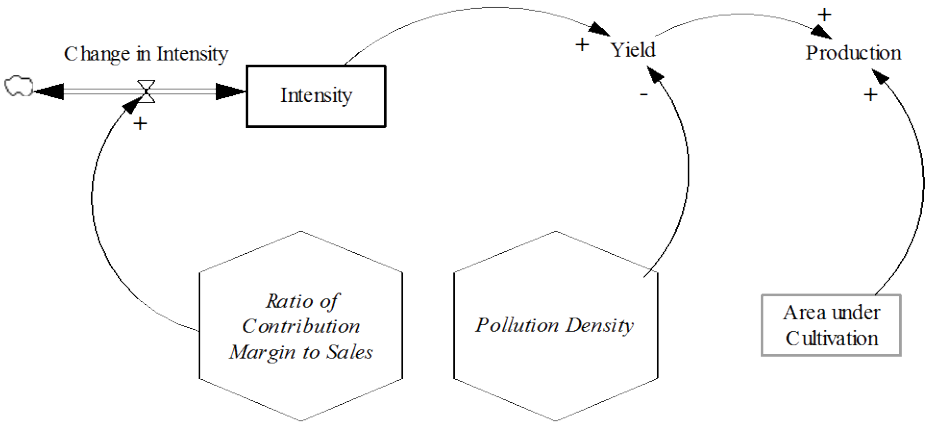

Figure 12: Decision Structure Diagram of *Culture* Sub-sector

5.4.2. Structure of the Environmental Sector

The *Environmental* sector deals with the dynamics of pollutants flowing through the Industry. The pollutants are generated in the shrimp farms during shrimp culture process. The unused portion of artificial feed, chemicals, and shrimp excreta create pollution in the pond ecosystem. The pollutants are discharged to the nearby water-source during the harvest of shrimp. The same polluted water is again pumped into the pond during the subsequent culture, and the cycle continues. A fraction of pollutants is, however, absorbed by the natural filtration process in the sea and creeks. This accumulation of pollutants is defined as a level variable, *Accumulated Pollution,* in the decision structure diagram of the *Environmental* sector (Figure 13).

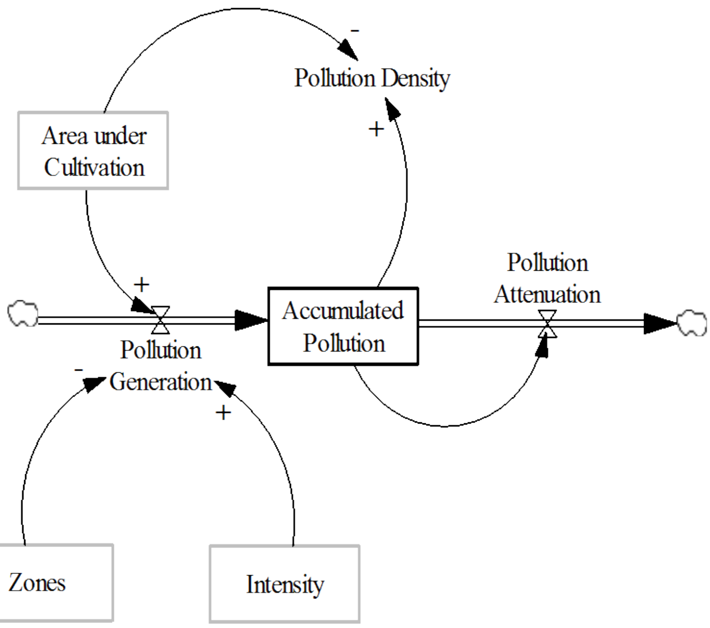

Figure 13: Decision Structure Diagram of *Environmental* Sector

5.4.3. Structure of the Institutional Sector

The *Institutional* sub-sector (Figure 14) deals with modeling the decision of *institutional actors* to control pollution level in the Industry. The actors in the *Institutional* sector collect information on pollution density, conduct meetings, and take and implement pollution control policies such as creating new shrimp farming zones and abandoning over-polluted shrimp farms.

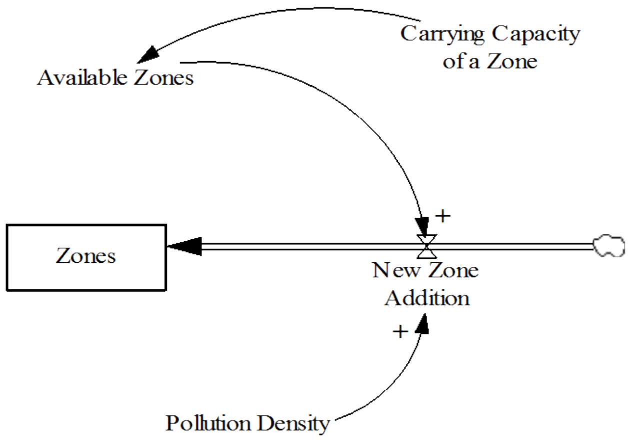

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Figure 14: Decision Structure Diagram of *Institutional* Sector

6 The Base Run and Model Validation

The Shrimp Industry model is simulated for 30 years starting from the year 1990 with of help of STELLA 5.0 software package. The year 1990 is chosen as the initial year of the simulation because large-scale commercialization of the Industry began in that year (Vasudevappa and Seenappa, 2002). The simulation time constant is taken as 1/16 month.

Figure 15 shows the base run behavior of *Area under Cultivation* (Curve 1), *Intensity* (Curve 2), *Accumulated Pollution* (Curve 3), *Zones* (Curve 4), and *Production* (Curve 5). The behaviors of the indicators are explained with the help of a causal loop diagram shown in Figure 5.

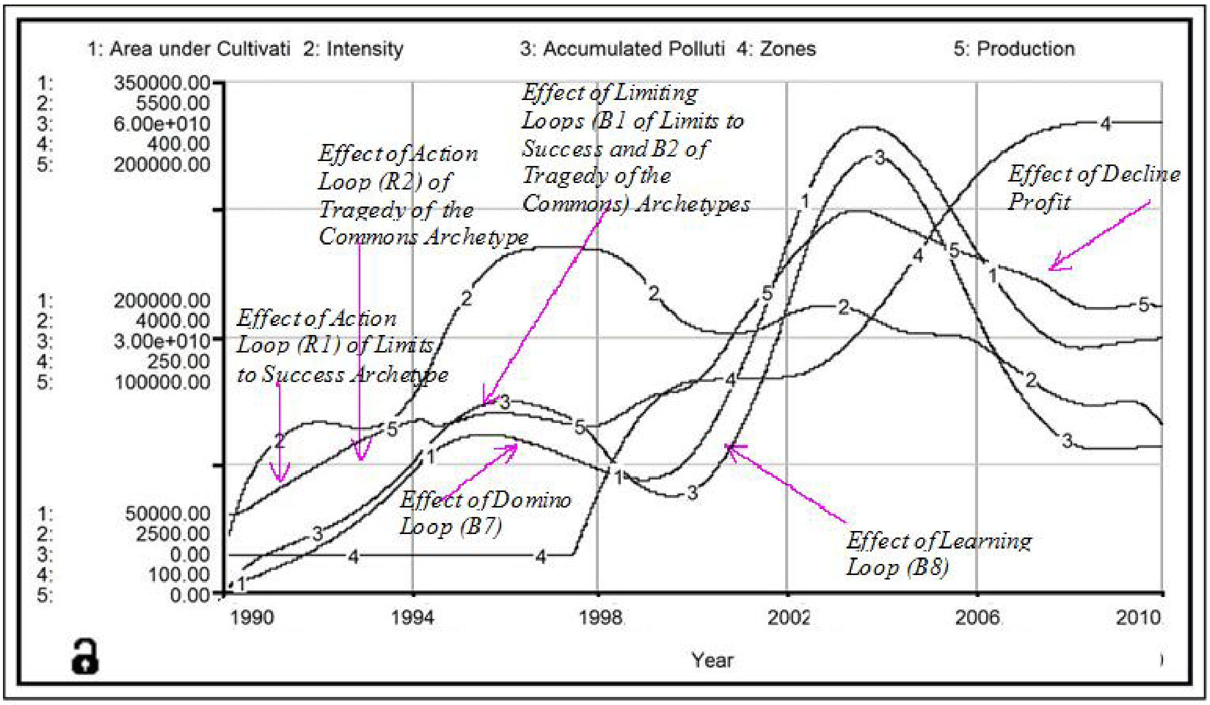

Figure 15: Base Run Behaviour of Shrimp Industry Model

Area under Cultivation, *Intensity*, and *Production* grow during 1990–1994 due to the simultaneous effect of R1 and R2 loops. In the same period, *Accumulated Pollution* rises due to the activation of B1 and B4 loops and causes the Industry growth to slow down during 1994. When the *Accumulated Pollution* exceeds its limiting condition. The *Domino Loops* (B6 and B7) reflecting the abandonment of shrimp farming by the producers starts to influence the Industry reducing *Area under Cultivation* and *Production*, thus pushing the Industry into the *Decline* phase during 1995–1997.

Towards the end of 1997, due to the activation of the *Learning Loop* (B8), more shrimp farming areas are explored that increases *Zones*, thus reducing the *Accumulated Pollution* and weakens the *Limiting Loops*, B1 and B4. Hence, after 1997, there is an increase in *Area under Cultivation* and *Production*—representing the *Revival* phase of the Industry. The level of *Intensity*, however, continues to be at a low level because of the *learning* of the producers regarding the ill effects of the intensity on shrimp growth. The Industry shows again a declining trend after 2001 due to a drop in the profitability of the Industry because of *Anti-dumping Duties* (unusual events) imposed on the exported shrimp from India and economic recession which hit the Industry.

The Shrimp Industry model was subjected to various types of *tests* that are suggested in the system dynamics literature (Forrester and Senge, 1980; Mohapatra *et al.*, 1994; and Sterman, 2000). The model was passed through *Model Structure Test Structure Verification Test, Parameter Verification Test, Boundary Adequacy (Structure) Test, Dimensional Consistency Test), Model Behaviour Tests (Bebahvior-Reproduction Test, Behavior-Anomaly Test, Behaviour-Sensitivity Test), and Policy Implication Test (Changed-Behaviour-Prediction Test and Policy Sensitivity Test). The model was found to pass most of the validation tests.* The family of *Model Structure Test* helped us to consider parameters explaining area development delay, explaining rate of construction of farms, explaining total fixed cost of production, explaining unit variable cost of poduction, explaining average pond life, explaining the producers' response to abandon shrimp farms in case loss of profit, and explaining the speed of farmers reaction to take production related decisions, as variables instead of constants. It also warranted modifications of the structure defining variables explaining regulatory forced abandonment of farms, variables explaining identification and declaration of shrimp farming zones, and variables explaining survival fraction of shrimps in a shrimp pond to safeguard the model generating abnormal behaviour during extreme conditions.

When subjected to the behaviour-reproduction test, *Area under Cultivation, Yield,* and *Production* showed similar trends and fluctuations as those in their actual behavior giving *Mean Absolute Percentage Errors* (MAPE) of 17%, 15%, and 11% respectively. The calculation of Theil inequality statistics on the actual and simulated values of Area under Cultivation, Yield, and Production are presented in Table 1. Various components of the errors i.e., U^M, U^S, and U^C, were analyzed for each of the three variables. In case of Area under Cultivation, the lower values of U^M and U^S and higher value of U^C indicate that the point-by-point values of the simulated and actual series do not match. However, the matching between the average value and the dominant trends of both the series match well. These mismatches happen when there is a constant phase shift or translation of time of a cyclic mode. This is due to the presence of random components in the series values. The random components is obvious as the actual data collected on the Industry's key indicators are the only annual point estimates, which is largely susceptible to bias in the model values. Hence, the model could not be faulted for failing to generate random component of the data.

Table 1: Theil's U-Statistics of the Model

	U^M	U^S	U^C
Area under Cultivation	0.02	0.06	0.97
Yield	0.00	0.29	0.76
Production	0.02	0.00	1.03

The behavior-anomaly test helped us to introduce producers' *learning* from their past experience as an influencing factor on their decisions related to intensity of culture. We also carried out the family of Policy Implication Tests (Changed-behavior prediction test and Policy Sensitivity Test). Both the tests led to plausible model results. Modification of basic structure of the model by incorporating additional causal links depicted by the proposed S-Links (Section 3.3) resulted in a sustainable behaviour of the Industry. The policy-sensitivity test, when conducted for the policy of Cluster-based/Aqua-club-based implementation of Best Management Practices (BMP) in the shrimp farms, showed the policy to be effective as long as Industry's normal shrimp survival was 30% or more.

7 The *As-Is* Scenario

The model was simulated till 2020 with the Base Run setting generating the *As-Is* scenario of the Industry. *Area under Culture, Yield,* and *Production* in the *As-Is* scenario are shown in Figure 16 through Figure 18 for the years 1990–2020. As shown in Figure 16, *Area under Cultivation* exhibits the growth, decline, and revival behaviour as explained in Section 6 when the base run results were discussed. Unfortunately, the effect of *Anti-dumping duties* and economic recession made the shrimp business unprofitable after the year 2003 forcing many producers to quit the business, thus setting in the *Nosedive* phase of the Industry.

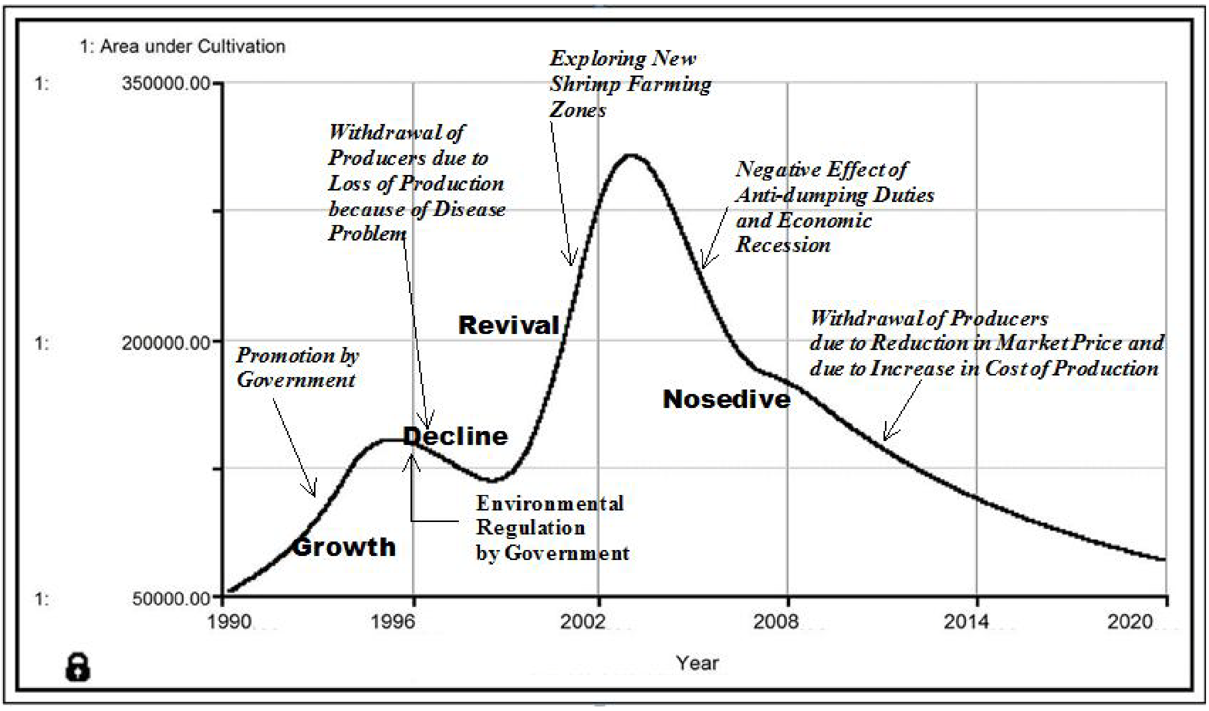

Figure 16: As-Is Scenario of Area under Cultivation (ha)

Yield (Figure 17) shows trends and fluctuations almost similar to those of *Area under Cultivation*, excepting during the years 2000–2005 during which *Yield* dipped (due to reduced level of intensity of culture practiced by the producers as a result of their learning of the ill effects of high-intensity culture) and recovered again (due to creation of new shrimp farming zones to counter the ill effects of increased pollution). This recovery was, short-lived, and *Yield* underwent a nosedive decline after the year 2009 following the imposition of *Anti-dumping duties* and occurrence of economic recession. *Production* (Figure 18), a direct function of *Area under Cultivation* and *Yield*, shows the familiar growth, decline, revival, and nosedive phases as discussed above.

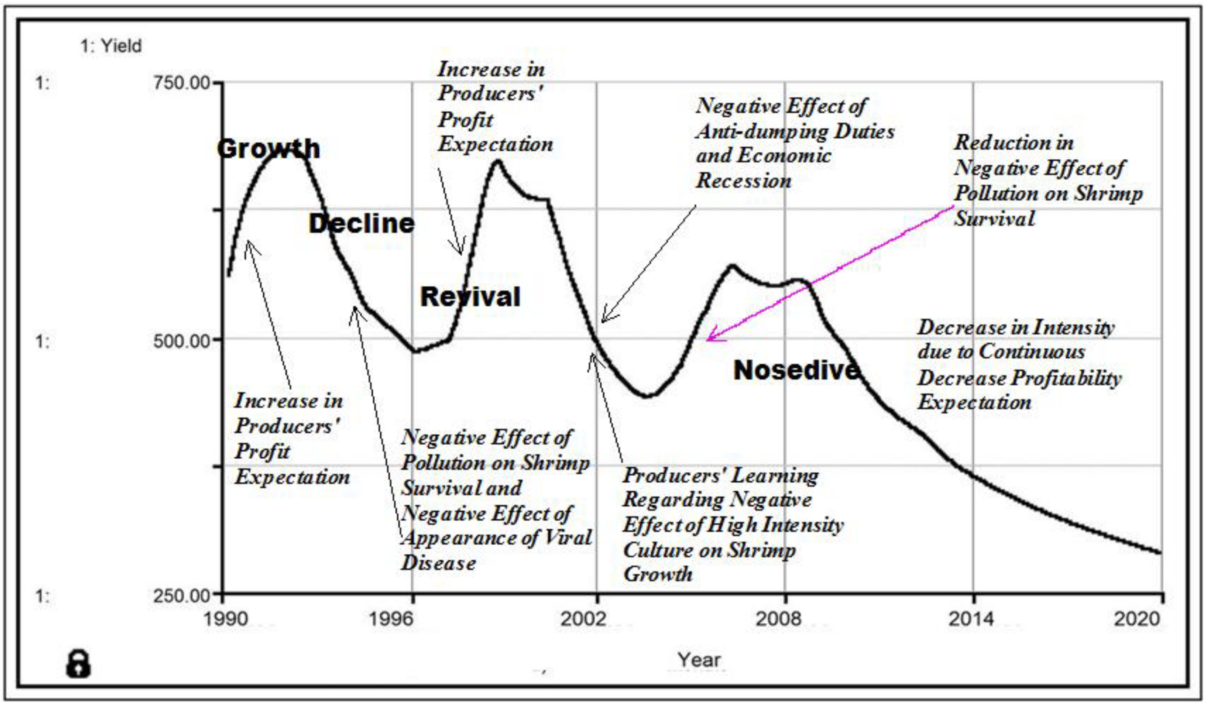

Figure 17: ***As-Is*** **Scenario of Yield (kg/ha)**

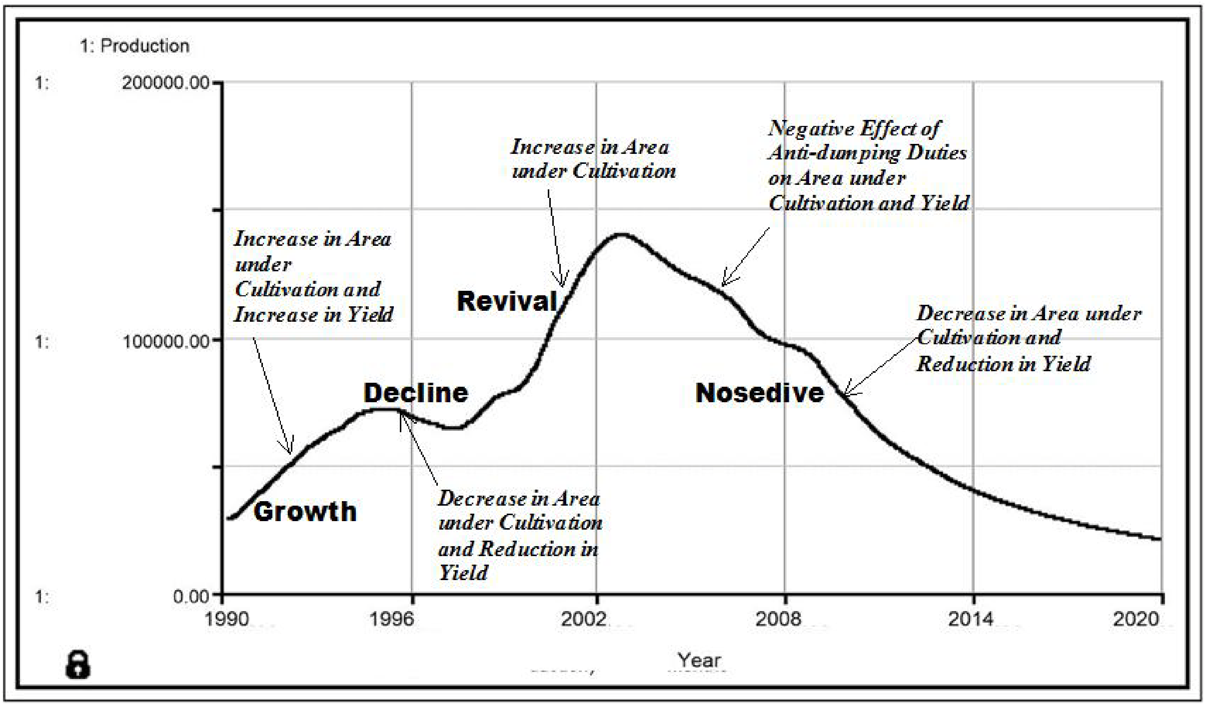

Figure 18: ***As-Is*** **Scenario of Production (t)**

8 Experiments with Pure Functional Strategy Sets

We have assumed that the individual strategies are implemented in the year 2010. The model is simulated till 2020 under various variable settings in the STELLA model. The scenario generated with a functional strategy set is named based on the name of the strategy set. For example, the scenario generated with *Production Strategy* set is named as *Production* scenario. Likewise, the other three scenarios are: *Environmental*, *Financial*, and *Marketing* scenario.

Figure 19 and Figure 20 show respectively the behaviour of *Area under Cultivation* and *Production* during 1990 and 2020, when various strategy sets are implemented in 2010. *Area under Cultivation* continues to decline in *Production*, *Environmental*, and *Marketing* scenarios. Even though the individual strategies of the *Marketing* strategy set increase the financial viability of the Industry, they could not revive the Industry. The *Financial* strategy set results in rising *Area under Cultivation* during 2010 and 2020.

Figure 20 exhibits the behavior of *Production* for different strategy sets. The growth in *Area under Cultivation* and *Production* during 2010–2020 for the *Financial* strategy set also declines towards the end of 2020, indicating the unsustainable tendency of the Industry when pure functional strategies are implemented. Although the *Financial* strategy set has the ability to revive the Industry, it tends to increase the *Pollution Ratio*.

We conclude that in their pure forms functional strategy sets are not capable of reviving the Industry and of ensuring its sustainable growth. It indicates that a *Mixed Strategy* set that comprises the features of the individual functional individual strategy sets may hold the key to Industry growth and sustainability.

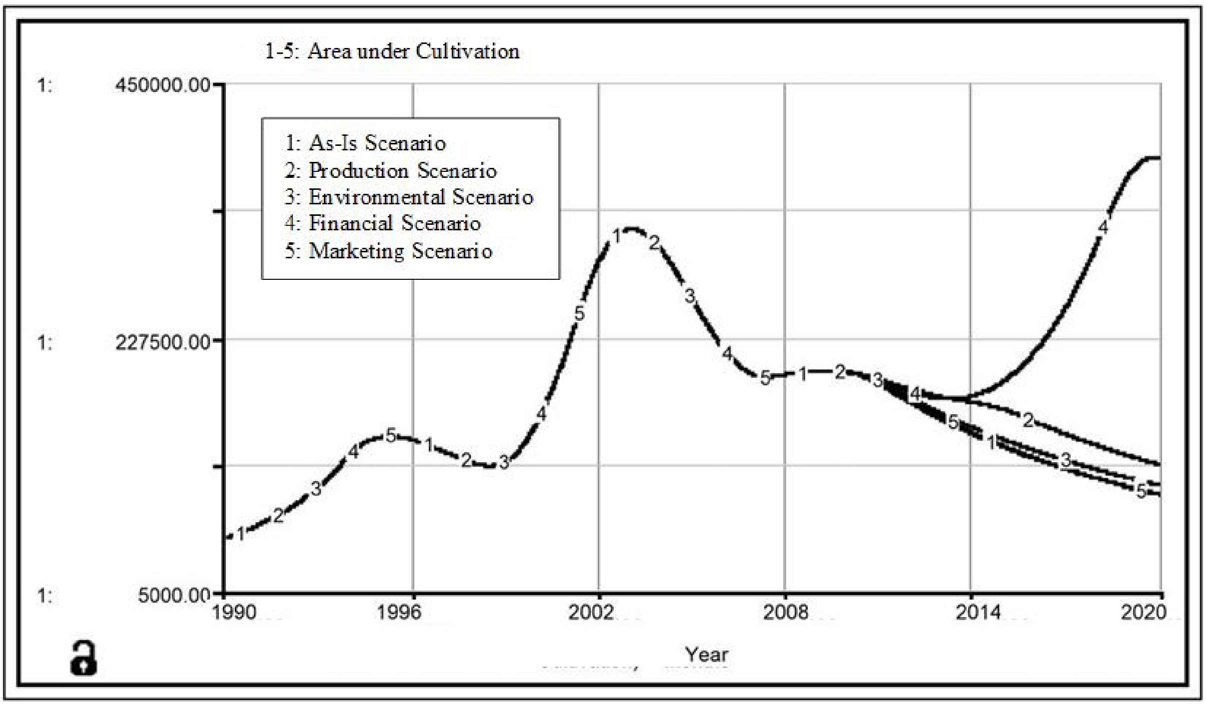

Figure 19: Behavior of *Area under Cultivation* (ha) during Strategy Experimentation

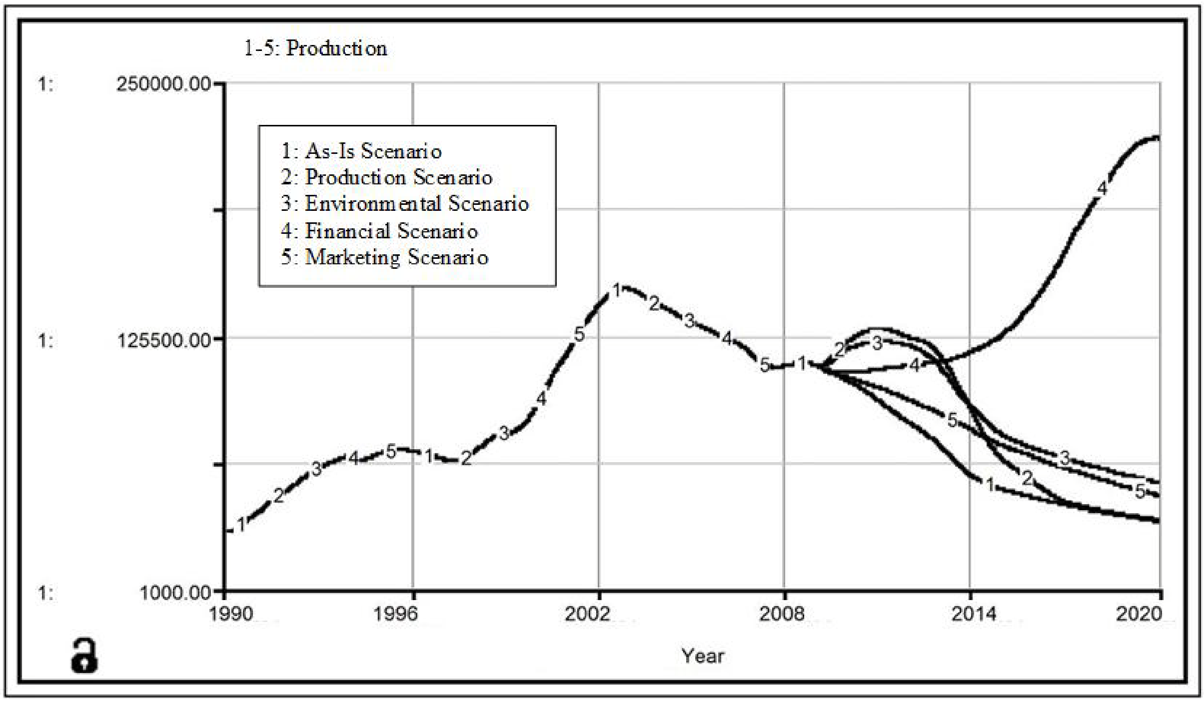

Figure 20: Behavior of *Production* (t) during Strategy Experimentation

9 Formulation of Robust and Sustainable Strategy Sets

In order to propose a robust and sustainable strategy set for the Industry, we define a *Mixed Strategy* set and a *Sustainable Strategy* set and test them under normal and adverse environmental conditions as projected by the Delphi panelists.

9.1. The Industry under Six Different Conditions

In order to formulate a robust and sustainable strategy set, we picked up the most influential strategies from every functional strategy set and combined them to define a mixed set of strategies. The *Mixed Strategy* set is expected to rejuvenate the Industry in all four functional dimensions—*Production, Environment, Finance, and Market.* The individual strategies of the *Mixed Set* and their corresponding effects on the model variables are shown in Table 1.

In order to make the strategy set more sustainable, we incorporated additional strategies based on the two S-Links (the first to invest more in pollution prevention activities by the producers and the second to reduce delay in creating new zones by the policy makers). The *Mixed Strategy* set combined with those based on the S-Links is defined as the *Sustainable Strategy* set.

Table 2: Individual Strategies of *Mixed*

Use more efficient technologies like *Best Management Practices*, *Recirculatory System*, and *Efficient Aeration* in hatcheries and farms.
Field-test and slowly adopt P. *vannamei* as a complementary species to P. *monodon* (Indian Tiger shrimp).
Extend the technologies developed in fisheries research institutes to the farmers.
Promote *organic* shrimp farms.
Share true price of shrimp and maintain proper co-ordination among the players of the value chain.
Reduce middle-men effect across the value-chain of shrimp.
Produce and export of Value-Added Products of Indian Tiger shrimp.
Supplying Indian Tiger shrimp to other countries and places, where shrimp supply from other countries are not there.
Invite FDI and private companies to value-added production sector.
Provide 50% subsidy for investment in value-added production firms.
Position Indian Black Tiger shrimp separately through advertising it as a high-valued product (for its taste and quality) and create a high-end customer base.
Set up a distribution chain, like cold-chain facilities, for domestic market.
Provide adequate financial support to shrimp farming as it is provided to agriculture.
Implement stable long-term policies on export, land lease, and marketing of shrimp.
Label the shrimp product along its value-chain, starting from farm-site.

Set

To test the effectiveness of these strategy sets, we tested them in two environmental conditions: (1) Normal environmental conditions (environmental conditions as they prevailed up to the year 2010 to continue into the future) and (2) Adverse environmental conditions (as projected by Delphi panellists to occur in the future). **Table 2** specifies the changed values of model variables to create the adverse environmental conditions in the model. Thereafter, the model is simulated till the year 2100 generating six different scenarios as presented in Table 3.

Table 3: Projected Environmental Conditions and Their Effect on Model Variables

Projected Environmental Conditions
Extreme pollution in the coastal water due to other sources like industry pollution and agricultural pollution.
A stringent anti-pollution law will be effective.
Appearance of another viral disease
There will be scarcity of fresh-water in the coastal areas.
Pollution taxes will be levied on the Industry.

Table 4: Six Scenarios for Developing Robust and Sustainable Strategy

Strategy Group	Environmental Condition *Normal* (Figure 21.)	 *Projected* (Figure 22)
No Strategy Inputs	*As-Is Scenario (1)*	*As-Is Scenario under Projected Conditions (1)*
Mixed Functional Strategy	*Mixed Scenario (2)*	*Mixed-Scenario under Projected Conditions (2)*
Sustainable Strategy	*Sustainable Scenario (3)*	*Sustainable Scenario under Projected Conditions (3)*

9.2. Six Scenarios of the Industry

Figure 21 and Figure 22 present the variation of *Production* in normal and adverse environmental conditions respectively. Figure 21 shows that *Production* increases significantly in the *Mixed* scenario (Curve 2) and continues to rise till the year 2100 in normal environmental conditions. *Production* in the *Sustainable* scenario (Curve 3), however, overshoots and stabilizes at a lower value. The embedded strategies that are derived based on the S-Links in the *Sustainable Strategy* sets reduce the normal pollution level of the Industry, providing better *Yield* and profitability of the culture business. Higher profitability attracts development of more number of farms in zones, resulting in an increase in *Area under Cultivation.* However, the financial burden on the producers put by those embedded strategies lowers the long-term profitability forcing many old producers to withdraw from shrimp farming and acts as an disincentive for new entrepreneurs. Hence, there is a fall in the behavior of *Production* in the case of *Sustainable Scenario* in normal environmental conditions.

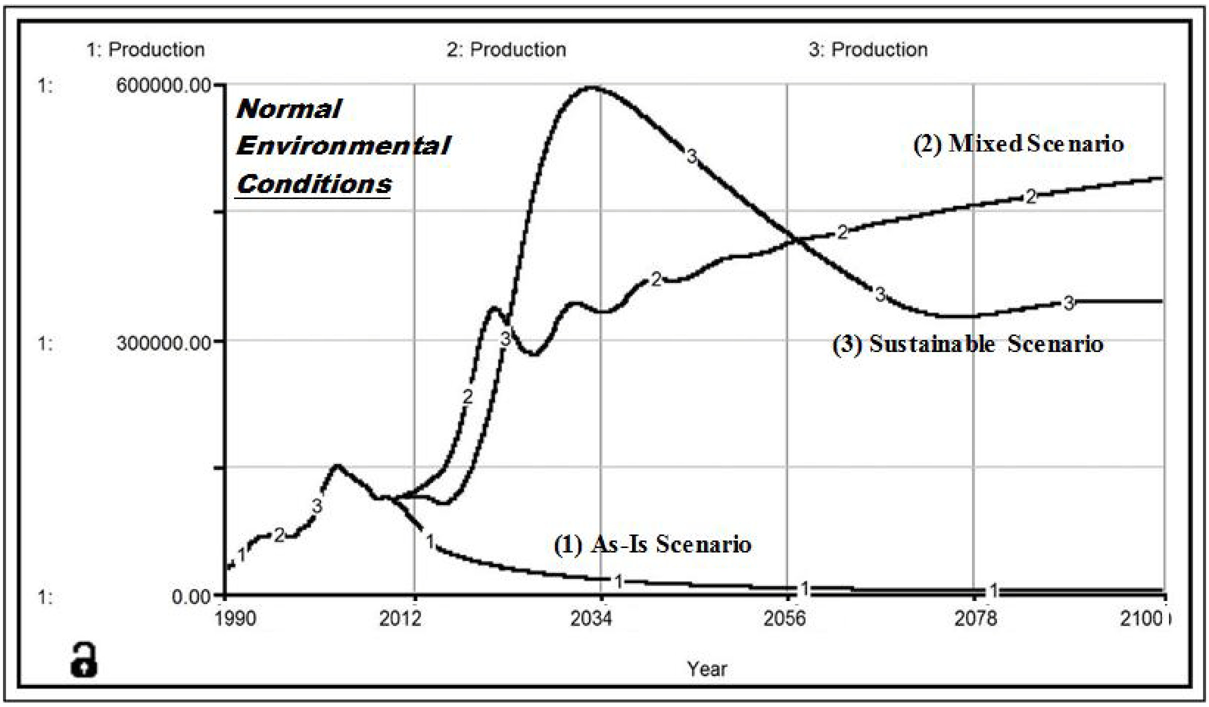

Figure 21: Production (t) of the Industry under Normal Environmental Conditions

Production in the *Mixed* scenario in the adverse environmental conditions (Figure 22) shows cyclic fluctuations around a steady state value of 115,000 t (Curve 2), whereas the *Sustainable* scenario indicates a stable *Production* behavior (Curve 3) of the Industry with a steady state value of 117,000 t. The failure of the *Mixed* strategy set in reviving and stabilizing the Industry behavior in the adverse environmental conditions can be attributed to the intense negative impact of the environment on the production sector of the Industry. However, in case of the *Sustainable* strategy set, the embedded *S-Links* help the Industry by preventing pollution generation. Figure 23 presents a comparative scenario of *production* figures in both normal (with *Mixed Strategy* set) and adverse (with *Sustainable Strategy* set) environmental conditions.

In the light of the results obtained and discussed above, we propose two sets of sustainable strategies for the Industry: (1) A set of *Mixed Strategy* in the normal environmental conditions and (2) A set of *Sustainable Strategy* in the adverse environmental conditions.

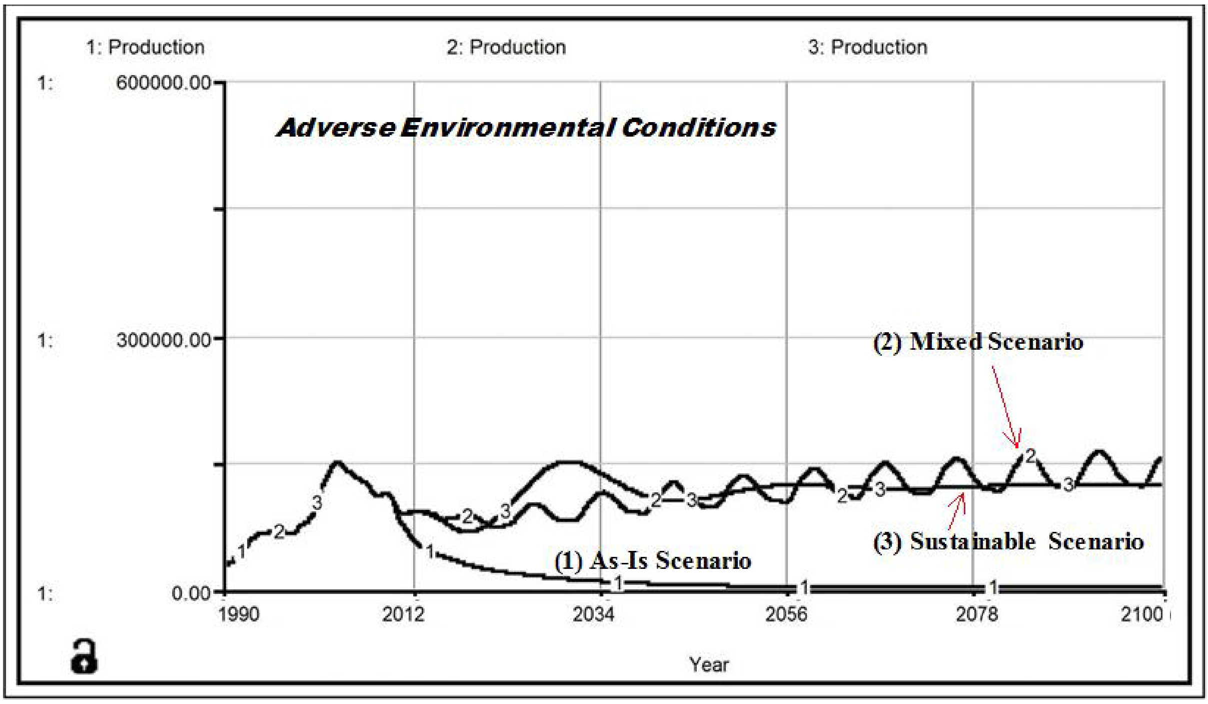

Figure 22: Production (t) of the Industry under Adverse Environmental Conditions

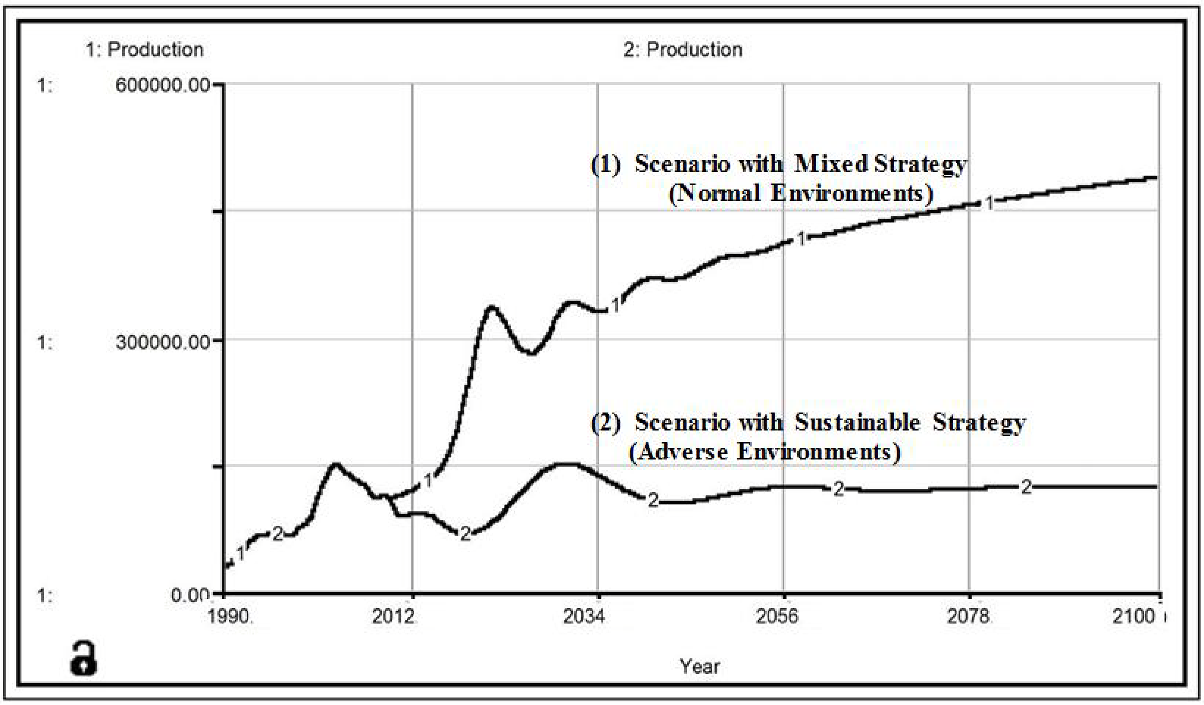

Figure 23: The Industry's Production (t) in Normal and Adverse Environments

10 Sustainable Growth Strategies for the Industry

From the wide range of strategy experiments with the model, we recommend the *Mixed Strategy* set as the sustainable growth strategies for Indian Shrimp Industry in normal environmental conditions and the strategies of the *Sustainable Strategy* sets as the sustainable growth strategies in the adverse environmental conditions.

The constituents of the *Mixed Strategy* set that need to be implemented in normal environmental conditions are the following.

1. Field-test and slowly adopt P. *vennamei* as alternative to P. *monodon* (Indian Tiger shrimp);
2. Extend the technologies developed in fisheries research institutes to the farmers;
3. Provide 50% subsidy for investment in value-added production firms;
4. Invite FDI (Foreign Direct Investment) and private companies to value-added production sector;
5. Set up a distribution chain, like cold-chain facilities, for domestic market;
6. Implement stable long-term policies on export, land lease, and marketing of shrimp;
7. Use more efficient technologies like best management practices, recirculatory system, and efficient aeration in farms;
8. Produce value-added Products of Indian Tiger shrimp;
9. Export value-added products of Indian Tiger shrimp;
10. Supply Indian Tiger shrimp to other countries and places, where shrimp supply from other countries are scarce;
11. Position Indian Black Tiger shrimp separately through advertising it as a high-valued product (for its taste and quality) and create a high-end customer base;
12. Promote organic shrimp farms;
13. Share true price of shrimp and maintain proper co-ordination among the players of the value chain;
14. Reduce middle-men effect across the value-chain of shrimp; and
15. Label the shrimp product along its value-chain, starting from farm-site.

In adverse environmental conditions, the *Mixed Strategy* set needs to be augmented to include the the following additional strategies.

1. Invest a fraction of the *profit per unit area* in adopting various pollution prevention strategies.
2. Contribute a fraction of the *profit per unit area* towards the development of R&D for minimizing pollution generation during shrimp production processes.
3. Explore and develop new shrimp farming zones for expansion.
4. Follow a stringent license and renewal of license strategy for the new producers and old producers respectively.
5. Regulate and control the rapid development of shrimp farms in particular zone.

11 Conclusions and Strategy Implementation

An extensive exercise of generating various candidate strategies by the means of *Industry Analysis* (using Porter's Five Forces model), of the Delphi survey (involving various stakeholders of the Industry), and of the analysis of the Industry in a *System Archetypical* framework (considering the dynamics of the Industry's behaviour) has, nonetheless, helped us congregating a set of collectively exhaustive strategies that have the potential of influencing the Industry from multiple perspectives. The strategies developed using the *Porter's Five Forces* analysis strengthen the Industry against the structural forces that enhances the competitiveness of the Industry. The strategies developed using the Delphi survey have the potential of increasing the effectiveness of value addition processes of the shrimp value chain as it considers the opinion of various stakeholders of the Industry. The strategies formulated through the analysis of system archetypical structure have given a thrust upon the dynamic relationships among the key factors of the Industry and are intended for the dynamic stability of the Industry's behaviour. The multiple ways of generating strategies helped us having an exhaustive set of strategies for the Industry, which include strategies that can strengthen the elements of the structure of Industry, are aligned with the goals of the Industry set by the stakeholders, and include strategies that can prevent the Industry from delayed reactions from environmental sector. The collation and segregation of the individual strategies have generated a list of four pure functional strategy sets that have the potential of bringing growth of the Industry in four directions. They are: *Production Strategy, Environmental Strategy, Marketing Strategy,* and *Financial Strategy* sets.

A system dynamics model of the Industry is discovered capable of facilitating the testing of candidate strategies for their likely impact on the Industry. The *As-Is* scenario shows a *Nosedive* phase of the Industry towards 2020, characterized by a fast decline in the behaviour of *Area under Cultivation, Yield,* and *Production.* The fast decline of the Industry that started during 2002 due to the negative effect of *Anti-dumping duties* imposed on the Industry and due to the negative effect of economic recession continues into the future, indicating the inadequacy of the present strategy sets implicitly followed in the Industry.

When tested with the *Production Strategy, Environmental Strategy,* and *Marketing Strategy* sets, the Industry shows a declining behaviour of *Area under Cultivation* and *Production.* This is due to (1) the emphasis of the Industry on increasing *yield* and reducing environmental pollution under the *Production Strategy* and *Environmental Strategy* sets, and (2) the focus of the Industry in the *Marketing* strategy on value-addition of shrimp and improving profitability. Though the *Financial Strategy* set helps the Industry to increase *Area under Cultivation, Yield,* and *Production,* it increases the pollution level of the Industry. We conclude that the pure functional strategy sets are ineffective, when implemented in isolation;

it requires selectively combining the individual strategies from the pure functional strategy sets and developing a *Mixed Strategy* set.

The *Mixed Strategy* set was formulated by picking up the most favourable strategies from the pure functional strategy sets. When the *Mixed Strategy* set was tested for its effectiveness, it was found to be effective in normal environmental conditions because it could revive the Industry from the declining stage as depicted by the *As-Is* scenario. However, under adverse environmental conditions (as projected by the Delphi panellists), the *Mixed Strategy* set resulted in fluctuations and instability in the Industry's behaviour. In order to achieve stability in the behaviour of the Industry, we developed a *Sustainable Strategy* set by coupling the *Mixed Strategy* set with the strategies derived based on the S-Links of the Industry *archetype.* The *Sustainable Strategy* set when tested with the model in the adverse environmental conditions generated a stable behaviour of the Industry avoiding fluctuations and instability. We conclude that the *Mixed Strategy* set is effective viable strategy set in the normal environmental conditions and the *Sustainable Strategy* set is effective in the adverse environmental conditions. The process of picking the most influential strategies from the pure functional strategy sets and again collating them to form a *Mixed Strategy* set has helped us in gathering the most effective strategies that can significantly influence the Industry's behaviour. The least effective strategies are able to be eliminated in such process.

We conclude that the sustainable growth strategy (in normal environmental conditions) recommended for the Industry calls for (1) Applying best management practices in production and processing (2) Adopting P. *vennamei* and organic shrimp farming and exporting value-added shrimp, (3) Increasing efficiency of value-chain, (4) Creating new market segments for Indian shrimp, and (5) Extending the Government support to facilitate adoption of latest technologies by the farmers, and to attract foreign and Indian private companies for investment in the value-added production sector. During the adverse environmental conditions, the additional strategies required to be implemented are: (1) those controlling over-expansion in a particular zone and (2) those controlling pollution generation by the producers.

The sustainable growth of the Industry needs efficient planning and implementation of the sustainable growth strategies. Depending on the responsibility to plan and implement the strategies, we assign them to different bodies. Thus we divide the recommended strategies among the actors in the Institutional sector (i.e., the Government), the Industry Associations, and individual actors in the value-chain. In normal environmental conditions, the Government needs to pursue: (1) Adopting P. *vennamei* as a substitute P. *monodon*, (2) Extension of technologies from R&D to farmers, (3) Inviting FDI and private companies for setting up of value-added production firms, (4) Subsidizing value-added production firms, (5) Developing infrastructure for domestic market, and (6) Having a long-term policies related to export, land lease, and marketing of shrimp. In adverse environmental conditions, the strategies to be pursued by the Government are: (1) to explore new shrimp farming zones for Industry's expansion, (2) to follow a stringent license and renewal of license strategy for the new producers and old producers respectively, and (3) to regulate and control the rapid development of shrimp farms in particular zone.

The strategies that need to be implemented the Industry Associations across the shrimp value-chain include: (1) Promoting organic shrimp farms, (2) Sharing true price information and maintaining proper co-ordination among the players/actors, (3) Reducing the middle-men effect across the value-chain, and (4) Tracking the shrimp product across the value-chain, from farm to export house.

Individual actor of the shrimp value-chain needs to be responsible for implementing various strategies. The hatchery owners and farmers need to follow best management practices in hatcheries in both normal and adverse environmental conditions. However, in adverse environmental conditions, the farmers need to need to spend in pollution prevention activities. These strategies can be implemented through formation of registered aqua-clubs among the hatchery owners and farmers. The processing house owners and exporters need to emphasize on processing and export of value-added shrimp products and to invest in marketing of those products in export market.

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