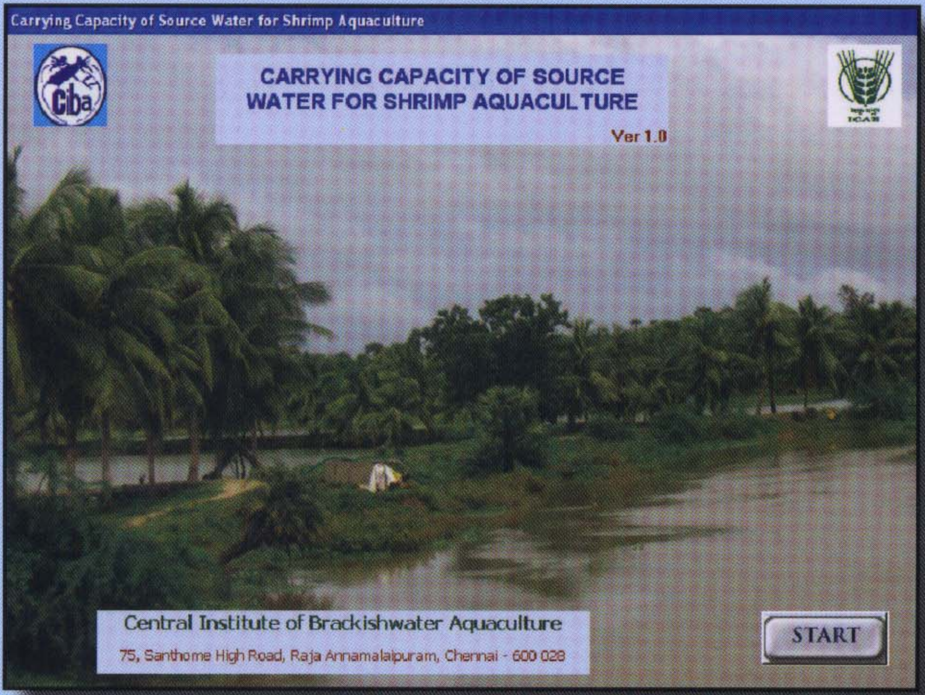
CIBA Technology Series - 2

Decision Support Software on Carrying Capacity: Estimation of Maximum Area under Shrimp Farming for a Selected Water Body



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The carrying capacity software is designed by Shri S.Nagarajan, T-5 based on the methodology and models developed under the Institute projects and Dr.A.Nagavel, T-5 assisted in the case studies.

Background

The concept of sustainable development is closely linked to the carrying capacity of ecosystems. Ecosystem carrying capacity (ECC) provides the physical limits to economic development and may be defined as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a defined planning region without progressively impairing bio-productivity and ecological integrity. It aims not only at environmental harmony, but also at long term sustainability of the natural resource base. A key of sustainable development of shrimp farming is to stay within the "carrying capacity" of the environment. The country has witnessed faster development of shrimp farming since 1990. The unplanned and uncontrolled expansion of shrimp aquaculture had lead to exceeding the carrying capacity of the source water bodies, which resulted in negative impacts of poor productivity and occurrence of diseases. The present day failure rate in shrimp farming experienced in the country is at least partly related to the very high concentration of farms in certain areas and declining water quality.

Importance and necessity

Most environmental assessment guidelines require analysis of the relationship between new developments or development programme and ECC. The Honduras Government had stopped further development of shrimp farms until an objective determination of carrying capacity has been achieved and guidelines provided for considering further increase in area under shrimp farming for the various estuaries in Gulf of Fonseca, a large estuarine embayment on the Pacific coast of Central America. Network of Aquaculture Centres in Asia (NACA) study on the preliminary assessment of carrying capacity of Kandaleru Creek in Nellore District, Andhra Pradesh has recommended that Government should limit any further development (intensification and / or horizontal expansion). Codes of conduct and codes of practice refer to carrying capacity either explicitly or implicitly. According to FAO Code of Conduct for Responsible Fisheries, under aquaculture development "states should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities" (Article 9.1.3). In many countries there is a continued need for aquaculture and planning authorities to produce and regularly update comprehensive plans for promoting, regulating and reporting on the aquaculture sector. Given the possible contributions of aquaculture to enhanced food supply and rural development, it may be very useful to design aquaculture development plans with due consideration of existing plans and efforts aiming at food security, sustainable agriculture and rural development. FAO Technical Consultation on Policies for Sustainable Shrimp Culture held in December 1997 at Bangkok recommended that appropriate research should be undertaken to determine carrying capacity of coastal ecosystems for shrimp culture with an emphasis on application of this knowledge to local areas. International Principles for Responsible Shrimp Farming mentioned not to locate new shrimp farms in areas that have already reached carrying capacity for aquaculture.

Carrying Capacity (CC) is the number of organisms or number of enterprises or total production which can be supported by a defined area, ecosystem or coastline. Environmental capacity is sometimes confused with carrying capacity and has been subject to a range of interpretations and definitions. Environmental capacity is a property of the environment and its ability to accommodate a particular level of activity with acceptable levels of impact, i.e., the rate at which nitrogen can be assimilated. Carrying capacity determination depends on both environmental capacity and the rate of waste output from aquaculture. In shrimp aquaculture CC of a water body can be used to estimate the maximum area under shrimp farming that can be accommodated without excessive water quality degradation. The water source (brackishwater canals, estuaries, creeks, agricultural drains) is a common property and withdrawal of water from and discharge of wastes by the farms into the same water source leads to potential eutrophication and hence there is a need to study the carrying capacity of such water source. In relation to the water body receiving the discharge water from shrimp farming, CC can be defined in terms of the maximum nutrient loading which can be assimilated by the water body without exceeding the permissible levels. This self limiting density, i.e., the number of ponds that can be operated sustainably must be quantified as a basic management parameter and its estimation requires detailed field studies and modeling. As the water quality deteriorates, carrying capacity actually shrinks, leaving the water body not able to support even the existing number of ponds. Carrying capacity of the water bodies is likely to become a significant issue with increasing levels of shrimp culture activity.

The carrying capacity based developmental planning process (Fig.1) involves generation of alternative socio-economic developmental scenarios within the assimilative and supportive capacities in the region. The supportive capacity of a region is the capacity of the ecosystem to provide resources for various anthropogenic activities in the defined planning region without impairing bio-productivity and ecological integrity. The formulation of models using water quality and estuarine dynamics data for predicting carrying capacity of water bodies will be of immense benefit to the shrimp aquaculture sector for environmentally compatible development planning.

Conceptual basis

The development of shrimp culture requires an evaluation of water quality in the regions of existing and proposed shrimp farm operations, especially how the water quality is influenced by the anticipated waste loads from the shrimp farms and from other wastewater discharge sources located in the region. If the combined effect of effluent loads is to reduce water quality below an acceptable value, then it can be said that the carrying capacity of the system has been exceeded. The evaluation of the carrying capacity requires development of suitable mathematical models in a simple and cost-effective way to determine the concentration of important parameters that result from a given level of waste loading.

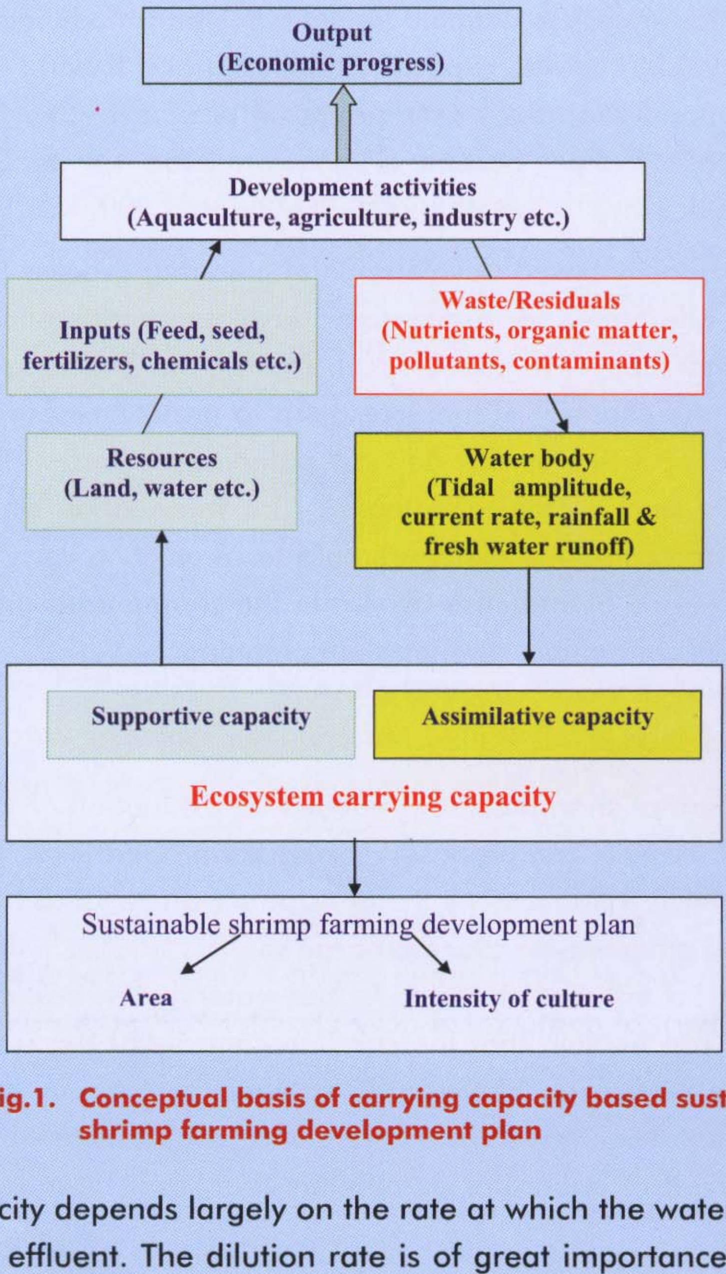


Fig.1. Conceptual basis of carrying capacity based sustainable shrimp farming development plan

Carrying capacity depends largely on the rate at which the water body (creek) can dilute the effluent. The dilution rate is of great importance in predicting nutrient enrichment in the creek. Creek bathymetry and hydrology (flushing rates, volumes at high and low tide), morphology of the creek (influence of water movement, mixing and stratification) along with impact from other land uses and freshwater runoff from the catchment area decide the final levels of nutrients. The flushing time can be estimated in relation to the dilution rate, which is the inverse of the flushing time. A greater density of farms can be developed in areas with higher flushing rates. Current flows and water depths are important in calculating dilution rate. Phosphorous is the limiting factor for fresh water, whereas nitrogen is the limiting factor for coastal and marine water. Since both fresh water and saline water environments persist in the brackishwater bodies, it is necessary to apply fresh water as well as coastal water models. Mass balance equation with a dilution term can be used to predict the nutrient loading.

Carrying capacity is site dependant and vary with time. They are contingent on technology, preferences, and the ever-changing state of interactions between the physical and biotic environments. The distribution of critical regions in a water body (well circulated areas or poorly circulated areas) and the resultant carrying capacity will vary with the hydrodynamic conditions. Almost all of the discussions on carrying capacity focus on its estimation rather than on the issue of how to ensure that it has not exceeded or how to manage or allocate, once it has been estimated.

Methodology for the estimation of carrying capacity

The carrying capacity of coastal areas for aquaculture should be estimated and based on this estimation, guidelines are to be provided for considering further increase in area under shrimp farming in the coastal region. The methodology for the assessment of carrying capacity of water bodies in relation to shrimp farming has been developed with the following step-wise activities.

1. Data collection on land use pattern, existing shrimp farm area, culture system, management practices and average shrimp production.
2. Establishment of environmental quality parameters and standards.
3. Quantification of the amount of nutrient load (N and P) released into the water body from shrimp farms and other activities. The nutrient overload could be from aquaculture and also from other activities on the land.

4. Use of numeric models to predict the total nutrient load in the water body and the resulting level of nutrients.

5. Estimation of carrying capacity by relating the predictions to the pre-culture values.

Software package for carrying capacity

Decision support software has been developed in Visual Basic to estimate the maximum allowable shrimp farming area for a particular creek or drainage canal. The flow chart of process for the estimation of CC is depicted in Fig.2 and the steps followed in the software is given below.

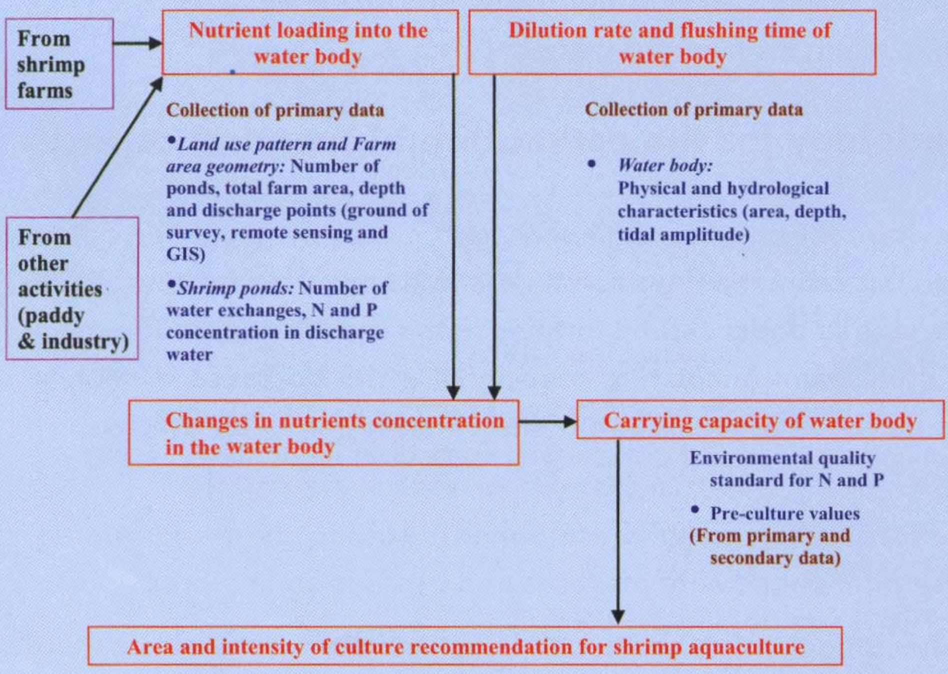
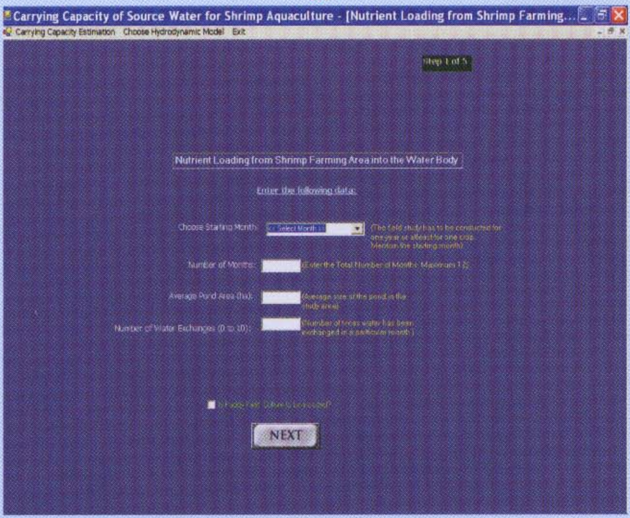


Fig. 2. Flowchart of steps in CC estimation software

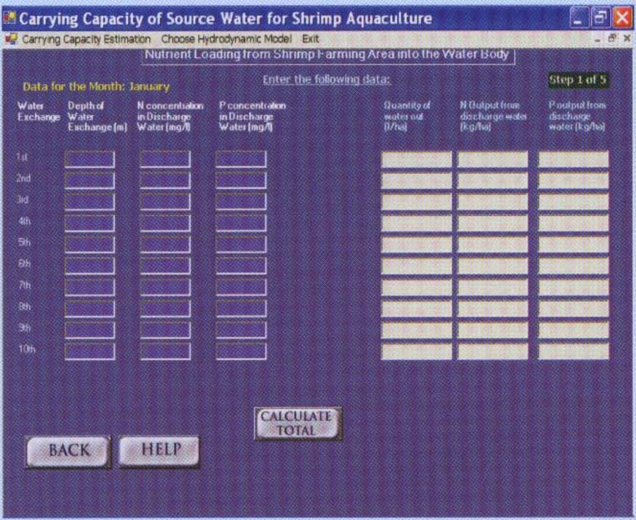
Step 1. Nutrient loading from shrimp farming into the water body

A



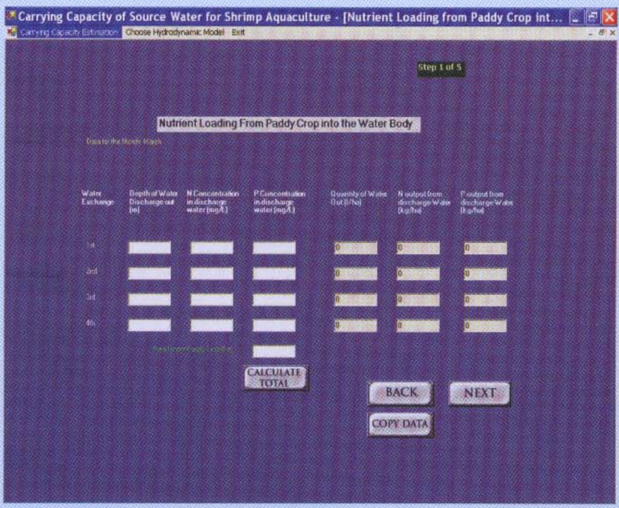
Information about basic farm details, such as number of months the study conducted, starting month of the study, average pond area in the study area and number of times water exchanged in that particular month have to be given as input data. Select the option of other activities (paddy fields) releasing the discharge water into the water body.

B



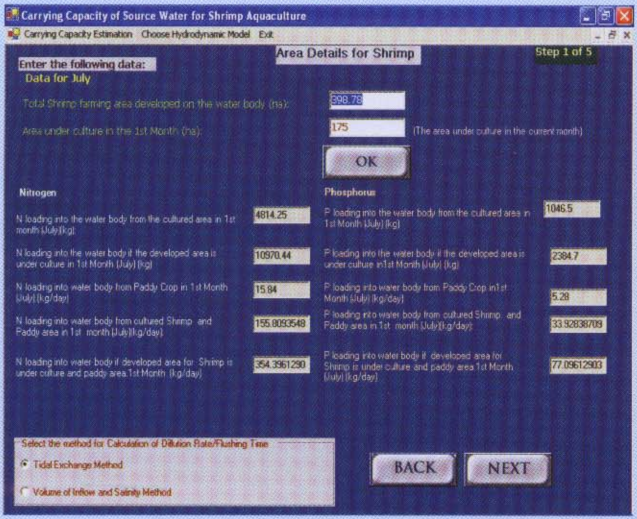
The information on water exchange, total nitrogen and phosphorus concentrations in the discharge water from shrimp farms serve as input data and this gives the output of nutrient loading (kg/ha) from shrimp farms into the water body.

C



The information on water exchanged, total nitrogen and phosphorus concentrations in the discharge water from paddy fields and area under paddy culture serve as input data and this gives the output of nutrient loading from the paddy fields into the water body.

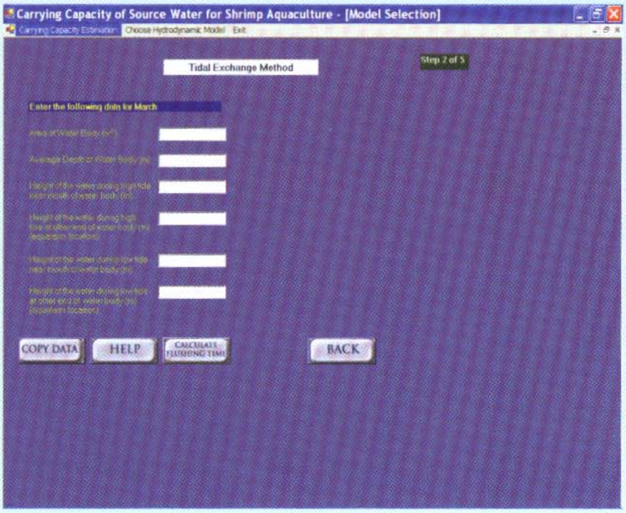
D



The information on average area under culture following water exchange and the total area developed for shrimp farming in the particular water body are given as input and this gives the output of nutrient loading for the cultured and developed shrimp farming area and total nutrient loading into the water body. Select the method for calculation of dilution rate and flushing time.

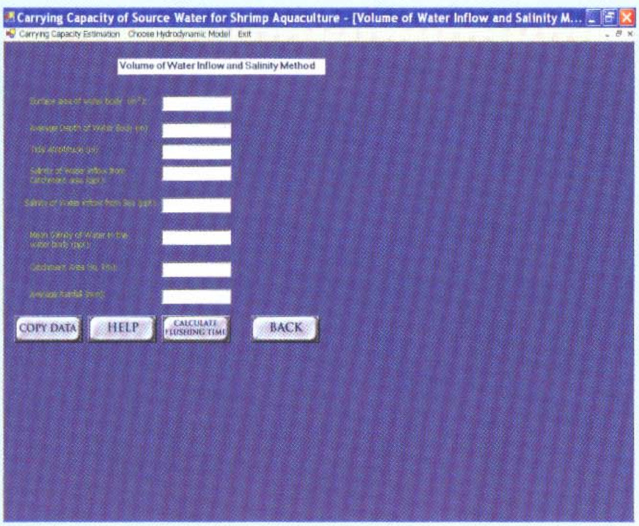
Step 2. Hydrodynamic model for calculation of dilution rate

A.Tidal exchange method



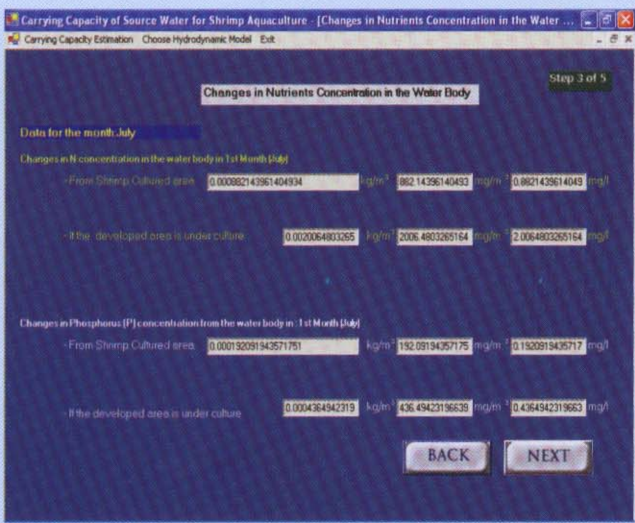
Area and average values of depth of water body during high and low tides near mouth of water body and at the other end where aqua farms are located are given as input and this gives the output of dilution rate and flushing time of the water body.

B. Volume of water inflow and salinity method



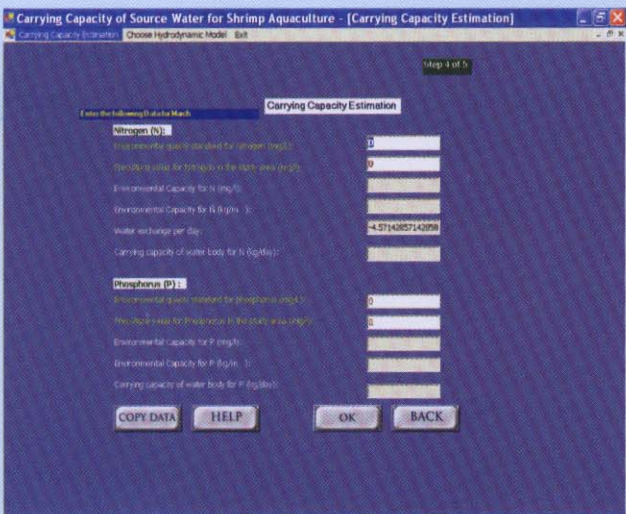
Area and average values of depth of water body, tidal amplitude, salinity of the water inflow from catchment area and sea, mean salinity of water in the water body, area of the catchment and average rainfall in the study area are given as input and this gives the output of dilution rate and flushing time of the water body.

Step 3. Changes in nutrients concentration in the water body



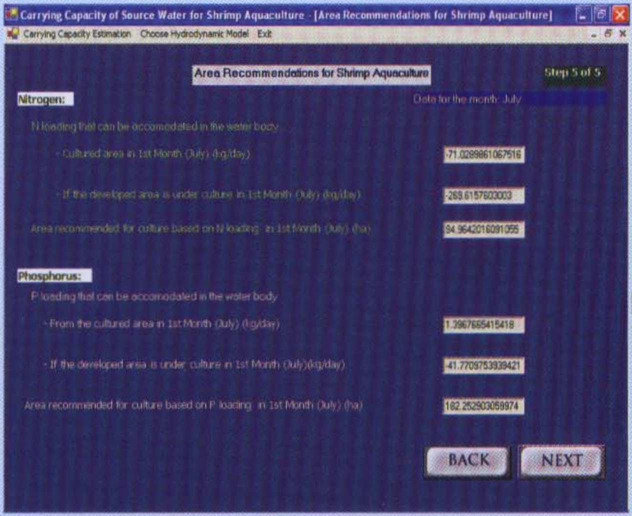
This step gives the output of changes in different nutrient concentrations in the water body

Step 4. Carrying capacity estimation



Environmental quality standards of the parameters and pre-culture values in the study area are given as input and this gives the output as carrying capacity of the water body.

Step 5. Recommended area for shrimp aquaculture



This step gives the output as nutrients loading that can be accommodated or if it has exceeded the carrying capacity of the water body and the total area recommended for shrimp aquaculture.

Case studies conducted

Case studies were conducted to validate the computer model in Andhra Pradesh and Tamil Nadu, where, discharge water was only from shrimp farms or from both shrimp farms and paddy fields and the recommended area for shrimp aquaculture were made by taking into account the rules of Coastal Regulation Zone and Coastal Aquaculture Authority and supportive capacity of the ecosystem. Based on the studies carried out, the tool can be customized and applied to determine the carrying capacity of other water bodies.

Results of case studies in two geographical areas

Case study 1: Water bodies that are source and sink for only one activity, shrimp farming

Polekuru Island in East Godavari District, Andhra Pradesh is surrounded by four major source water bodies *viz.,* Bandha Creek, Sarrihaddu Kaluva, Gaderu River and Vadalanali Creek. Based on the monthly estimates of nutrient loading from the shrimp farms and assimilation capacity for one year, area that can be taken up for shrimp culture was calculated. The nutrient loading into Bandha

Creek and Sarihaddu Kaluva will exceed the assimilation capacity at harvest time, if the whole area is under culture, whereas, the nutrients loading into Gaderu Creek and Vadalanali Creek is within the assimilation capacity. Though Gaderu and Vadalanali Creek are having good dilution and flushing rate, there was no scope for further development on Gaderu Creek as there was no land area and on Vadalanali Creek, unauthorised development has taken place. Out of 2000 ha developed, a total area of 1300 ha was recommended for culture (Table 1).

Table 1. Source water wise recommended area details for shrimp farming in Polekuru Island

Source water	Total area developed (ha)	Area recommendation based on		Remarks
		Assimilation capacity (ha)	Carrying capacity (ha)	Assimilation capacity only looks at actual nutrient loading and flushing/dilution rates. Carrying capacity takes into consideration both assimilation and supportive capacities.
Bandha Creek	280	69	69	Flushing rate is less, hence area has to be decreased or stocking density should be very low.
Sarihaddu Kaluva	780	291	291	
Gaderu River	290	7183	290	High dilution and flushing rates. But no scope for further development since suitable land is not available.
Vadalanali Creek	650	831	650	
Total	2000		1300	

Case study 2: Water source for shrimp farms and sinks for discharge water from both shrimp farms and paddy fields

Mogalthur Drain in West Godavari District, Andhra Pradesh was divided into three zones for collection of discharge water samples from the shrimp farms and paddy fields. Based on the nutrient loading into the drain from shrimp farms and paddy fields and carrying capacity of the drain, allowable maximum area was recommended for shrimp farming in each zone (Table 2).

Table 2. Carrying capacity based area recommendation for shrimp farming on Mogalthur Drain

Area details	Zone 1	Zone 2	Zone 3
Developed area (ha)	206.39	316.98	398.78
Recommended area for further development (ha)	369.52	357.24	94.96

Utility of software

1. This carrying capacity based planning tool can be used to sensitize stakeholders of the issues involved and guide the agencies that are interested in environmentally sustainable shrimp development.
2. It will also results in awareness among shrimp farmers of the impact of shrimp farming on the environment and encourages them to pursue sustainable production methods.
3. The software permits a reliable estimation of the combined impacts of the shrimp farms and other land use impacts in a region under various scenarios of increased development.
4. The carrying capacity models will provide information necessary for the formulation of strategies (preferred scenario) to integrate shrimp farming into coastal zone management.
5. The water quality data generated through field sampling and analysis will serve as the baseline to monitor the long-term trends in quality of water bodies.
6. It will help in framing future guidelines and policies for sustainable development of shrimp farming.
7. The tool increases the capacity of fishery and planning professionals to develop management systems that will reduce the likelihood of aquaculture development having deleterious impact on the environment.
8. The tool will help state governments and other regulatory organizations to regulate the level of shrimp farming activity for each receiving water body.

9. For private entrepreneurs who would like to develop large areas for shrimp farming, this software can be used as a planning tool so as not to exceed the carrying capacity of the receiving water body.

Future developments in the software

* Site specific variables like organic load, total suspended solids etc., will be added in the methodology of CC estimation and by incorporating new modules in the software.
* Adding visual display of the results and scenarios for sensitizing farmers and policy makers.
* Simulation models to study the environmental impacts.
* Models to show the necessity of ETP for the treatment of shrimp farm discharge water.

Transfer of technology

The utility of the software will be explained to the desired departments dealing with aquaculture planning. Training programme will be organised to explain the operations of the software. The software is useful to farmers cluster groups and private entrepreneurs interested in the development of shrimp farming based on the investigations on the quality of water bodies.

For details please contact

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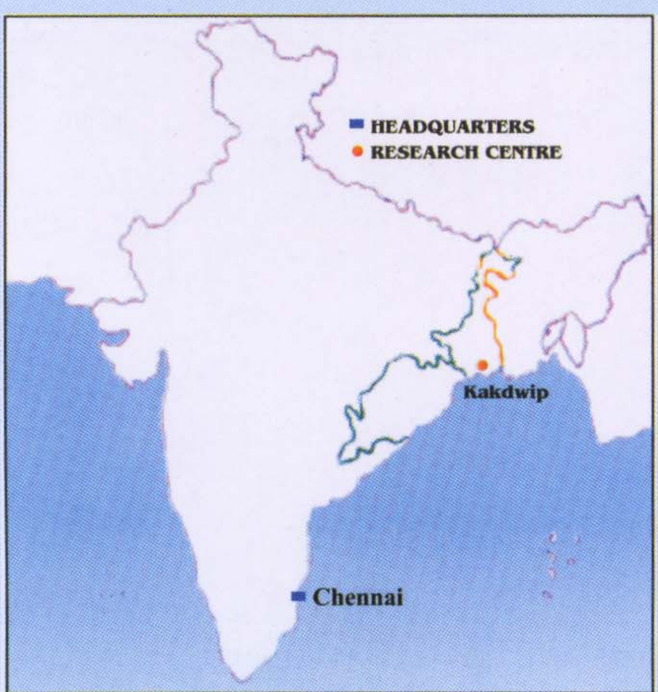

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