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Quality of aquaculture farm practice in Sirkazhi coast

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Abstract
To maintain the overcrowded shrimp population in intensive production systems, and attain higher production efficiency, copious amounts of artificial feed, pesticides, chemical additives and antibiotics must be continuously added. These compounds, together with excrement from the shrimp, make the wastewater from the ponds poisonous. The polluted wastewater is generally pumped back into the surrounding environment in order to save costs, poisoning coastal waterways and the sea, fresh groundwater supplies, native flora and fauna, and adjacent communities. In addition shrimp pond effluents are often high in organic matter, with a resulting high biological oxygen demand that can cause oxygen depletion in receiving waters. The combination of surplus organic matter and increased salinity from pond effluents can cause severe problems, especially for fish populations and other sea life that inhabitant the receiving waterways. Saltwater in the ponds also seeps into the local groundwater and the increased salinity damages drinking water supplies and surrounding agriculture land, making alternative cropping (such as rice) nearly impossible. As with other types of farming, shrimp farming frequently uses exotic species and varieties that are not indigenous to the local area. What effects the introduction of new species will have on the local ecosystem is not yet known. Even if an exotic species of shrimp can be contained in the ponds to which they were introduced, and even though it may appear to be innocuous, there is always the danger of diseases and parasites spreading to local shrimp species.

Key words: shrimp pond, aquaculture pollution, inorganic pollution

Introduction
The tendency of shrimp farming systems to be too profit-oriented exacts a high social cost and creates a host of new complex environmental problems. As with agriculture and fishing, the rapidly growing world demand for the products of modern aquaculture has resulted in development of technologies and production systems that accelerate increasing scale and intensity of operations until they outstrip the carrying capacity of the environment. Factory farming has led to depleted and eroded soils, reduced genetic stock, and widespread crop failures; Factory fishing has created global over fishing and the collapse of several commercially important fishery stocks, and even entire marine ecosystems; and now "factory" aquaculture is headed in the same direction. Shrimp aquaculture provides a particularly disturbing example: as the intensity of operations and the density of shrimp farms has exploded along tropical coastlines, there has been degradation of coastal ecosystems and hardships suffered by neighboring communities; wild stocks of shrimp, and now even the cultured stocks, are collapsing due to rampant disease and other problems.

The environmental pressures from industrialized shrimp farms have impacts well beyond the boundaries of the immediate site itself. The additional ecological or biophysical "costs" have become known as the "ecological footprint". This "ecological footprint" is the minimum area of productive ecosystem required to sustain resource inputs to and assimilate waste outputs from an aquaculture operation. In order for shrimp ponds to maintain intensive yields and high returns the wholesale conversion of surrounding land areas is required. Aquaculture production of shrimp (and also some types of farms producing fin fish) has become the most relentless destroyer of large areas of pristine tropical wetlands. Mangrove forests are the most notable ecosystems that have fallen prey to shrimp pond construction, with the massive destruction of mangrove forests in Latin America and Asia.

Problem Statement
The waste water from aquaculture pond let out to the nearby areas caused surface and sub

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surface water pollution. Estuarine waters are the recipients of urban, industrial, agricultural and aquaculture pollution. Shrimp aqua culturists consider their crop failures to be mainly due to organic and inorganic pollution coming from other sources. Waste and sewage from urban and industrial centers from modern agriculture frequently pollute shrimp ponds with heavy metals, pesticides and other toxic products. In areas densely covered with intensive shrimp farms, however, the industry is responsible for considerable self-pollution particularly for bacteriological and viral contamination. Each hectare of pond produces tons of undigested feed and fecal wastes for every crop cycle. These ponds discharge ammonia, nitrites and nitrates. The latter is fatal to fish when it binds with the hemoglobin of their blood.

Objectives
The present research has a focus on the following objectives:
a. To collect the water samples from the selected aquaculture farms physically and analyze the bio-geo-chemical components to find out the nature of contaminants/ abnormal limits to the environment that affect the quality of life in this region,
b. To compare the bio-geo-chemical analysis results to enable the dominating or depending variable that affects the one on the other and also to study the causal relationships,

Methods
To study the bio-geo-chemical analysis of the surface water quality parameters in the shrimp farm zones of Sirkazhi and its environs, among the 82 existing farms, 28 shrimp farms from different zones were selected with the help of the map (Figure -1). These farms are located in different villages, namely, Mahendhirapalli, Thandavankulam, Radhanallur Thirunagavi etc., From these sites sample of 1000 ml of water has been taken from each and every farm to be subjected for various bio-geo-chemical analysis water samples were collected from the place for sample analysis.

The water samples were analyzed in the Microbiology Laboratory and the results were derived for the following parameters: They are: Temperature, pH, Transparency, Conductivity, Total Solids, Total Dissolved Solids, Total Suspended Solids, Ridex Potential, Total Alkalinity, Carbonates, Acidity, Free Carbon-di-oxide, Dissolved Oxygen, Ammonia, Chloride, Calcium, Magnecium, Total Hardness, Salinity Chloride, Phospate, Silicate, Sulphate, Biological Oxygen Demand, COD, Bicarbonate and Hydroxyl Alkalinity. Similarly for the soil sample analysis the following seven parameters were tested: pH, Conductivity, Chloride, Salinity, Total Alkalinity, Phosphaste and Sulphate. The results of the analysis have been discussed in detail in the third chapter with the permissible limits of the quality of environment. From the above analytical results selected water analysis results were taken and they were further subjected to the simple correlation and regression analysis to find the existing relationship and the trend of the variable when it behaves in the same manner what would be the future trend.

Bio-chemical qualities of surface waters in Sirkazhi shrimp farm zones
Once shrimp ponds become operational, there are a host of ecological impacts generated with devastating consequences for the effected environment and human communities in the area. Pollution from shrimp farming has severe side effects for local people who inhabit and use the surrounding environment to maintain their food supplies and subsistence economies. Shrimp ponds demand large and continuous supplies of fresh and salt water and thus use local water resources with great intensity. Shortages of fresh water have resulted in many shrimp producing areas such as southern Thailand and Tamil Nadu, in India.

Physico-chemical qualities of surface waters nearby shrimp farms
To study the existing physico-chemical qualities of nearby shrimp farms in the 28 ponds the following selected parameters were taken in the year 2013 to find the excess limits as per the WHO and ISI standards. Isoline maps (Figures - 2 to Figure - 10) for the selected parameters were drawn to show the spatial distribution pattern of the selected physico-chemical qualities of surface waters of the nearby shrimp farms.

Hydrogen-ion activity (pH)
The effective concentration (activity) of hydrogen ions could be expressed in the same kinds of units as other dissolved species, but H+ concentrations in milligrams per liter or moles per liter are very low for water solutions that are not strongly acid. The activity of hydrogen ions can be expressed most conveniently in logarithmic units, and the abbreviation "pH" represents the negative base-10 log of the hydrogen-ion activity in moles per lite. (Figure 2).

The notation "pH" is now generally taken to mean hydrogen-ion activity rather than concentration, although the distinction between these concepts was not understood at the times Sorensen proposed the use of the pH notation in 1909. The hydrogen-ion content of natural water computed in moles per liter (milligrams per liter for H+ is nearly the same as millimoles per liter) is usually in the "trace constituent" range. At pH 7, only 1×10^{-7} moles per liter of hydrogen ion are present, for example. The major constituents of most waters are in the concentration range of 10^{-4} moles per liter and up. Thus the hydrogen-ion content does not begin to approach the status of a major component of the solution until the pH goes below 4.0. A pH of less than 0 or greater than 14 can be attained in concentrated acid or base solutions. The hydrogen-ion activity in an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. The dissociation equilibrium for water is always applicable to any aqueous solution, but much other equilibrium and many non equilibrium reactions that occur in natural water among solute, solid and gaseous, or other liquid species also involve hydrogen ions. The pH of natural water is a useful index of the status of equilibrium reactions in which the water participates. According to the WHO and ISI standards between 6.5 to 9.2 is present in all the eighteen wells and it is well within the normal limits.

Specific electrical conductance
Electrical conductance, or conductivity, is the ability of a substance to conduct an electric current. Specific electrical conductance is the conductance of a body of unit length and unit cross section at a specified temperature. This term is synonymous with "volume conductivity" and is the reciprocal of "Volume resistivity". The American Society for Testing and Materials (1964, p 383) defined electrical

conductivity of water as "the reciprocal of the resistance in ohms measured between opposite faces of a centimeter cube of an aqueous solution at a specified temperature. "This definition further specifies that units for reporting conductivity shall be "micromhos per centimeter at t0C.", Because the definition already specifies the dimensions of the cube to which the measurement applies, the added precaution of including the length in the unit may not be essential and is often omitted in practice. Geophysical measurements of resistivity, however, commonly are expressed in ohm-meters, referring to a cube 1m on a side, so it may be a good idea to emphasize that conductance of water refers to a centimeter cube. The standard temperature for laboratory measurements is 250C, but because other standard temperatures were used in the past it is important that the temperature of measurement be specified.

Pure liquid water has a very low electrical conductance: a few hundredths of a micro mho per centimeter at 250C. This value has only theoretical significance, because water this pure is very difficult to produce. The presence of charged ionic species in solution makes the solution conductive. As ion concentrations increase, conductance of the solution increases; therefore, the conductance measurement provides an indication of ion concentration.

The conductance of surface and ground waters has a wide range, of course, and in some areas may be as low as 50 mho/cm where precipitation is low in solutes and rocks are resistant to attack. In other areas, conductance's of 50,000 mho/cm or more may be reached; this is the approximate conductance of seawater. Brine associated with halite may contain as much as ten times the dissolved-solids concentration of seawater. The structure and composition of silicate minerals cannot be considered in detail here, but some knowledge of the subject is useful in understanding the behavior of silicon in natural water. There are six principal patterns in which the SiO_4 tetrahedra are joined to build up the framework of silicate minerals. The kind of pattern that occurs is a function of the relative abundance of oxygen in the rock compared with the abundance of silicon. In systems in which oxygen is abundant relative to silicon, the predominant pattern is one in which adjacent tetrahedra are linked through chemical bonding of oxygen with a divalent cation such as magnesium, for example, in the magnesian olivine, forsterite (Mg_2SiO_4). This pattern extends in three dimensions, and silicates of this type are called nesosilicates. A second structural pattern is made up of pairs of tetrahedra sharing one oxygen ion between them, the sorosilicates. Few natural minerals have this structural pattern. A third pattern consists of rings in which three or more tetrahedra each share two oxygen ions. A six-member ring structure occurs in the mineral beryl ($Be_3Al_2Si_6O_{18}$). The silicates having isolated rings in their structure are called cyclosilicates. This structure also is rather uncommon (Figure 3).

The structural features of silicate minerals are described in greater detail by Hiickel (1950, p. 740-755) and in many more recent texts on inorganic chemistry and mineralogy. The structural pattern is rather closely related to the stability of the various mineral species when they are attacked by water. The silicon-oxygen bond is stronger than the metal-oxygen bonds that occur in the silicate minerals. Thus, the resistance to chemical attack, which involves breaking the bonds holding the structure together, is greatest in mineral structures in which a larger proportion of the bonds are between silicon and oxygen.

Chloride
A significant fact illustrating the geochemical behavior of this element is that more than three-fourths of the total amount present in the Earth's outer crust, atmosphere, and hydrosphere is in solution is the ocean as Cl - ions. Chloride forms ion pairs or complex ion with some of the cations present in natural waters, but these complexes are not strong enough to be of significance in the chemistry of freshwaters. They may be of more significance in seawater and brine. Chlorine gas dissolves readily in water and has somewhat stronger and more rapid oxidizing effect than does dissolved oxygen. The element has long been used as a disinfectant or biocide in purification of water supplies. Organic solutes are attacked also, as are other easily oxidized species, and the biological sterility of the solution after the reactions have been completed is readily ascertainable by testing for the presence of free chlorine. It is common practice in water-supply technology to maintain a few hundred micrograms per liter "residual" of free chlorine in solution throughout the distribution system. The WHO and the ISI standards of chloride are 200-600 and 1000 ppm respectively. According to these standards among the 28 sample locations all the farms are having beyond the excess limits of WHO standards and except one well the rest of them are beyond the prescribed limits (Figure 4).

Ammonia
The term ammonia refers to two chemical species, which are in equilibrium in water (NH_3, un-ionized and NH_4+, ionized). Tests for ammonia usually measure total ammonia (NH_3 plus NH_4+). The toxicity to ammonia is primarily attributable to the un-ionized form (NH_3), as opposed to the ionized form (NH_4+). In general, more NH_3 and greater toxicity exists at higher pH. However, limited data also indicate that less NH_3 is needed at lower pH to produce its toxic effects. For the remainder of this discussion, NH_3 always refers to un-ionized ammonia. The USEPA publishes water quality criteria for aquatic organisms. They base these criteria on published studies on fish and other aquatic life and focus on lethal concentrations, typically the concentration at which 50 percent of the test animals die. Other studies have examined the effects at lower "sublethal" concentrations. Although most of the studies on fish deal with food fish (trout, salmon, etc.), some were based on aquarium fish such as oscars and guppies. Among the food fish, salmonids are the more sensitive, so there are separate published criteria for these fish (Figure 5).

EPA's criteria are presented in terms of pH and temperature for both total ammonia and un-ionized ammonia (NH_3), for 1-hr values and 4-day averages. They do not publish one single number. The total and un-ionized concentrations correspond to the equilibrium percentages shown above. EPA recommends that these levels not be exceeded more than once in three years to permit a system to recover from the stress caused by the ammonia pollution. EPA recognizes that some mortality is acceptable in order to protect most ecosystems and that the criteria are inappropriate when there are sensitive, locally important organisms.

For most aquarists, therefore, an additional "margin of safety" is recommended in order to avoid any mortality. For our purposes, therefore, I relabel EPA's concentrations as "Lethal Concentrations". In this water quality analysis

except 12 farms the rest of them are having beyond the excess limits of 0.5 ppm in the nearby shrimp farms as per the ISI standards.

Nitrate
Domestic Use 50 mg/litre
Based on health considerations a limit of 50mg/liter is recommended for babies less than three months old and 100mg/liter for older children and adults. Nitrate levels can be reduced if necessary with the ion exchange process. Stock Use 400 mg/L: Excess nitrate can cause toxic symptoms and even death by reducing the oxygen carrying capacity of the blood. Stock may tolerate higher nitrate concentrations in drinking water provided nitrate concentrations in feed are not high. Levels above 1500 mg/L are likely to be toxic and should be avoided.

Occurrence of phosphate in water
The high phosphate concentration (14mg/LPO4) as well as the nitrate content may be related to waste disposal (Laird, 1964). The concentration of phosphate present in other samples obtained at this sampling point in 1962 was much less. Phosphate has been reported to occur in rather high concentrations in geothermal water in certain localities. Stauffer and Thompson (1978) found, however, that high concentrations reported for Yellowstone Park waters actually represented mostly arsenic, which can interfere with the orthophosphate determination (Figure 6).

Phosphorus associated with particulate material in surface water is of interest in evaluating potential effects on aquatic biota, and a "total" or "total extractable" value for phosphorus is commonly reported. Such numbers have little or no relationship to solutions composition. Date in the literature or stored in data banks may not distinguish clearly between dissolved and dissolved-plus-particulate status for phosphorus. Abadian and Lipton (1976) identified the mineral brushite ($CaHPO_4.2H_2O$) in particulate form in the Neckar River in Germany.

A statistical evaluation of recent trends in "total" phosphorus concentrations at more than 300 NASQAN stream - sampling stations during the period 1972-79 was prepared by Smith and other (1982). At most stations, no significant trend could be discerned. Where there were apparent trends, more were in a downward direction than upward.

Oxygen
The equilibrium concentration of dissolved oxygen (DO) in water in contact with air is a function of temperature and pressure, and to a lesser degree, of the concentration of other solutes. Tabulated values for DO in water in equilibrium with water-saturated air at 101.3 kilopascals (1 atmosphere) at temperatures from 0^0 to $500C$, and having 0 to 20,000 mg/L dissolved Cl-, are given in "Standard Methods for the Examination of Water and Waste Water" (American Public Health Association and others, 1980, p 392). At $50C$ in fresh water the equilibrium DO value is 12.75 mg/L. At $300C$ the concentration is 7.54 mg/L. Values for DO in water analyses may be given in milligrams per liter or as a percentage of saturation at the temperature of measurement.

The higher forms of aquatic life require oxygen for survival, and the DO determination is used widely in evaluations of the biochemistry of streams and lakes. The DO concentration may be depleted by processes that consume dissolved, suspended, or precipitated organic matter, and values above equilibrium can be produced in systems containing actively photosynthesizing biota. For various reasons, determining dissolved oxygen in ground water has not been a standard practice. The dissolved-oxygen concentration of a ground water could not be used as an indicator or organic pollution. Nor would it be significant in evaluation the usability of the water for ordinary purposes. The determination would require special sampling equipment and care and would normally need to be completed immediately after sampling. In this sample study as per the ISI specification range between 4.0 – 6.0 except seven farms namely, SMP, Lingam farm, Balaji, Sri Matha, Kannan, Sathish and Everlast aqua culture farms and the rest of them are having excess limits.

Biochemical Oxygen Demand (BOD)
The BOD determination is commonly made by diluting portions of a sample with oxygenated water and measuring the residual dissolved oxygen after a period of incubation (usually 5 days at $200C$). The results are commonly expressed in terms of weight of oxygen required per unit volume of the initial sample. Sometimes the pollution load of a given waste stream is expressed in terms of the human population level whose normal domestic sewage production would equal the BOD of the stream. The determination is slow to make and has no particularly direct geochemical significance, but it is extensively applied in pollution studies. It is generally considered to be a use ful way of expressing stream-pollution loads and of comparing one set of conditions with another. The WHO has specified the normal limit standards of 6 and when it is concerned, except one well rest of the seventeen wells is in the abnormal limits (Figure 7).

Chemical Oxygen Demand (COD)
To determine pollution or oxidizable material loads more quickly, wet oxidations with strong oxidizing agents have been used extensively. The results can be expressed in terms of oxygen equivalent. Heating the sample with an aliquot of standard permanganate or dichromate is one such procedure. The results of COD determinations obviously do not correspond to values obtained by BOD determinations, but they may be helpful in comparing conditions in a stream at one time with those at another time. According to the WHO standards the normal value is 10 and when compared with the eighteen wells all of them are well within the normal limits (Figure 8).

Hardness
The concept of hardness as an evaluation of certain chemical properties of water has become deeply imbedded in the literature of water analysis and in the habits of thought of almost everyone concerned with water quality. In spite of wide usage, however, the property of hardness is difficult to define exactly, and several definitions are in common use. The terms "hard" and "soft" are contained in a discourse on water quality by Hippocrates (460-377 B.C.) quotated as follows by Baker (1949): "Consider the waters which the inhabitants use, whether they be marshy and soft, or hard and running from elevated and rocky situations." The use of the terms there could have some of the modern meaning; at least limestone was probably present in many of the upland regions familiar to Hippocrates. Over the years,

the property of hardness has been associated with effects observed in the use of soap or with the encrustations left by some types of water when they are heated. If the reactions with soap are the only ones considered, one might say that hardness represents the soap-consuming capacity of water (Figure 9).

Because hardness is a property not attributable to a single constituent, some convention has to be used for expressing concentrations in quantitative terms. Usually, this consists of reporting hardness in terms of an equivalent concentration of calcium carbonate. In practical water analysis, the hardness is computed by multiplying the sum of mille equivalents per liter of calcium and magnesium by 50. The hardness value resulting is generally called "hardness as CaCO3" in tabulated data. The same quantity is sometimes referred to as "Calcium Magnesium hardness" or "total hardness". The usual wet-chemical procedures for determining calcium and magnesium include an amount of these metals approximately equivalent to any other alkaline-earth metals; hence, a reasonable, practical definition of hardness is "the effect of alkaline earth cautions". The WHO prescribed normal limit is 500 ppm and the ISI has permitted 600 ppm. When the sample locations are tallied with the WHO and ISI standards as per the WHO all the shrimp farms are in the abnormal limits. But in the case of ISI standards except one farm rest of them are beyond the normal limits.

Redox Potential

In the section "Electrochemical Equilibrium" the concept of the redox potential, or Eh, of an aqueous system was introduced. It was shown that when the oxidation and reduction processes within the system are at a state of equilibrium, the Eh of the system is a function of the standard potential of the reduction half-reaction and the activities of participating species. This relationship, the equation, was used in the discussion of iron chemistry to develop pH-Eh diagrams that summarize the redox chemistry of the element.

The redox potential is a numerical index of the intensity of oxidizing or reducing conditions within a system, with the hydrogen-electrode potential serving as a reference point of zero volts. Positive potentials indicate that the system is relatively oxidizing, and negative potentials indicate that it is relatively reducing. In the notation used in this book, Eh values are given in volts. As noted earlier, the calculated pH-Eh relationships are useful for predicting and defining equilibrium behavior of multivalent elements.

Total dissolved solids

Water is a good solvent and picks up impurities easily. Pure water - tasteless, colorless, and odorless -- is often called the universal solvent. Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water. TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, that is the plumbing. In the United States, elevated TDS has been due to natural environmental features such as: mineral springs, carbonate deposits, salt deposits, and sea water intrusion, but other sources may include: salts used for road de-icing, anti-skid materials, drinking water treatment chemicals, storm water and agricultural runoff, and point/non-point wastewater discharges (Figure 10).

In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the total dissolved solids test provides a qualitative measure of the amount of dissolved ions, but does not tell us the nature or ion relationships. In addition, the test does not provide us insight into the specific water quality issues, such as: Elevated Hardness, Salty Taste, or Corrosiveness. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water. The sources of total dissolved solids can include all of the dissolved cations and anions, but the following table can be used as a generalization of the relationship of TDS to water quality problems. The presence of TDS prescribed by the normal limit is 500 and as per this ISI and WHO specifications all the eighteen wells are within the abnormal limits.

Figure - 4

Figure - 5

Figure - 6

Figure - 7

Figure - 8

Figure - 9

Figure - 10
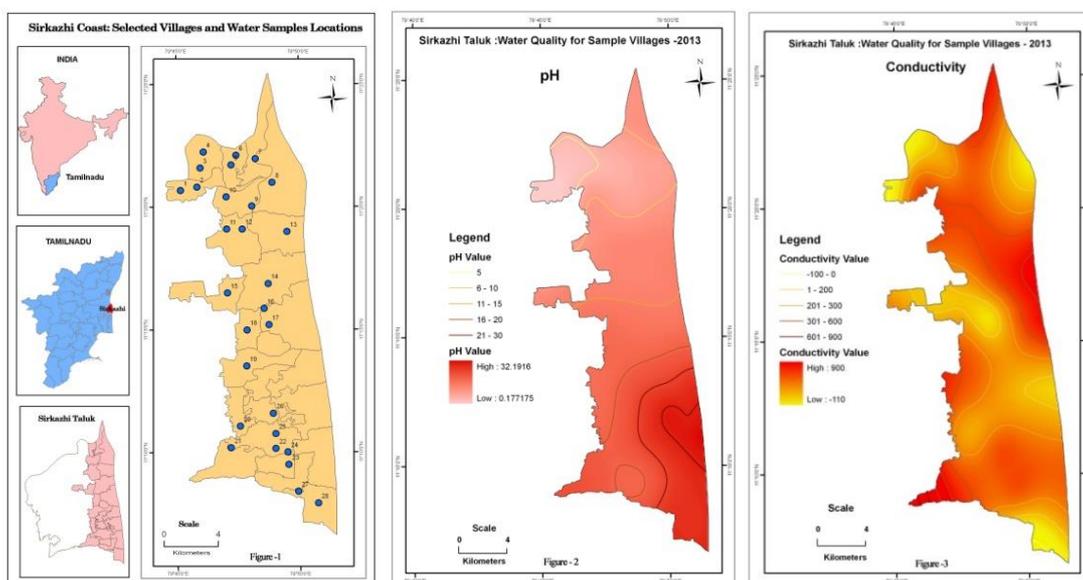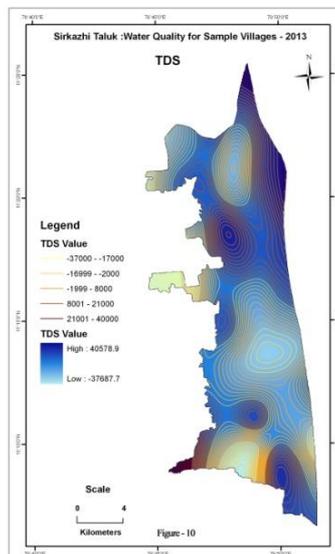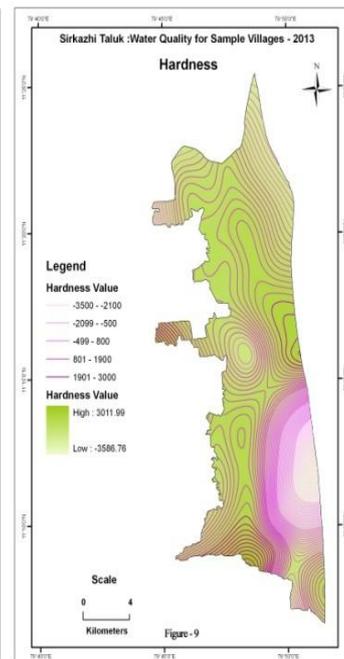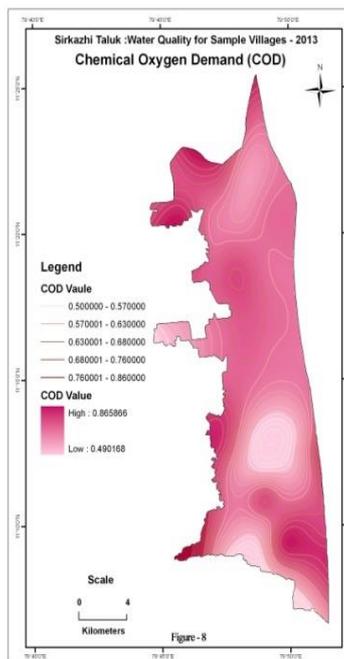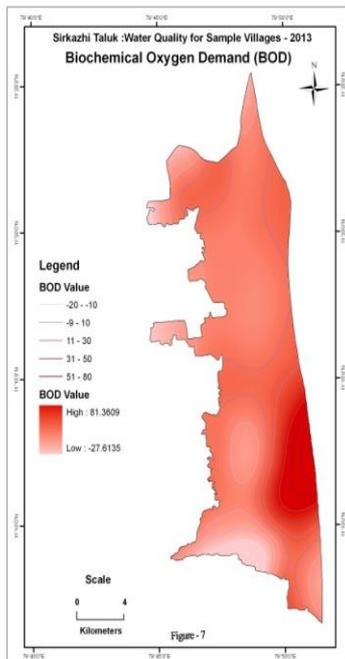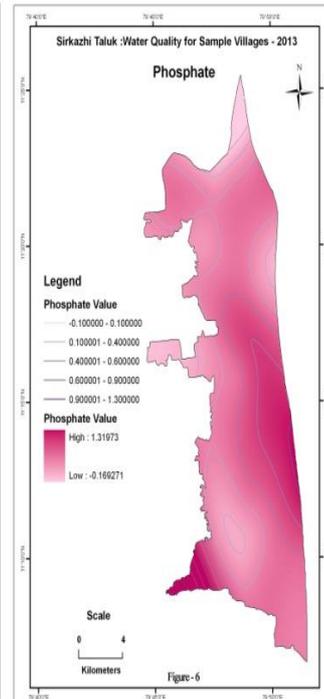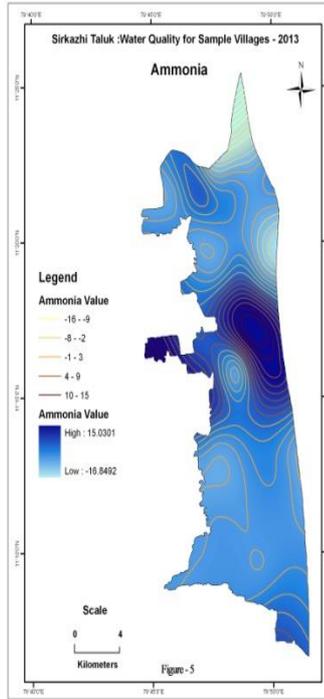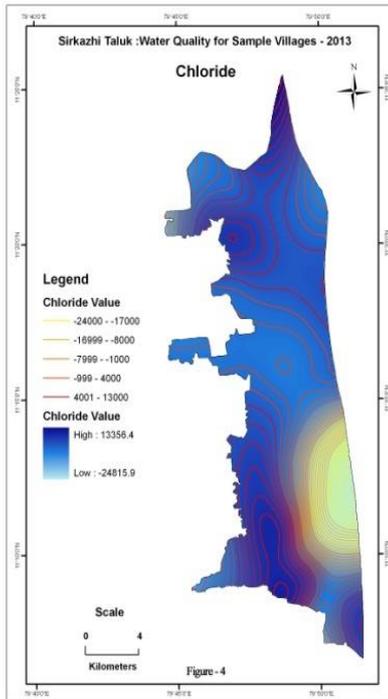
Conclusion

The shrimp farming industry is characterized by boom and bust cycles. The latter are usually caused by production crashes resulting from disease outbreaks. The economic and socioeconomic consequences of these crashes have dire impacts across all levels of the economy but especially for the local communities directly involved in and dependent on shrimp farming for their livelihoods. Moreover, shrimp production is a major contributor to coastal zone pollution and degradation. Another common characteristic of the industry is the use of intensive farming methods. Encouraged by the high and quick profits, intensive farming is perceived by many to be the only profitable option. It involves high stocking densities and excessive use of artificial feed to supplement growth. While there is growing evidence of a strong correlation between intensive farming and disease occurrence, farmers are willing to risk intensive production.

Effectively farmers have two choices. The first is to employ intensive farming techniques and hope for no disease. In the event that they do occur farmers may opt for an early harvest, but for a lower price due to smaller shrimp size. The second choice is to employ techniques, which require lower stocking levels and less risk of disease outbreaks. However, many farmers believe that disease occurrences are beyond their control and that, irrespective of their actions, outbreaks will occur. It is certainly the case that disease outbreaks are to a large extent dictated by the actions of the other farmers. This is because the water they use for the ponds comes from a common system and disease from one farm is easily transmitted through the water channels, with a high probability of wider infection. In a sense we have a prisoner's dilemma, and unless cooperation among farmers is guaranteed, it is optimal for individual farmers to choose a high-risk strategy and to take their chances. With luck a farmer may harvest a full crop; if not there is still a harvest, albeit at a lower price. Many aqua culturists argue that intensive farming is not the only cause of disease outbreaks. They emphasize that, with good pond management, intensive farming can be made sustainable. It must be stressed that diseases cannot be completely eradicated, as there is always the natural random factor. Moreover, as mentioned above, individual farm management can only reduce the disease probability to a certain extent. Yet even this can be mitigated to a certain extent with new water management techniques, which reduce the frequency of water exchange with the common system. This, coupled with the use of chemicals to clean the water, has gone a long way to reduce the degree of dependency on other farming strategies. Although these factors have been highlighted as critical variables governing the probability of disease outbreaks, there have been very few studies analyzing the quantitative contribution to this probability.

References

1. Aquaculture. Outbreak of Shrimp Viral Disease in Central America: Situation Report 1999-2000.
2. Baird IB, Quarto A. The environmental and social costs of developing shrimp aquaculture in Asia. Trade and the Environment: Prospects for Regional Cooperation Berkeley, CA: Nautilus Institute. 1994, 188-214.
3. Bakr, Mahmoud. A Stochastic Inverse-Management Approach to Groundwater Quality. 2000, 6164-6176.
4. Barg UC. Guidelines for the promotion of environmental management of coastal aquaculture development. FAO Fisheries Technical Paper No. 328. Rome, FAO. 1992, 122.
5. Barg UC, Bartley DM, Tacon AGJ, Welcomme RL. Aquaculture and its environment: a case for collaboration. 1997, 462-70.
6. Beveridge MCM, Phillips MJ, Macintosh DJ. Aquaculture and the environment: the supply of and demand for environmental goods and services by Asian aquaculture and the implications for sustainability. Aquaculture Research. 1997; 28:797-807.
7. Boyd CE. Codes of Practice for Responsible Shrimp Farming. Global Aquaculture Alliance, St. Louis, MO. 1999a.
8. Chen HC. Water quality criteria for farming the grass shrimp, Penaeus monodon in : Proceedings of the fist International conference on culture of Penaid prawns/ shrimps, edited by Y, Take, J.H. Primavera and J.A. Liobrea. 1980, 165.
9. Collins A, Russel B. Inland Prawn farming trail in Australia. Pond study tests Penaeus. Monodon performance in low salinity ground water. Global aquaculture advocate. 2003, 74-75.
10. Doyle RC, Stanton GC, Wolf DC. Effectiveness of Forest and Grass Buffer Filters in Improving the Water Quality of Manure Polluted Run-off, American Society of Agricultural Engineers, St Joseph, MI. 1977; 77:2501.
11. Goldburg R, Triplett T. Murky Waters: Environmental effects of Aquaculture in the United States. 1999. [viewed on November 10, 1999].
12. Heinrichsen D. Coastal Waters of the World: Trends, Threats, and Strategies, Island Press, Washington, DC. 1998.
13. Phillips MJ, Beveridge MCM, Clarke RM. Impact of Aquaculture on water resources. in D. E. Bruen, and J.R. Tomasso, (Eds.), Aquaculture and water quality. Adv. World Aquaculture. 1991; 3:568-591.
14. Pruder GD, Duerr E, Walsh W, Lawerence A, Bray W. The Technical Feasibility of Pond Liners for Rearing Pacific White Shrimp (Penaeus vannamei) in Terms of Survival, Growth, Water Exchange Rate and Effluent Water Quality. Aquacultural Engineering. 1992b; 11:183-201.
15. Simpson HJ, Pedini M. Brackishwater Aquaculture in the Tropics: The Problem of Acid Sulphate Soils, Fisheries Circular No. 791, Food and Agriculture Organisation of the United Nations, Rome. 1985, 32.