Chapter 7

Future directions

This thesis presents the study of plankton dynamics in the presence of predator kairomones from ecological and mathematical point of view. Predator-prey interactions are the most important factor in energy flow from one trophic level to higher trophic level through food webs. The effect of predators can be direct and lethal, or it may be indirect and non-consumptive. The presence of predator (predator kairomone) can change the life history, morphological and behavioral traits in prey individuals. Such inducible defenses affect the trophic interactions by altering predator feeding rates through changes in attack rate or handling time, or both, which may alter the flows of energy. Such short-term effects of inducible defenses in prey individuals can influence long-term community dynamics. The main results of this thesis consisting of various models are to make predictions of the effects of altered energy flow caused by the costs and benefits of antipredator defenses on community stability, and community structure. The work helps unveil the characteristics of the
DVM and reverse DVM of prey and predators respectively, and the impact of environmental factors on it.

Future direction is one of the most important issues of this thesis. The philosophy and the simple mathematical tools used in this thesis, will provide a great inspiration for researchers in recent future.

The results thus obtained from the theoretical studies, I like to perform some field/laboratory based studies. Based on those studies, I like to estimate the values of model parameters and these will help to simulate the models. I hope some new things will come out, which will receive a considerable interest to the experimentalists to do further studies.

The dynamics of nutrient recycling by zooplankton in combination with diel vertical migration is interesting one. Nutrient recycling is important for phytoplankton especially in oligotrophic lakes because the amount of available nutrients is an important factor influencing phytoplankton population growth. It is obvious that the direction of the gross nutrient transport by migrating zooplankton depends on the nutritive value of the food in the epilimnion and hypolimnion of a lake. For example in a lake with low food densities in the hypolimnion, DVM can lead to a reduction of available nutrients for the phytoplankton in the epilimnion due to the fact that the zooplankton population transports more nutrients from the epilimnion into the hypolimnion and vice versa. On the other hand, recent research has drawn attention to deep-chlorophyll maxima which would ultimately lead to an opposite effect as described above (Williamson et al. 1996, Winder et al. 2003; the present study).
ima is a virgin field to be worked on.

Another interesting area where we can do work in the future is the spatio-temporal variability of natural plankton community. A general hypothesis is that prey population approximates the predation pressure by the abundance of predator or predator-exudates in the system. However, the defense mechanisms observed in prey population are regulated by the predator population available in their neighborhood, not by the whole predator population. Populations of ecological species do not remain fixed in space, their distribution changes continuously due to the impact of environmental factors, and/or due to self-motion of individuals. Mathematical modeling requires the use of reaction diffusion equations to describe the above phenomena and we can easily extend the temporal equations to diffusion equations. In this manner, spatio-temporal effects can be explored under realistic conditions. Then by considering spatially-explicit model, we can study the role of local competition among fish and zooplankton. By varying the neighborhood size of fish population, we can compare localized dispersal with dispersal over longer distances.

We can modify our model systems by incorporating complex stochastic processes which in turn are capable to explain more realistic situations of our systems. The main problem in analyzing stochastic differential equation (SDE) is the lack of tools to find the stability property of these systems. Here we can try to develop some suitable technique to analyze the stability of a system of SDEs.

Different biotic (like, presence of omnivore predator, predator switching, gestation delay, disease induced incapability of reproduction and defense mech-
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Animals, etc.) and abiotic (like, diel and seasonal variation in temperature, light, etc.) factors can also be incorporated in our proposed model to study more realistic systems.

Before ending the thesis, I would like to mention that mathematical models help a lot to understand the complex biological properties of a system. It would be more enriched if we can collaborate with the experimental biologists. I shall try to collaborate my future studies with the experimental biologist/ecologist.
Publications from the Content of the Thesis

Published:


Communicated:

1. **Sudip Samanta** and Joydev Chattopadhyay. Effect of kairomone on predator-prey dynamics - a delay model. *International Journal of Biomathematics* (under revision)