Preface

Looking into the water of a shallow lake or pond one might have a crystal clear view of gently waving submerged plants, fishes darting off and small animals moving busily around. More likely, however, the water is murky, troubled by blooming algae and suspended sediment particles hiding whatever is going on below. Remarkably, intermediate situations between these two extremes seem relatively rare. This impression may result from our persistent tendency to dichotomize in an attempt to simplify the world, but research suggests that in this case there is some truth in the dichotomy.

The two situations represent strongly contrasting community states, both of which have stabilizing feedback mechanisms. In the turbid state, the development of submerged vegetation is prevented by low underwater light levels. The unprotected sediment is frequently resuspended by wave action and by fish searching for food causing a further decrease of transparency. Since there are no plants that could serve as refuges, zooplankton is grazed down by fish to densities insufficient to control algal blooms. In contrast, the clear state in eutrophic shallow lakes is dominated by aquatic macrophytes. The weed beds prevent sediment resuspension, take up nutrients from the water, and provide a refuge for zooplankton against fish predation.

In view of these feedback mechanisms it is not surprising that shallow lakes refuse to obey simple rules such as the classical relationships between algal biomass and nutrient loading. The response of shallow lakes to eutrophication is often catastrophic rather than smooth, and several lakes are known to have switched back and forth between a clear and a turbid state repeatedly without obvious external forcing. In view of the relative neglect of shallow lakes in limnological literature, this disparate behaviour has apparently discouraged rather than tempted researchers for a long time. Even in countries where almost all the lakes are shallow, like Denmark and The Netherlands, limnological research has traditionally been focused entirely on the few deep lakes that were available. Over the last decade, however, this situation has changed.

Many of the shallow lakes have become turbid during this century because of eutrophication, and efforts to restore the clear state by means of reduction of the nutrient loading are often unsuccessful. This has invoked experiments with additional methods such as temporary reduction of the fish stock. The potential impact of such disturbances on shallow lake ecosystems appears to be huge, and several lakes have switched to a stable clear state in response. The careful monitoring of these changes has catalysed the

development of insights into the mechanisms that govern the dynamics of shallow lake communities.

Writing this book has been an (unfinished) journey towards the goal of constructing a coherent picture of 'how shallow lakes work'. Unravelling the origin of main ideas is probably as difficult as unravelling the functioning of lake ecosystems, but some things can be said about the intellectual roots of the views presented in this book. The feeling that there was something like alternative stable states in our lakes, and ideas about the roles of fish and vegetation have been fermenting for at least a decade in a group of English, Danish and Dutch limnologists. Surely, Brian Moss and Erik Jeppesen were very important inspiring thinkers in this group. At our institute Andre Breukelaar, Harry Hosper and Marie-Louise Meijer were my partners in discussing these exciting views.

Erik Jeppesen was the one who after reading the first draft encouraged me, explaining that it was going to be great, but pointing out kindly that I needed to do quite a bit of extra homework. The book ripened during the subsequent phase when I tried to understand the often conflicting results from countless descriptive and experimental studies, a process that definitely helped the theoretician in me to become more modest. Sergio Rinaldi was my guide in the fascinating and dazzling world of dynamical systems theory with its attractors, bifurcations and other abstract structures. Together we looked for parallels to the even more dazzling world of aquatic food webs. Rob de Boer and Yuri Kuznetsov developed wonderful software for analysing models and guided me in using it.

Don DeAngelis, who suggested me to write this book, invited me over at the Oak Ridge National Laboratory to work, and gave many useful advices and comments. Eric Marteijn and the rest of the staff at RIZA have been very supportive and flexible, allowing excursions into research topics that go beyond a directly applied context, and giving me the time to write this book. It was a great pleasure to write a large portion of it in the beautiful Tennessean country house of Bob and Dorothy Jolley.

With Adriaan Achterberg I shared an unforgettable time doing our first work in aquatic ecology trying to figure out what happens in ditches. He made a number of pen drawings especially for this book (Figs. 4.3, 4.42, 1.4, 4.49, 3.13, 5.1, 2.15, 4.46). The cover illustrations are made by Ad Swier. Bert Jansen prepared most of the technical drawings and kindly tolerated my numerous changes of mind. Rita van Leeuwen did an invaluable job localizing relevant literature. Egbert van Nes has been a crucial help all the way, solving problems with software packages, writing better ones, helping organizing and finding literature, discussing countless important and unimportant ideas during our lunch-walks and quietly pointing out crucial problems in seemingly brilliant reasonings.

The complete draft of the book has been read by Irmgand Blindow, Steve Carpenter, Hugo Coops, Milena Holmgren, Harry Hosper, Mark Hoyer, Bas Ibelings, Erik Jeppesen, Eddy Lammens, Marie-Louise Meijer, Stuart

Mitchell, Brian Moss, Egbert van Nes, Ruurd Noordhuis, Marcel van der Berg and Diederik van der Molen, while portions were reviewed by Herman Gons and Hendrik Buiteveld. Without their extensive comments the book would have been much harder to read.