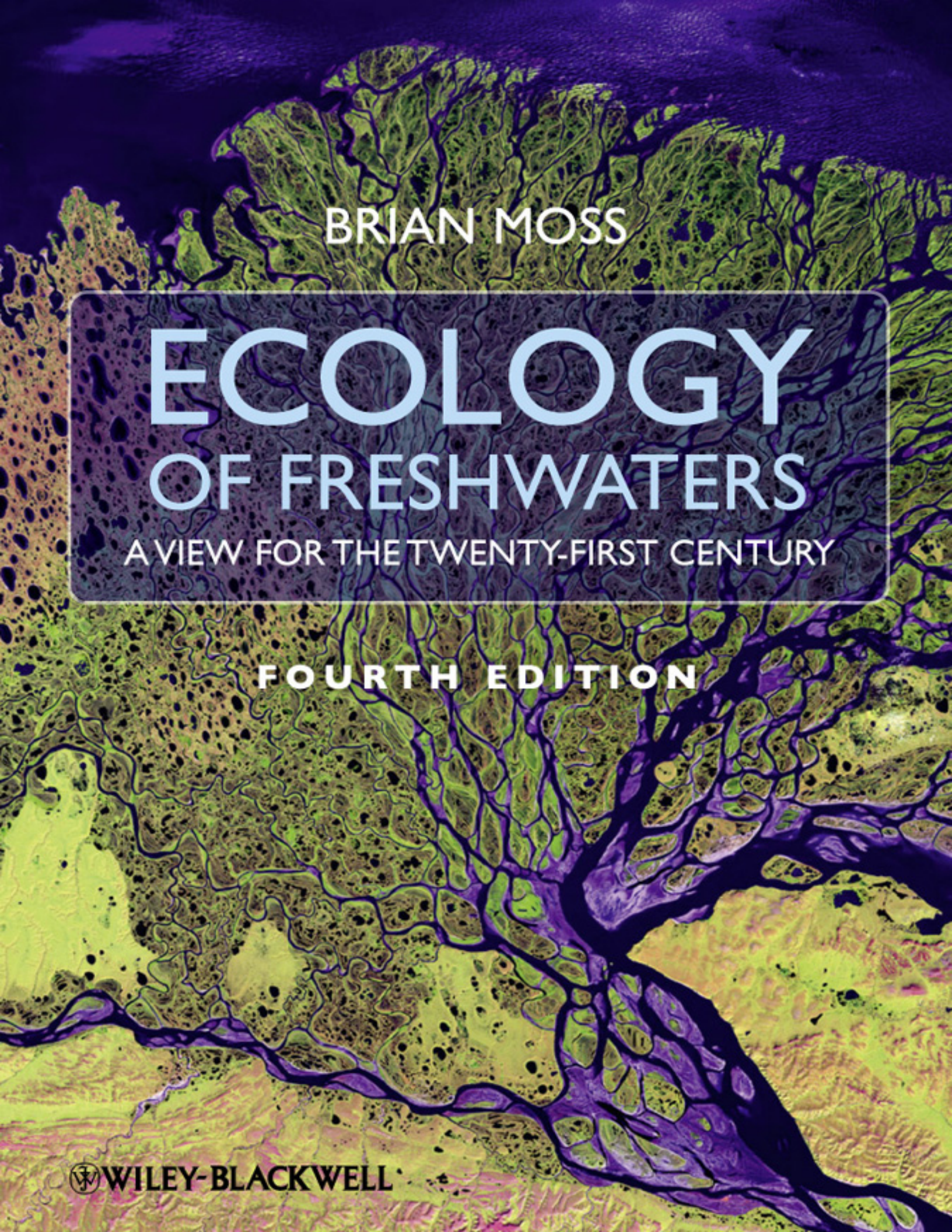
BRIAN MOSS
ECOLOGY
OF FRESHWATERS
A VIEW FOR THE TWENTY-FIRST CENTURY
FOURTH EDITION
WILEY-BLACKWELL

CONTENTS

Fourth Edition

ECOLOGY OF FRESHWATERS

A VIEW FOR THE TWENTY-FIRST CENTURY

Brian Moss

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WILEY BLACKWELL


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Dedication

For my wife, Joyce, my daughter Angharad,
my friends and colleagues, and all who have not sacrificed
their honesty and principles for personal
aggrandisement, wealth and power
O quam cito transit gloria mundi
(How quickly the glory of the world passes away)
Thomas à Kempis, 1418

Companion website

A companion website for this book is available at:
www.wiley.com/go/moss/ecology
The website includes figures from the book for downloading.

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Chapter 1

INTRODUCTION

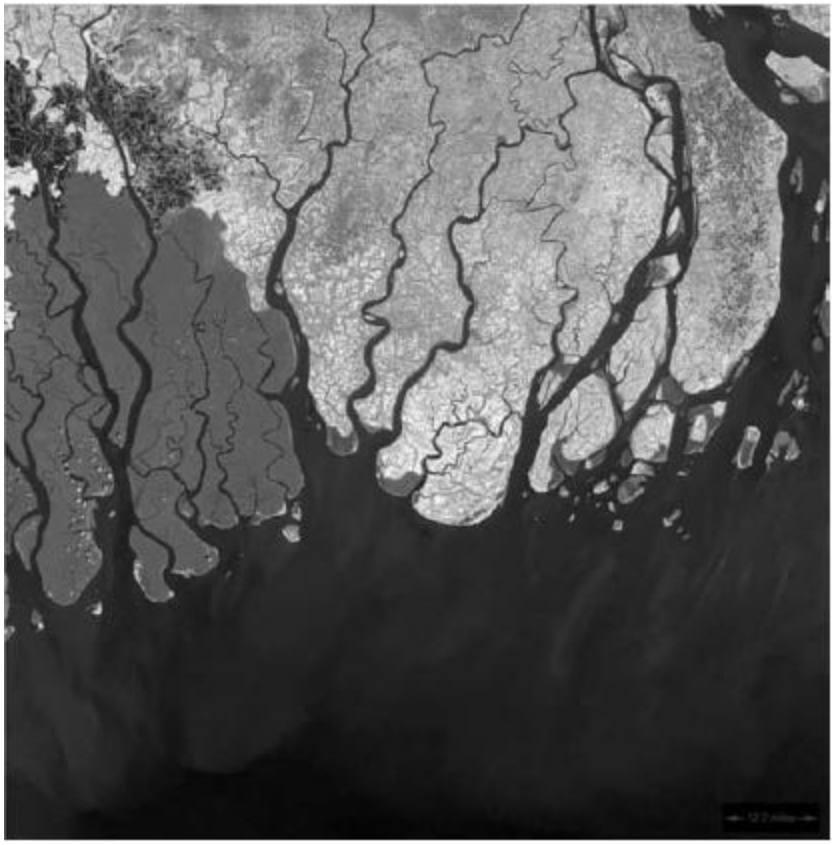
1.1 WHY?

Textbooks usually sound a bit pompous. It's in their nature as the factual 'text': that which has to be known. Yet some, at least, come from the passions of their authors wanting to pass on their enthusiasms, reflected in the facts. But the relative importance of facts changes as understanding grows and the facts only increase in number as time passes. A huge number appear in articles, books and websites on almost everything, and although there is a lot of repetition, sometimes direct, sometimes just new examples of general principles, and sometimes recycling, by newer methods, of ideas that originated long ago, the amount is nonetheless daunting. Most of the scientific literature is written as if no one wants to communicate anything, anyway. The writing is pompous, self-serving, full of unnecessary jargon and distinctly off-putting. Quite a lot of it is deceptive in that something is written as if it is an entirely new revelation when this is far from the case. I have had to wade through a lot of it, often needing to read things several times for glimmers of understanding to emerge. Not surprisingly the population in general cannot be much bothered with scientific findings. The positive side is that when one teases out the meaning, it is completely fascinating! This is the fourth edition of this textbook. The previous editions have grown bigger and bigger so I decided to write a shorter fourth completely from scratch, mostly because I wanted to break away from the near complete emphasis on Europe or

North America that most freshwater textbooks have had. Faced with so much information, however, this proved trickier than I had thought.

My first difficulty was that water is part of everything environmental. You cannot overestimate its importance. Planet Earth is very unusual, in the immediate Universe at least, in having a surface skin dominated by water. Two-thirds of its surface is ocean. Moreover, the evaporation and condensation of water, driven by the Sun's energy, controls the climate and hence what grows where and how well. The river systems, with their lakes and floodplains, stitch the land surfaces and the coastal seas together (Fig. 1.1) with the threads of water and mineral cycles, yet constitute only a small percentage of the total water. Most of it is in the ocean, polar icecaps or underground in the interstices of soils and rocks. More than 90% of the content of all living things is water; even land animals are totally dependent on a continual supply of it. We ourselves can only maintain our settlements where there is a reliable supply of freshwater, and because surface freshwater is relatively scarce, its division among different people and interests causes major political problems, even wars. If you are to write a book on freshwater, you have, at least, to pretend to be a polymath.

Fig. 1.1 The Ganges Delta in Bangladesh seen from a satellite. The interconnectedness of the land, the river system and the ocean can be clearly seen from satellite photographs. (Copyright U.S. Nautical and Space Administration.)



One relief was that it was to be a book on freshwaters, so the ocean could be nearly ignored - but only nearly! A famous speech by a North American Indian chief, Seathl (Fig. 1.2), contains the sentence 'All things are connected'. The speech was about the natural linkages between land and, water, plants, animals and people, and there is some doubt that he actually said it. But to a professional ecologist, it rings completely true. All things really are connected. There are people who call themselves lake ecologists (limnologists), river ecologists (potamologists) and wetland, or mire, ecologists, let alone the larger camp of terrestrial ecologists, subdivided into grassland ecologists, forest ecologists, desert ecologists or evolutionary ecologists, community and population ecologists, even theoretical ecologists, who thrive in warm offices rather than wet and windy hillsides. Yet there is really only one tribe of ecologists and ultimately only one

ecological system, the biosphere as a whole. One cannot write a book covering everything, however, so this one tries to single out the catchment (watershed or river basin) as the unit.

All the land surface is divided into one catchment (Fig. 1.3) or another, on which water falls then passes through streams and rivers, lakes and wetlands eventually to the sea or, in very arid regions, which cover nearly half the land surface, as vapour to the atmosphere. All of streams, rivers, lakes and wetlands are basically the same. They are depressions of the land through which freshwater passes, and there are many common features to them. There are also differences based on how quickly the water passes through and it is useful to look at them individually to discern what is happening. But fundamentally they march to the same drumbeat.

The connectedness appears in every aspect of ecology. Every action has consequences radiating in every direction. You cannot dam a small river in the highlands without having some effect on the river estuary perhaps hundreds of kilometres away. You cannot farm the land and expect a downstream lake to stay the same as it was before. You cannot change the climate and expect everything to go on as usual. The land and the freshwaters together have to be seen and discussed as a whole. Freshwater science is a microcosm of the whole of environmental science. There is something of everything in it.

Fig. 1.2 Photograph of Chief Seattle (also Sealth, Seathle, Seathl or See-ahth) (*c*. 1786–1866), who was a leader of the Suquamish and Duwamish Native American tribes and after whom the city of Seattle is named. He made a speech in his native language, Salish, on the arrival of a newly appointed territorial governor, which has become important in environmental thinking. In it he is purported to have said: '*All things are connected. Whatever befalls the earth befalls the sons of the earth. Man does not weave the web of life; he is merely a strand of it. Whatever he does to the web, he does to himself*'. In truth he may have said something along these lines, based on notes taken at the time by Dr Joseph Smith, but these words, though nonetheless inspiring, were written by a scriptwriter, Ted Perry, in 1972 for a film called 'Home', produced by the Southern Baptist Radio and Television Commission.

There was a difficulty in drawing boundaries with time also. A very well-known ecologist, G. Evelyn Hutchinson (Fig. 1.4), used the metaphor of the environmental (or ecological) theatre and the evolutionary play. As the environment changes (and it does so continually), the players, who can be thought of as the genes, the individuals or the species, must change too if they are to stay on stage. And as each of these players changes, there are consequences for other players, who might be competitors, predators or prey, and who might also have to change. Some reference to evolution is needed, for that is what the process of change in organisms is about. Many of the ecological features of particular organisms reflect the conditions under which they first evolved. Cyanobacteria still retain the preferences for low oxygen waters that hark back to the anaerobic world, two or three billion years ago, in which they originated, but themselves began to modify by evolving oxygen-producing photosynthesis. The adults of many freshwater insects and the flowers of most aquatic plants are essentially aerial for it was from land-based ancestors that they entered the water. Time has many scales. Lakes and rivers have ecological histories, sometimes quite short for many were obliterated by the last glaciation and emerged anew only 10,000–15,000 years ago. Others may have persisted for some millions of years, but because climate changes naturally over that scale, they have been bigger or smaller, freely flowing or isolated from time to time. They also change from year to year and biological changes may be recognizable from minute to minute. The multimillion-year scales of evolution are not a major subject of this book but a study of ecological history is essential to understanding the processes of the present.

The third difficulty was in coping with ourselves. Most freshwater ecologists used to head for the hills in their research. They sought the least disturbed, ideally the

pristine environments, where the results of the evolutionary play are still intact and where the design of the environmental theatre has not been wrecked by the incompetent architectural abilities of people. As a result we can draw for you pictures of intensely fascinating ecologies: the floodplain forests of the Amazon, with their seed-eating fish; the connections between wolves and bears in the functioning of river systems of the north-temperate zone; the division of the available food in the African Great lakes among fish so specialized that some scrape the scales or bite the eyes of others. We can take you to lakes and wetlands in seemingly endless landscapes of forest and savannah, steppe and even desert. We can be more escapist than the glossiest of travel brochures.

Yet what we also know is that these gems are just the meagre crumbs of what the world once was like, but no longer really is. People have been around for perhaps one or two million years and evolved along with the natural ecosystems that give us great delight. The ways in which people meshed, as hunter–gatherers or even simple cultivators, with other animals and with plants, when people were neither numerous nor too ambitious, are parts of the fascination of natural systems. The reality for recent generations has been very different. The past 200 years have seen the progressive destruction of the detail of the freshwater, indeed of all environments (Fig. 1.5). There is no longer any completely pristine freshwater system in Europe and arguably, since we have contaminated the entire atmosphere with pesticides, emitted gases that fall as acid in the rain, and are now changing the climate, perhaps there are none anywhere (Fig. 1.6). Those who live in cities will see rivers embanked with concrete;the ponds and lakes will often have signs warning of toxic blue-green algae; rivers in the lowlands will have been straightened and the woody debris that was so important for their ecology removed;

lakes will have muddy deltas where the products of erosion wash in from cultivated land. The bears and wolves have long gone and even many of the fish that were once common, Atlantic salmon in Europe for example, are now rare. Previous ecological textbooks, including earlier editions of this one, pretended that the world was intact and tagged on human influences as secondary. That is truly no longer the case. The world is heavily damaged and more than half its natural ecosystems are seriously degraded. An honest textbook must reflect this.

Fig. 1.3 The north-west of England showing the land surface made up from abutting river catchments. The world's entire land surface is divided up in this way. Many catchments adjoin those of a larger river and eventually discharge to the seas and oceans, but this is not necessary. Many catchments are entirely land-bound and water leaves them, not at an estuary, but by evaporation to the atmosphere.


Derwent (NW)
South West Lakes
Kent/Leven
Lune
Ribble
Wyre
Douglas
Irwell
Alt/ Crossens
LIVERPOOL
Mersey Estuary
MANCHESTER
Upper Mersey
Weaver/Gowy
STOKE-ON-TRENT
N
340,000
440,000
Kilometres
0 10 20 30 40
IRISH SEA

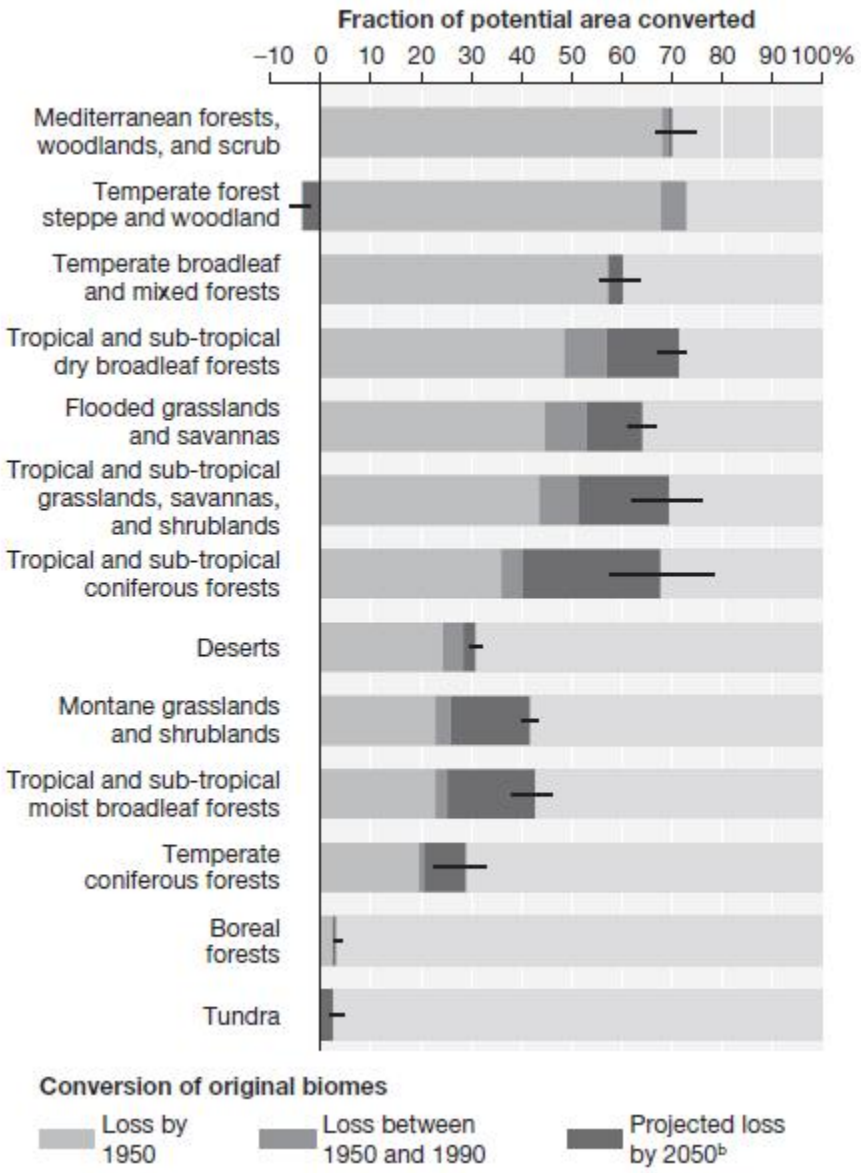
Fig. 1.4 G. Evelyn Hutchinson (1903–1991), born in the UK and working mostly in the USA after a period in South Africa is well-known for his work in limnology and the writing of a major set of books on the subject. But he had a very wide vision of ecology and biogeochemistry and was widely familiar with oceanography, anthropology, paleontology, sociology and animal behaviour, whilst also being well versed in the arts and music. Such breadth is rare but often contributes the more interesting ideas and new trends to individual sciences.

So the final difficulty is one of motivation, for both of us, reader and author. Ecologists do not particularly want to write as historians of what once was, but no longer is. They do not want to appear as doomsayers, perpetually depressed and backward-looking. Nor do they want to instil the idea that things are going so steeply downhill that nothing can be done. To undermine optimism and morale is the greatest disservice and is self-fulfilling. Better to see things like this. We are studying perhaps the most

interesting scene of the evolutionary play so far. People are immensely successful organisms, arch-competitors that have already out-competed many species and brought many already to extinction, and that milk is spilt.

Yet when one looks at the population fluctuations of an animal or plant, there are times when numbers (and thus impact) rise temporarily above the notional line of carrying capacity. For a very small part, a few decades, of our million-year history we have been above this line. It has had immense effects, but we live on a planet that has its own mechanisms of stabilizing its environment and may make its own adjustments, though these may be something of a shock to our eventual numbers. We can avoid that, however, for we know a lot about how these systems work. We already have the capacity to start readjusting and redesigning so that we maintain ecological systems that will not be the same as those in the past, but which will still be interesting, pleasant and functioning. It is there that freshwater, indeed all, ecological science starts to involve the human social sciences, for all things are also connected with human societies. In the final analysis, our present difficulties, frustrations and depressions can be a significant but reversible blip of human history not the start of an unending nightmare. There is a whole science of restoration ecology (Fig. 1.7): the putting together again of the bits that have been taken apart.

Fig. 1.5 Major damage and losses of major world biomes by 1950 and 1990, and projected on present trends for 2050. Where damage occurs to the biome in general, this is reflected in the freshwater systems contained within it to a considerable extent, for the waters draining the land are greatly affected by what happens on the land. Only the tundra and boreal forests have not suffered very extensive damage. Partly this may be because two groups of aquatic insects, the mosquitoes and the black flies, make them difficult to live in. (Source: Millennium Ecosystem Assessment.)



And against all these difficulties, there is one monumental bastion. Freshwater ecology is immensely interesting. I do not want to sound parochial about this. Anything is very interesting if you go deeply enough into it. But freshwaters are so much a part of our daily lives (go and turn the kitchen tap on) that they have a special place. One of my colleagues illustrated this by asking students to imagine somewhere where they would feel most relaxed. Almost invariably the scene involved water. A few years ago, I was informed by my increasingly bureaucratic University administration that

the course (newly called a module) I had taught for several decades in one form or another must have ‘Aims and Objectives’. I replied that these were simple: to interest and enthuse. When they said that was against the rules and not adequate, but forgot to make a rule that I could not write in verse, I produced the following. It’s the theme of this book.

> At this module’s end, you’ll know,
> That water comes from rain and snow,
> Dissolves most things then rests in basins,
> And seals the fates of arid nations.

Fig. 1.6 Trends in damage to major world habitats and their reasons. The intensity of shading indicates the degree of damage so far. The arrows indicate whether this damage is decreasing (pointing downwards), staying the same (horizontal), or increasing to a moderate (sloping upwards) or high (vertical) degree. Changes are grouped as habitat change (mostly complete destruction), climate change, invasive species, overexploitation (by fisheries, for example) and eutrophication (pollution by excessive nutrients). Inland waters have suffered perhaps the greatest damage so far and are under the greatest future threats. (Source: Millennium Ecosystem assessment.)