Weed Ecology in Natural and Agricultural Systems

Weed Ecology in Natural and Agricultural Systems

Barbara D. Booth

Department of Plant Agriculture
University of Guelph
Canada

Stephen D. Murphy

Department of Environment and Resource Studies
University of Waterloo
Canada

and

Clarence J. Swanton

Department of Plant Agriculture
University of Guelph
Canada

CABI *Publishing*

CABI *Publishing* is a division of CAB *International*

CABI Publishing
CAB International
Wallingford
Oxon OX10 8DE
UK

Tel: +44 (0)1491 832111
Fax: +44 (0)1491 833508
E-mail: cabi@cabi.org
Web site: www.cabi-publishing.org

CABI Publishing
44 Brattle Street
4th Floor
Cambridge, MA 02138
USA

Tel: +1 617 395 4056
Fax: +1 617 354 6875
E-mail: cabi-nao@cabi.org

A catalogue record for this book is available from the British Library, London, UK.

Library of Congress Cataloging-in-Publication Data

Booth, Barbara D.
Weed ecology in natural and agricultural systems/Barbara D. Booth, Stephen D. Murphy, and Clarence J. Swanton.
p. cm.
Includes bibliographical references (p.).
ISBN 0-85199-528-4 (alk. paper)
1. Weeds—Ecology. 2. Weeds. I. Murphy, Stephen D.
II. Swanton, Clarence J. III. Title.
SB611.B59 2003
632’.5—dc21
2002010884

ISBN 0 85199 528 4

Typeset by Wyvern 21 Ltd, Bristol
Printed and bound in the UK by Biddles Ltd, Guildford and King’s Lynn

Contents

Preface

Our goal in writing this book was to describe why weeds occur where they do. We have made no attempt to discuss their management and control: there are excellent texts available for that. Rather, we think that students should understand how and why weeds fit into their environment. This text presents ecological principles as they relate to weeds. Ecology is central to our understanding of how and why weeds invade and yet there are few books that make this connection. That is the niche we hope to fill.

We make no excuses for using the word 'weed', and, since humans decide what species are considered to be a weed, we make no attempt at a detailed definition. We could really have used the word 'plant' throughout the text. We have tried to present a broad array of weed examples, and have therefore selected weed examples from different types of systems – agricultural, managed (e.g. forestry) and natural systems – and from around the world.

The book was designed as a teaching text for a middle year undergraduate course. No ecological background is assumed, although some basic biology is required. We have tried to write it and arrange the material so that it is presented in a clear concise manner. At the beginning of each chapter, we have listed concepts that will be addressed, as an overview of what is to come, and to assist the reader when reviewing the material. At the end of each chapter there is a list of questions, the first of which refers to a weed of your (the student's) choice. It can be a common widespread weed, or it may be a local problem. You will be asked to summarize information that is known about your weed in relation to the material discussed in each chapter. There may be a lot or very little information available to you. The idea behind this is to apply the ecological principles you learn in the chapter to a weed of interest, and to give you practice in researching a topic. Our hope is that by the end of the book, you will have created a 'case history' of your chosen weed.

For the instructor, we designed this book so that the material could be covered in a single-term course by covering approximately one 'content chapter' per week. Chapters 1 and 15 are a brief introduction and conclusion. Two chapters (10 and 14) discuss how ecology 'is done', i.e. methodology, experimental design and basic calculations. These can be used as you see fit. We have tried to keep the writing precise and concise and to include only pertinent information. If we have done our job well, students should be able to read and understand all of the information.

We have used common names throughout the text with Latin names given the first time the species is mentioned in each chapter. We did this because common names are easier to remember when first learning about a species. A species list of common and Latin names is provided at the end of the book.

We thank many people who assisted in the writing and production of this book. David Clements and Jason Cathcart provided detailed comments on many versions of the text. Cheryl Corbett, Sara Mohr and Sheryl Lonsbary read sections or chapters. Of course we accept the responsibility for any errors that occur. We also thank the authors and publishers who allowed us to use their illustrations and Tim Hardwick of CAB *International* who kept us on in spite of many missed deadlines.

Finally, we thank our spouses, David Beattie, Tara Murphy and Josee Lapierre, who probably heard more about 'the book' than they wanted, but kept smiling and nodding their heads anyway. We dedicate this book to them.

1
Ecology of Weeds

Concepts

- The terms 'weed', 'invader', 'colonist', 'exotic', 'non-native' and others are often used in overlapping and conflicting manners.
- Weeds are classified based on their impact on human activities. Therefore, the effect of a weed is difficult to quantify because it depends on our personal biases.
- Definitions and classifications in ecology are often arbitrary and made for purely practical reasons. They do not necessarily reflect any innate structure of nature.
- Ecology can be studied at a variety of levels. In this book, we focus on population and community ecology.
- Weed ecology provides a basic understanding of the distribution and abundance of weeds in natural and managed systems. In the long term, it may change our attitudes and perceptions towards weeds and alter the way we manage them.

Introduction

It may be tempting for you to start this book with Chapter 2. After all, the *real* information doesn't start until then, and exam questions rarely focus on what you learn in Chapter 1. *However*, Chapter 1 is important because it sets the tone for what is to follow. A Shakespearean play or an opera always begins with a prologue. If you walk in after the prologue has finished, you will certainly follow the plot and enjoy the play, but you might not understand the 'why' of the characters' actions. Consider this chapter to be a prologue. You may already know much of what we are about to say, and you may not be tested on it, but it will put what you are about to learn into context.

There are a number of excellent weed science (Radosevich *et al.*, 1997; Zimdahl, 1999a) and plant ecology (Crawley, 1997a; Barbour *et al.*, 1999) texts. We have found, however, that very few texts are devoted entirely to the basic ecology of weeds. A number of books are available on plant invasions; however, they often: (i) assume an in-depth understanding of ecological principles; (ii) focus heavily on the control and management of invasive species; or (iii) provide a detailed description of the biology of

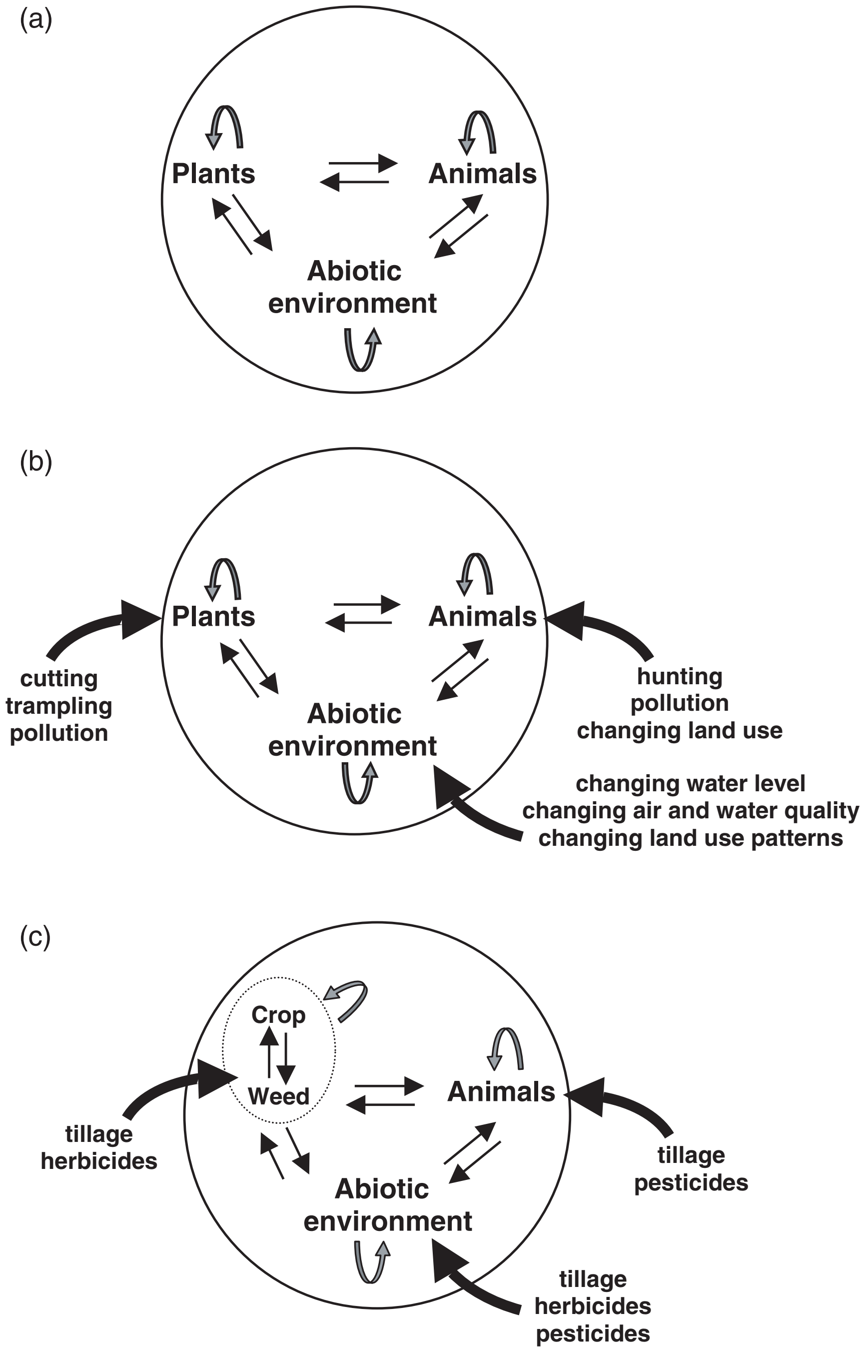

Fig. 1.1. Schematic diagram of three community types: (a) natural community with no human disturbance, (b) natural community with human disturbance and (c) agricultural system.

individual weedy species without providing a broad background. Our goal is to provide you with a link between the fields of weed science, plant invasions and ecology. This book will give you a basic ecological understanding of how plants invade natural, disturbed and agricultural ecosystems.

This book was not designed to replace a good, comprehensive text on basic ecological theory. Rather, we hope to entice readers into exploring such volumes, by presenting an overview of ecology and suggesting ways in which it is useful to applied situations. While ecology texts may seem intimidating and not useful to applied scientists, we hope that, by providing examples of how these concepts are useful in real situations, the importance of ecological theory will become apparent. If we can convince one of you to pick up one of those large, intimidating tomes, then we will have succeeded.

While the focus of this book will be the use of ecological principles to the study of weeds, it is also important to recognize the role that weed science has played in the development of ecology. Several of the earliest ecologists began their careers working on agricultural weeds. The eminent population ecologist John L. Harper began as an agronomist. Early in his career he recognized the importance of ecology to weed management (Harper, 1957). He also developed many of the basic principles of plant population ecology and his 1977 book titled *The Population Biology of Plants* is still a basic text cited in many population ecology papers and texts. Many examples used by him to illustrate ecological principles are weeds. In fact, 'ecologists have far to repay the debt to agriculture for all that they have learned from it' (Trenbath, 1985).

The scope of this book is to examine weeds in systems from highly managed agricultural and grazing land to disturbed or undisturbed natural communities. Is this possible? On the surface, it appears impossible to compare a forest to a field. To the eye, they appear very different in structure and function. However, all types of ecological systems are controlled by the same processes including natural and anthropogenic (human caused) disturbances (fire, construction, tillage) (Fig. 1.1). The human activities that influence natural or managed systems are ultimately biological in nature.

In the three main sections of this chapter we introduce you to weeds, to ecology and finally to weed ecology. In Part I, we present the muddled vocabulary used to describe, define and characterize weeds. In the second section, we describe how ecology is related to other fields of study and how ecology studies can be approached in different ways. In Part III, we integrate the study of weeds with ecology.

Colonizers, Invaders and Weeds: What's in a Name?

Every book on weeds or invasive species must first start with an attempt at defining the terms. Many attempts have been made to define 'weed', 'invasive', 'non-invasive', 'alien', 'naturalization' and other terms describing a species' status, place of origin or population trend (Schwartz, 1997). Pyšek (1995), for example, reviewed definitions of 'invasive' and found it to be described as:

- an alien in a semi-natural habitat (Macdonald *et al.*, 1989);
- a native or alien entering any new habitat (Mack, 1985; Gouyon, 1990);
- a native or alien that is increasing in population size (Joenje, 1987; Mooney and Drake, 1989; Le Floch *et al.*, 1990);
- any alien increasing in population size (Prach and Wade, 1992; Binggeli, 1994; Rejmánek, 1995), or
- any alien species (Kowarik, 1995).

Weeds have typically been defined as 'plants which are a nuisance' (Harper, 1960) or 'a plant where we do not want it' (Salisbury, 1961). Barbour *et al.* (1999) defined a weed as a 'non-native invasive plant' and they distinguished between 'invasive plants' that invade only natural or slightly disturbed habitats, and 'pest plants' that interfere with agricultural or managed natural areas. This definition, however, requires us to further define 'non-native' and 'invasive', and to separate natural from disturbed habitats. The Weed Science Society of America defines a weed as ‘any plant that is objectionable or interferes with the activities and welfare of humans’. These definitions are based on our perceptions of the impact of the plant. Thus, the term ‘weed’ is more a convenient classification than a grouping of plants with common biological characteristics.

Crawley (1997b) recognized the difficulties of defining weeds, and suggested that for a plant to be considered a weed (a problem plant), its abundance must be above a specific level and someone must be concerned. This refines the definition somewhat because it suggests that a plant is only a weed if it is present above a specific abundance; however, it introduced the problem of determining what that threshold level is. This definition recognizes that a weed is only a weed under specific circumstances, that the inclusion of a plant into this category is arbitrarily based on human perceptions and that a specific plant species will not always be considered a weed.

The terms weed, invader and colonizer have often been used in a conflicting manner. The distinctions between them are quite subtle and result from differing viewpoints. According to Rejmánek (1995), *weeds* interfere with human land use; *colonizers* are successful at establishing following disturbance; and *invaders* are species introduced into their non-native habitat. There is substantial overlap among these terms. A plant may be considered as only one of these, or it may be included in all of these categories (Fig. 1.2).

Clearly, we will not definitively solve the problem of ‘what is a weed’ in this text and it is not necessary to do so. Here, we take a general, all-inclusive view of the term ‘weed’. To us, a weed is a native or introduced (alien) species that has a perceived negative ecological or economic effect on agricultural or natural systems.

The traditional approach to the study of weeds is to examine their control or management rather than study their effect on the community. Our focus is on the latter. Whether a weed is in a natural community or a highly managed farm, the underlying questions and principles will be the same. The first part to weed management is to understand why weeds exist and why they have an impact. We leave the bulk of the discussion of weed management to others (Luken and Thieret, 1997; Radosevich *et al.*, 1997; Zimdahl, 1999a).

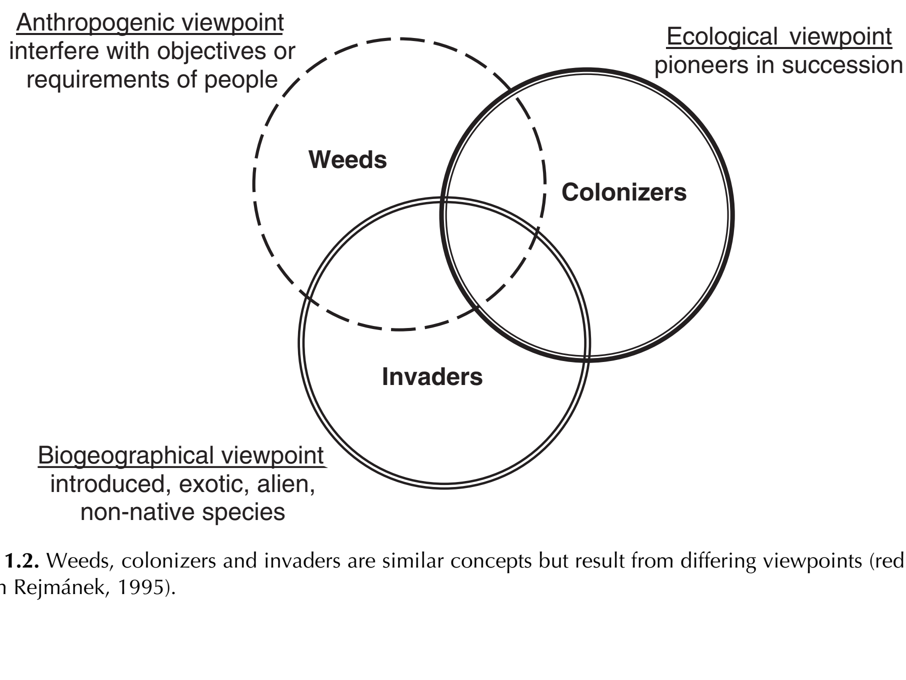

Fig. 1.2. Weeds, colonizers and invaders are similar concepts but result from differing viewpoints (redrawn from Rejmánek, 1995).

Table 1.1. Classification of weeds based on habitat type (based on Holzner, 1982).

Classification	Explanation
Agrestals	Weeds of agricultural systems, e.g. cereal/root crops, orchards, gardens, plantations
Ruderals	Weeds of waste/human disturbed sites (ruderal sites), e.g. roadsides, railway lines, ditches
Grassland weeds	e.g. pasture, meadows, lawns
Water weeds	Weeds that affect water systems, e.g. affect navigation, recreational use
Forestry weeds	e.g. tree nurseries, afforestation sites
Environmental weeds	Suppress native vegetation

Types of weeds

One common way to categorize weeds is based on the habitat they invade. Holzner (1982) divided weeds into agrestrals, ruderals, grassland weeds, water weeds, forestry weeds and environmental weeds (Table 1.1). Environmental weeds have often been called invasive species. There is a tendency to use the word 'invasive' when considering natural habitats, and 'weed' for managed habitats; however, there is a gradient between natural and managed systems, and some apparently natural systems are managed.

Weed characteristics

There have been many attempts to list characteristics associated with weeds. Baker (1965, 1974) summarized weed characteristics based on adaptations (Box 1.1). A species with more of these characteristics is more likely to be a successful weed. Baker (1965) said that a plant possessing all of the traits would be 'a formidable weed, indeed'. A weed will not necessarily possess all (or even any) of these characteristics, and conversely, a plant possessing some (or all) of these characteristics will not necessarily be a weed. A weed may require certain characteristics to invade, but a community must be invasible in order for the invasion to be successful.

A list of a species' characteristics cannot necessarily be used to predict its weediness or invasion success. Weed characteristics, community characteristics, the interaction between the community and the potential weed, as well as timing and chance will determine whether an introduced species is successful (Lodge, 1993; Hobbs and Humphries, 1995). Furthermore, while disturbance is often cited as a prerequisite for invasion to occur, this is not always true. Certain types of disturbance (i.e. cyclic fires) may, in fact, prevent invasions.

Box 1.1. Traits of an 'ideal' weed (based on Baker, 1956, 1974).

1. Germinates in a wide range of environmental conditions
2. Long-lived seeds that are internally controlled so that germination is discontinuous
3. Rapid growth from vegetative through to flowering stage
4. Self-compatible, but not completely autogamous or apomictic
5. Cross-pollination (when present) by wind or generalist insects
6. Seeds produced continuously throughout the growth period
7. Seed production occurs under a wide range of environmental conditions
8. High seed output when environmental conditions are favourable
9. Propagules (seeds) adapted to short- and long-distance dispersal
10. If perennial, has a high rate of vegetative reproduction or regeneration from fragments
11. If perennial, ramet attachments fragment easily, so it is difficult to pull from the ground
12. Strong potential to compete interspecifically via allelopathy, rosettes, rapid growth and other means

Impact of weeds

Negative effects

The harmful impacts of weeds can be classified as land-use effects or as ecosystem effects. Land-use effects are easier to quantify because they can be measured in terms of decreased crop yield or increased control costs. Costs to the ecosystem may be just as great, but are less well understood and the impact is harder to quantify in numerical terms.

In managed (agricultural) systems, weeds can decrease the growth of a crop, often in a very predictable and quantifiable way. Zimdahl (1999a) divided the harmful effects of agricultural weeds into nine categories according to the target and type of damage done (Table 1.2). The most commonly known effects are those that either directly affect the crop through competition, increased production costs or reduce the quality of the crop. Less direct effects are those to animal or human health, by increased production or management costs or by decreasing land value. A weed may have one or many of these effects. Attempts to quantify the damage by weeds in agricultural systems have been done (Pimentel *et al*., 2000); however, these can only be taken as estimates (Zimdahl, 1999a). These have been calculated as a proportion of the potential annual crop yield lost to weeds and as the amount of money spent on weed management.

Quantifying the damage done by weeds to a natural system can be difficult because they cannot be quantified in terms of dollars or time. We can express damage as the cost to control the weed; however, this does not address the actual ecological impact. A weed may effect the survival or growth of other species or change ecosystem processes like nutrient cycling. For example, the fire tree (*Myrica faya*), which was introduced to Hawaiian islands in the 1700s to control erosion in pasture, invaded large tracts of land and replaced the native forest because it increased the nitrogen level of the soil (Vitousek *et al*., 1987; Vitousek and Walker, 1989). As a legume, it fixes nitrogen causing the nitrogen level of the volcanic soils to increase. This has increased the invasion of other weeds which require higher nitrogen. While the effect of fire tree on the ecosystem is clear, how does one quantify the damage?

Benefits

The benefits of weeds are less well understood than the negative effects, and more difficult to quantify because they occur over a longer time scale. Altieri (1988) and Holzner (1982) reviewed the benefits of weeds in

Table 1.2. Potential harmful effects of agricultural weeds on human land use (based on Zimdahl, 1999a)

Harmful effect	Explanation
Compete with crop	Compete with crop plants for nutrients, water, light and space
Increased protection costs	Weed may harbour crop pests or diseases
Reduced quality of crop	Weed seeds become mixed with crop seed during harvest and will therefore affect the quality of seed crop
Reduced quality of animals	Weeds in rangeland may poison or kill animals, can affect animal products (meat, milk), or affect reproduction
	Weed plants and seed may physically damage animals or their products (wool)
Increased production and processing costs	Cost of weed control (tillage, herbicides)
	Cost of cleaning seeds
Water management	Weeds may impede flow of water through irrigation ditches
Human health	Cause respiratory, digestive or skin ailments, or other health effects
Decreased land value	Cost of restoring land (esp. perennial weeds)
Reduced crop choice	Restrict possible crops that can be grown
Aesthetic value	Recreational land or traffic intersections/thoroughfares

agricultural situations. Weeds may increase crop growth under certain circumstances. For example, in some dry areas of India, three 'weeds' (Arabian primrose, *Arnebia hispidissima*; buttonweed, *Borreria articularis;* and cockscomb, *Celosia argentea*) increase the growth of millet (bajra, *Pennisetum typhoideum*); however, this is not true for sesame (til, *Sesamum indicum*) (Bhandari and Sen, 1979). A fourth weed, indigo (*Indigofera cordiflora*), was beneficial to both crops. Thus, the specific site conditions and species involved must be considered before drawing conclusions about the value of a particular plant.

In some traditional agroecosystems, the importance of certain weeds is recognized even if they are known also to reduce crop yield. These weeds have other functions that compensate for loss of crop yield. For example, in Tabasco, Mexico, some weeds are left because they are recognized for their food, medicinal, ceremonial or soil-improving uses (Chacon and Gliessman, 1982). These weeds are termed 'buen monte' (good weeds) while others are 'mal monte' (bad weeds). In other situations, weeds may be harvested for food, animal fodder or fertilizer. In Australia, *Echium plantagineum* is considered a noxious weed in grazing land, but it also serves as an emergency feed under some conditions (Trenbath, 1985). Its dual names, 'Paterson's Curse' and 'Salvation Jane' reflect this. Weeds are now being recognized for the potential role they may play in mediating crop–predator interactions. Weeds may provide a habitat for some beneficial insects, which could result in higher yields due to a decreased pest load on the crop.

Non-native weeds can be beneficial in non-agricultural situations, especially when the environment has been degraded (Williams, 1997). Non-native species have been useful in a number of restoration projects. For example, natural regeneration of woody plants in subantarctic forests of Argentina is limited due to overexploitation and overgrazing by cattle. However, the introduced European mosqueta rose (*Rosa rubiginosa*) is able to establish in degraded sites, resists grazing and provides shelter for the regeneration of native woody species (De Pietri, 1992).

Finally, weeds may also have beneficial properties such as erosion control (Williams, 1997). However, the properties that make some species excellent at controlling erosion may also make them excellent weeds as well. In the southeastern USA, farmers were encouraged to plant kudzu (*Pueraria montana* var. *lobata*) to control soil erosion; however, after 1953 it was considered a noxious weed by the United States Department of Agriculture (USDA) and was no longer on the list of permissible cover plants. It is now a troublesome weed in the southeastern USA.

A weed is not always a weed

A plant may be both a 'weed' and 'not a weed' depending on where and under what circumstances it is growing. The decision of what is a weed can be quite complex. A plant species may be both a weed and a desired species, depending on its location and on the desired land use. Following are three examples of plants that could be considered weeds or not.

- Proso millet (*Panicum miliaceum*) is a crop grown in Canada and other parts of the world. In the last 30 years, however, weedy biotypes of proso millet have developed and it is now an important agricultural weed in Canada and the USA. The crop and the various weed biotypes differ in seed characteristics, seedling vigour, germination patterns, inflorescence structure and dispersal mechanisms (Cavers and Bough, 1985).
- In Western Australia, where farmers alternate between wheat cropping and sheep pasture, annual grasses (such as annual ryegrass) are either the weed or the crop, depending on the rotation. During the pasture phase, grasses provide early forage and protection from erosion, but they also decrease the growth of nitrogen-fixing clover (*Trifolium*), which can decrease subsequent wheat yields (Trenbath, 1985).
- Monterey pine (*Pinus radiata*) is a native tree species in parts of California, a plan-

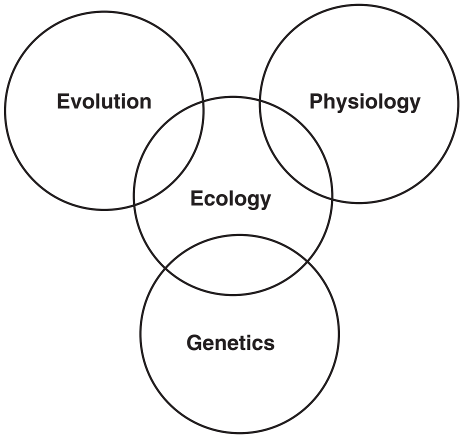

Fig. 1.3. Relationship between ecology and genetics, evolution and physiology.

tation tree in parts of Australia, New Zealand, South Africa and Chile, but is also a weed in natural areas adjacent to plantations.

What is Ecology?

The word ecology was derived from the German word (*oekologie*), which was derived from the Greek words *oikos* meaning 'house' and *logos* meaning 'the study of'. Thus, ecology is the study of organisms and their environment. We can divide the environment into biotic (living) and abiotic (nonliving) factors. Examples of biotic factors are competition and herbivory. Abiotic factors can be physical (e.g. temperature, light quality and quantity) or chemical (e.g. soil nutrient status).

Ecology is closely related to other fields of biology such as physiology, evolution and genetics (Fig. 1.3). There are no distinct boundaries between these fields and ecology, and indeed there is enough overlap that subdisciplines have arisen. The types of questions that these scientists ask are often the same. For example, an ecologist and a physiologist may both ask how a plant's photosynthesis is affected by the surrounding vegetation. To the ecologists, the focus is on the plant growth and survival; to the physiologist, the focus is on the process of photosynthesis.

Levels of ecological study

The field of ecology is vast. It is concerned with areas as diverse as the dispersal of seeds, competition within and between species, and nutrient cycling through ecosystems. Each of these operates on a different temporal (time) and spatial (space) scale, and each has a different focus. Thus, they address different types of questions, and require a different protocol to answer such questions. For convenience, ecological questions can be categorized into subdisciplines (Fig. 1.4). For example, individual organisms can be studied to examine how abiotic factors affect their physiology. Groups of individuals of the same species can be studied to look at population-level processes. Groups of co-occurring populations can be studied to ask community-level questions. Furthermore, interactions between a community and its abiotic factors can be studied to answer ecosystem questions. Each of these categories blends into the next. They are not discrete units of study, rather they are useful, practical and somewhat arbitrary divisions which help to simplify the field of study. In this book we

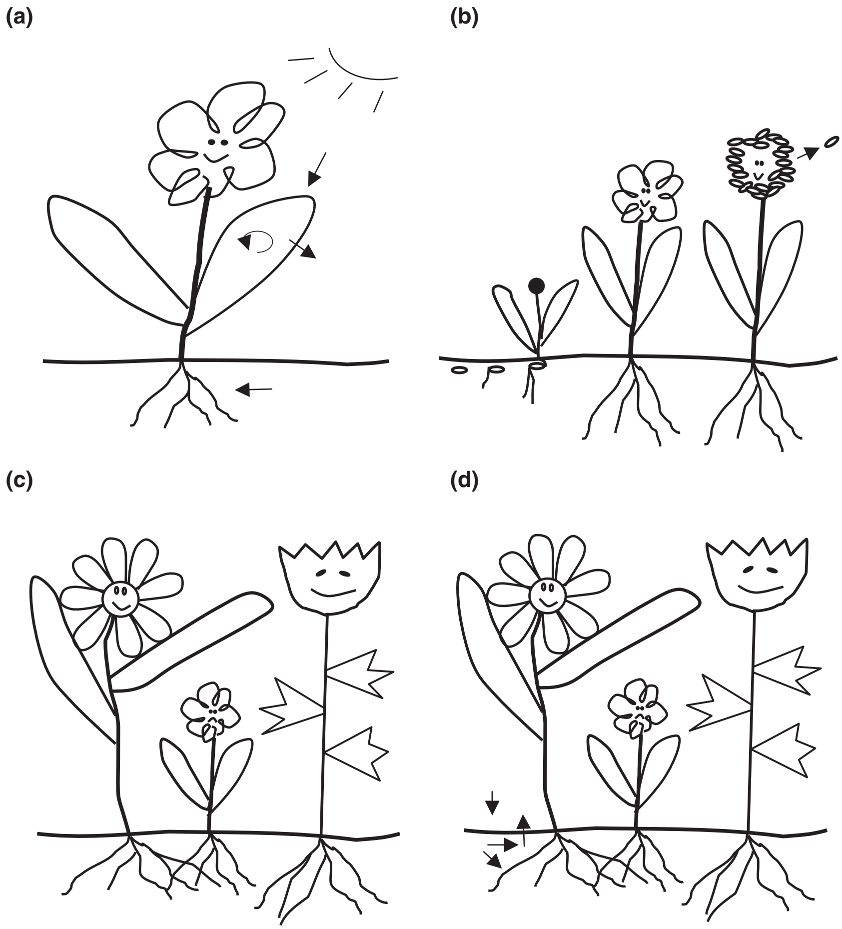

Fig. 1.4. Illustration of (a) ecophysiology, (b) population ecology, (c) community ecology and (d) ecosystem ecology.

are primarily interested in population ecology (Chapters 2–7), interactions between populations (Chapters 8 and 9) and community-level ecology (Chapters 11–14).

Population ecology

A population is a group of potentially interbreeding individuals of the same species found in the same place at the same time. Determining whether individuals are in the 'same space' may pose difficulties. In some cases, the population's distribution will be quite clumped and thus boundaries are easily imposed around these clumps of interacting individuals. Other times, boundaries may be determined by natural or anthropogenic features such as roads, rivers or mountains. Finally, we may impose arbitrary boundaries around our target population. While there is no one 'correct' way to do this, it is important to base one's decision on our knowledge of the organism's biology and on the goals of the study. We should be clear about the reasons for imposing these boundaries and keep in mind their effect when interpreting the results.

Populations can be studied in a number of ways (Table 1.3). A population's density and distribution quantify how it is dispersed over space. Age and sex structure quantifies the demographic characteristics of the population at one time. Population dynamics are quantified by measuring the change in natality (births), mortality (deaths), immigration and emigration over time. Note that each of these measurements is derived from data collected on groups of individuals and could not be a characteristic of any single individual (there is no such thing as the 'density' or 'age structure' of a single organism). Population ecologists ask questions such as:

- What determines a species' distribution and/or density?
- How do physiological, morphological and phenological traits influence the distribution and abundance of a species or population?
- How do biotic or abiotic factors affect a population's growth and reproductive rate?
- What is the age structure of the population?
- Is population size increasing or decreasing?

Community ecology

A community is a group of populations that co-occur in the same space and at the same time (Begon *et al.*, 1990). Definitions of communities are generally vague on where the community boundaries are. Again, we can define boundaries based on the needs of our study. A further difficulty with defining a community is deciding what organisms to include. This is another rather arbitrary decision. Do we look at just plants, animals, fungi or all three? Clearly, we *should* include all organisms within the boundaries of our community because any one may have an important function. However, because of the practical limitations placed on researchers, this is rarely done. Decisions on what constitutes a community can be done at any scale: from the community of fungi colonizing a piece of stale bread, to the community of maize and weeds in a field, to the entire flora and fauna of a boreal forest.

We can describe communities in terms of their structure and function (Table 1.3). Community structure refers to the external appearance of the community. Species composition (species lists, diversity), species traits (life span, morphology) and strata characteristics (canopy, shrubs, vines, herbs) are used to describe community structure. Function refers to how the community 'works'. Nutrient allocation and cycling, biomass production and allocation, and plant productivity are ways to describe community function. Community ecologists ask questions such as:

- How does community structure change over time?
- Can we predict community changes over time?
- Why are there so many (or so few) species in this community?

Table 1.3. Measurements used to characterize populations and communities.

Populations	Communities
Population structure	*Community structure*
Distribution and density of a species (spatial structure)	Species composition and richness
	Physiognomy
Age structure	Species traits
Population dynamics	*Community dynamics*
Natality, mortality, immigration and emigration	Succession
	Disturbance
Population interactions	*Community function*
Competition, herbivory, amensalism, commensalism and mutualism	Nutrient allocation and cycling
	Productivity and biomass allocation

- How does community composition change along spatial gradients?
- How does the addition (or loss) of one species affect the distribution or abundance of other?

What is Weed Ecology?

If ecology is the study of interactions between individuals and their environment, then the only thing that distinguishes weed ecology is that the organisms being studied are weeds. Therefore, weed ecologists ask questions such as:

- Are there specific characteristics or traits of weed populations?
- Do weeds function in a certain way within communities?
- Does the invasion by a weed change the community structure or function in a predictable way?
- What types of communities are easier to invade?

Why are ecology and weed science separate?

Ecology and weed science have developed as separate fields of study. Why is this? The way in which we study a topic is directly related to its historical development. Like familial lineages, there are academic lineages. There is ecology dogma and weed science dogma. There are accepted ways of asking questions, accepted experimental methodology and accepted statistical analyses. Breaking down these barriers is difficult.

To a certain extent, the types of people attracted to these two fields (ecology and weed science) will be different. Some people prefer asking 'applied research' questions while others prefer to ask 'pure science' questions. Ecologists are often biased towards working in natural environments, while weed scientists are often biased towards asking question that have applied 'real' answers. 'Were it not for the general predilections of ecologists to study only systems untouched by human hands, farming-systems research would clearly be called a branch of ecology' (Busch and Lacy, 1983).

The increasing interest in plant invasions into natural communities has expanded the middle ground between these fields. Such workers may ask ecologically based questions, but look for applied answers. For example, they may study the basic population ecology of a weed with an eye to eventually managing it with biological control, and thus both the ecology and weed science literature will be of interest to them. Scientists interested in agricultural and natural habitats may both be concerned with the same species. For example, garlic mustard (*Alliaria petiolata*) and dodder (*Cuscuta* spp.) invade natural and agricultural habitats. There is a renewed call to incorporate ecological thinking into applied fields of study such as weed science (Zimdahl, 1999b). We hope that this exchange of information will increase.

Summary

In this chapter, we have introduced the basic concepts of weed ecology. The term 'weed' is defined many ways; we prefer to use a loose definition that includes all plants that have a negative ecological or economic effect on natural or managed systems. Thus our view of 'weed ecology' is the study of how problematic plants interact with their biotic and abiotic environment. In this book, our goal is to understand why weeds occur where they do. We do not address how to get rid of them. In the next chapter, we begin by looking at plant populations. The first step towards investigating populations is to determine their distribution and abundance.

Questions

At the end of each chapter, you will be asked a series of questions related to a species of your choice. At this point, you should select a species that you wish to focus on. This may take some thought. Are you more interested in natural or managed systems? Are you interested in wide-ranging common weeds, locally problematic weeds or new species weeds? For some species, there will be a lot of literature available, while for others there may be large gaps in our knowledge. In the first case, you will have more information to read and synthesize. In the second case, you will be asked to suggest what information is needed and how this should be obtained. To get started, you may want to refer to a book on weeds in your region. It is a good idea to create a bibliography of references and resources you may need.

1. Name a plant that you would consider to be a weed but that someone else would not. Name a plant that you would not consider to be a weed but that someone else would. Explain how this is possible.

2. Describe why each characteristic listed by Baker (1956, 1974; Box 1.1) might be advantageous for an agricultural weed. Would each characteristic be equally advantageous for a weed in a natural habitat?

3. Why is it possible to define 'weed' in so many ways?

General References

Barbour, M.G., Burks, J.H., Pitts, W.D., Gilliam, F.S. and Schwartz, M.W. (1999) *Terrestrial Plant Ecology*, 3d edn. Benjamin, Cummings, California.

Crawley, M.J. (1997) *Plant Ecology*, 2nd edn. Blackwell Scientific, Oxford.

Zimdahl, R.L. (1999) *Fundamentals of Weed Science*, 2nd edn. Academic Press, San Diego, California.

Literature Cited

Alterieri, M.A. (1988) The impact, uses, and ecological role of weeds in agroecosystems. In: Altieri, M.A. and Liebman, M.Z. (eds) *Weed Management in Agroecosystems: Ecological Approaches*. CRC Press, Boca Raton, Florida, pp. 1–6.

Baker, H.G. (1965) The characteristics and modes of origin of weeds. In: Baker, H.G. and Stebbins, G.L. (eds) *The Genetics of Colonizing Species*. Academic Press, New York, pp. 147–172.

Baker, H.G. (1974) The evolution of weeds. *Annual Review of Ecology and Systematics* 5, 1–24.

Barbour, M.G., Burks, J.H., Pitts, W.D., Gilliam, F.S. and Schwartz, M.W. (1999) *Terrestrial Plant Ecology,* 3rd edn, Benjamin, Cummings, California.

Begon, M., Harper, J.L. and Townsend, C.R. (1990) *Ecology: Individuals, Populations, Communities*, 2nd edn. Blackwell Scientific, Boston, Massachusetts.

Bhandari, D.C. and Sen, D.N. (1979) Agroecosystem analysis of the Indian arid zone. I. *Indigo fera cordiflora* as a weed. *Agro-Ecosystems* 5, 257.

Binggeli, P. (1994) The misuse of terminology and anthropometric concepts in the description of introduced species. *Bulletin of the British Ecological Society* 25, 10–13.

Busch, L. and Lacy, W.B. (1983) *Science, Agriculture and the Politics of Research*. Westview Press, Boulder, Colorado.

Cavers, P.B. and Bough, M.A. (1985) Proso millet (*Panicum miliaceum* L.): a crop and a weed. In: White, J. (ed.) *Studies on Plant Demography: a Festschrift for John L. Harper*. Academic Press, London, pp. 143–155.

Chacon, J.C. and Gliessman, S.R. (1982) Use of the "non-weed" concept in traditional tropical agroecosystems of southeastern Mexico. *Agro-Ecosystems* 8, 1.

Crawley, M.J. (ed.) (1997a) *Plant Ecology*, 2nd edn. Blackwell Scientific, Oxford.

Crawley, M.J. (1997b) Biodiversity. In: Crawley, M.J. (ed.) *Plant Ecology*, 2nd edn. Blackwell Scientific, Oxford, pp. 595–632.

De Pietri, D.E. (1992) Alien shrubs in a national park: can they help in the recovery of natural degraded forest? *Biological Conservation* 62, 127–130.

Gouyon, P.H. (1990) Invaders and disequilibrium. In: di Castri, F., Hansen, A.J. and Debussche, M. (eds) *Biological Invasions in Europe and Mediterranean Basin*. Kluwer, Dordrecht, pp. 365–369.

Harper, J.L. (1957) Ecological aspects of weed control. *Outlook on Agriculture* 1, 197–205
Harper, J.L. (1977) *The Population Biology of Plants*. Academic Press, London.
Harper, J.L. (ed.) (1960) *The Biology of Weeds*. Blackwell Scientific, Oxford.
Hobbs, R.J. and Humphries, S.E. (1995) An integrated approach to the ecology and management of plant invasions. *Biological Conservation* 9, 761–770.
Holzner, W. (1982) Concepts, categories and characteristics of weeds. In: Holzner, W. and Numata, N. (eds) *Biology and Ecology of Weeds*. Dr W. Junk Publishers, The Hague, pp. 3–20.
Joenje, W. (1987) Remarks on biological invasions. In: Joenje, W., Bakker, K. and Vlijm, L. (eds) *The Ecology of Biological Invasions.* Proceedings of the Royal Dutch Academy of Sciences, Series C 90, pp. 15–18.
Kowarik, I. (1995) Time lags in biological invasions with regard the the success and failure of alien species. In: Pyšek, P., Prach, K., Rejmánek, M. and Wade, M. (eds) *Plant Invasions – General Aspects and Specific Problems*. SPB Academic Publishing, Amsterdam, pp. 15–38.
Le Floch, E., Le Houerou, H.N. and Mathez, J. (1990) History and patterns of plant invasion in northern Africa. In: di Castri, F., Hansen, A.J. and Debussche, M. (eds) *Biological Invasions in Europe and Mediterranean Basin*. Kluwer, Dordrecht, pp. 105–133.
Lodge, D.M. (1993) Biological invasions: lessons for ecology. *Trends in Ecology and Evolution*, 8, 133–137.
Luken, J.O. and Thieret, J.W. (1997) *Assessment and Management of Plant Invasions*. Springer-Verlag, New York.
Macdonald, I.A.W., Loope, L.L., Usher, M.B. and Hamann, O. (1989) Wildlife conservation and the invasion of nature reserves by introduced species: a global perspective. In: Drake, J.A., Mooney, H.A., di Castri, F., Groves, R.H., Kruger, F.J., Rejmánek, M. and Williamson, M. (eds) *Biological Invasions. A Global Perspective*. John Wiley & Sons, Chichester, UK, pp. 215–255.
Mack, R.M. (1985) Invading plants: their potential contribution to population biology. In: White, J. (ed.) *Studies on Plant Demography*. Academic Press, London, pp. 127–142.
Mooney, H.A. and Drake, J.A. (1989) Biological invasions: a SCOPE program overview. In: Drake, J.A., Mooney, H.A., di Castri, F., Groves, R.H., Kruger, F.J., Rejmánek, M. and Williamson, M. (eds) *Biological Invasions. A Global Perspective*. John Wiley & Sons, Chichester, UK, pp. 491–508.
Pimentel, D.A., Lach, L., Zuniga, R. and Morrison, D. (2000) Environmental and economic costs of nonindigenous species in the United States. *BioScience* 50, 53–65.
Prach, K. and Wade, P.M. (1992) Population characteristics of expansive perennial herbs. *Preslia* 64, 45–51.
Pyšek, P. (1995) On the terminology used in plant invasion studies. In: Pyšek, P., Prach, K., Rejmánek, M. and Wade, M. (eds) *Plant Invasions – General Aspects and Specific Problems*. SPB Academic Publishing, Amsterdam, pp. 71–81.
Radosevich, S.R., Holt, J.S. and Ghersa, C. (1997) *Weed Ecology: Implications for Management*. John Wiley & Sons, New York.
Rejmánek, M. (1995) What makes a species invasive? In: Pyšek, P., Prach, K., Rejmánek, M. and Wade, M. (eds) *Plant Invasions – General Aspects and Specific Problems*. SPB Academic Publishing, Amsterdam, pp. 3–13.
Salisbury, E.J. (1961) *Weeds and Aliens*. Collins, London.
Schwartz, M.W. (1997) Defining indigenous species: an introduction. In: Luken, J.O and Thieret, J.W. (eds) *Assessment and Management of Plant Invasions*. Springer-Verlag, New York, pp. 7–17.
Stirton, C.H. (1979) Taxonomic problems associated with invasive alien trees and shrubs in South Africa. In: *Proceedings of the 9th Plenary Meeting AETFAT*. pp. 218–219.
Trenbath, B.R. (1985) Weeds and agriculture: a question of balance. In: White, J. (ed.) *Studies on Plant Demography: A Festschrift for John L. Harper*. Academic Press, London, pp. 171–183.
Vitousek, P.M. and Walker, L.R. (1989) Biological invasion by *Myrica faya* in Hawaii: plant demography, nitrogen fixation, ecosystem effects. *Ecological Monographs* 59, 247–265.
Vitousek, P.M., Walker, L.R., Whiteaker, L.D., Mueller-Dombois, D. and Matson, P.A. (1987) Biological invasion by *Myrica faya* alters ecosystem development in Hawaii. *Science* 238, 802–804.
Williams, C.E. (1997) Potential valuable ecological functions of nonindigenous plants. In: Luken, J.O. and Thieret, J.W. (eds) *Assessment and Management of Plant Invasions*. Springer-Verlag, New York, pp. 26–34.
Zimdahl, R.L. (1999a) *Fundamentals of Weed Science*, 2nd edn. Academic Press, San Diego, California.
Zimdahl, R.L. (1999b) My view. *Weed Science* 47, 1.