Reptiles and amphibians as targets for nature management

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Reptiles and amphibians as targets for nature management

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ALTERRA SCIENTIFIC CONTRIBUTIONS 13

ALTERRA GREEN WORLD RESEARCH, WAGENINGEN

2004

Cover: Sand lizard (*Lacerta agilis*)

ISBN 90-3270339-0

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Preface

This thesis presents what I consider to be effective measures for the sustainable survival of reptiles and amphibians in the Netherlands. In spite of being legally protected since 1973, our herpetofauna is still on the decline. I feel I have a right to speak on these matters. My career as a herpetologist started about this time, and although I have seen how much has been achieved, I have also seen how much has been lost. The deep concern I feel in the face of this loss, and about the part in it played by present conservation practice in the Netherlands, has led me to write the present work.

Habitat management is common practice in nature management in the Netherlands and many good things are being achieved in the field. However, despite the hard work of the managers, there are too many targets that are not met. Such experiences are frustrating for everybody involved in nature conservation. I have investigated why the results are not good enough. My aim is to improve the success rate of faunal nature management with this contribution; as a herpetologist, I feel I have a recipe for doing better, and, furthermore, one that also take the interests of other animals into account.

Reptiles and amphibians have fascinated me since my childhood in the late fifties. I was ten years old when my father took me to the outskirts of the town to collect frogspawn. In those days, these animals were still easy to find. Many hours were spent watching the development of the eggs in a preserving jar on a coal-box in the garden. Curious, I went back to the ditch where we had found the eggs, and this time discovered fish-like creatures disturbing the water surface: newts, as I later learned. I succeeded in collecting some with a homemade fishing net and put my new trophies in another jar; many others would follow. It was a great surprise to learn that nobody in our part of the world had ever seen such animals before, let alone that there was any information available on their life history. Then shortly afterwards, we visited a cousin who kept a lizard in a small terrarium, and my enthusiasm grew even more when I saw this scaly animal alternating agile with motionless behaviour. From that moment on, I realised I had to know more about such animals, and that I wanted to become a biologist. My wish became true. I graduated in biology with amphibian ecology as my main subject; Hein Oomen was my teacher.

I found a job at a research institute for nature conservation, the RIN (*Rijksinstituut voor Natuurbeheer*), where I took part in a project for mapping the vegetation of the Netherlands, at the same time evaluating the quality of the landscape for nature (KALKHOVEN *ET AL*., 1976; STUMPEL & KALKHOVEN, 1978). These environmental maps were the start of a holistic consideration of nature, developed in particular by Eddy van der Maarel (VAN DER MAAREL & STUMPEL, 1974). While doing this work, I was already forming my ideas on appropriate conservation measures for reptiles and amphibians. Moreover, I was also actively involved in research on grass snakes, sand lizards and slow-worms, looking at their ecology with special attention to their habitats. There was little known about the ecology of either group, although the Animal Ecology Department at the Catholic University of Nijmegen was carrying out ecological research on reptiles and amphibians at that time. A chance discovery of a large population of tree frogs in the southwest of the country meant that my attention was brought to the state of amphibian habitats. I carried out ecological research that included detailed habitat analysis. Soon, it was obvious to me that reptiles and amphibians attracted far less interest than birds and mammals, and that there was little or no support for their conservation.

However, there were positive developments on the European front. The first international herpetological symposium was organised (COBORN, 1981), and there in Oxford, I met others like myself, concerned about the fate of these fascinating animals. This would be the start of an intensive co-operation with the prominent British herpetologist Keith Corbett and others throughout Europe. Up to that point, I had only been able to share my enthusiasm with one colleague at the RIN, namely Bert Hanekamp, with whom I would do so much useful work on habitat management in the nineteen eighties. At that conference in 1980, I presented a provisional list of species that I considered to be at risk (STUMPEL, 1981). The situation was already serious. Since then, I have been at the forefront of herpetological conservation, both at European and national level. In 1981, I was one of the initiators of the Conservation Committee (and would become its chairman in 2003) of *Societas Europaea Herpetologica* (SEH), the European herpetological society; the society had been founded in 1979.

At the beginning of the eighties, the RIN was concerned with the practical aspects of nature conservation. In 1983, a position of herpetologist was created at the institute, and I was thus given the opportunity to put all my energy into herpetology. The RIN was then part of *Staatsbosbeheer* (the State Forestry Service), an owner of nature reserves all over the country. My work entailed visiting reserves, monitoring the effect of measures and advising nature wardens on the appropriate vegetation management for developing structure suitable for the herpetofauna (cf., STUMPEL, 1985). It was a good and productive time because the wardens took the advice seriously. It was a pity that their supervisors gave them so little room for putting this advice into practice, in order to have a long-term effect. Later in the eighties, my advisory work was cut down; the government had decided to separate policy and management concerning nature conservation, and the institute chose the policy side. I was able to do little with what I saw happening: an increasing decline in our herpetofauna through mismanagement. However, outside my official work, I spent time in the field, keeping in touch with those carrying out nature management in practice. Also, by continuing my observations in nature reserves, I kept an eye on the quality of management of the habitats. The applied research that I carried out later in the laboratory helped clarify problems that I came across in the field.

I have always felt the wish to publish my experiences with the management of herpetofauna. However, when would the fruit be ripe enough? I now know this will hardly ever be the case, but the late summer of my career seems a good moment for presenting the state of affairs. I hope the information in this thesis will be used and contribute to a better conservation of reptiles and amphibians.

Acknowledgements

I am grateful for innumerable discussions in the field with a great variety of people, many of them nature managers and students, all of whom have helped me to form my ideas. For the exchange of expertise, I would especially like to thank Keith Corbett, Ben Crombaghs, Bert Hanekamp, Richard Podloucky and Chris van de Bund. Keith also made valuable comments on the draft manuscript, as did Henk Strijbosch and Jan van Gelder. Claire Hengeveld did a great job, not only by improving the English, but also, by editing the document in a very careful way, accentuating the text. Thanks to the technical assistance of Martin Jansen, Henny Michel and Tanya Levy, the manuscript was ready for the printer on time. I am also grateful to the members of the staff of the library *De Haaff*, who were always there to help when I was searching for literature. All photos in Chapter seven were provided by René Krekels. The cover is the work of Jos Tollenaar, who based his design on a photo by Fabrice Ottburg. He also took care of the technical adaptations needed before the cover could be printed.

I dedicate this thesis to my wife Suzette and my sons Evert and Joris. Words are not adequate to thank them for their support and patience during my whole career. Without them, this work would never have been accomplished.

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1 Introduction

Reptiles and amphibians are on the decline in the Netherlands. Effective measures are needed for their sustainable survival. The present work aims at contributing to the improvement of the practices used in management of their habitats.
The most important part of the thesis is the last chapter, Chapter 7, where I set out the measures herpetofauna need for survival in the various habitats where they occur. This introduction explains the background of present-day policy, especially with reference to Europe. The rest of the thesis comprises five articles concerning different aspects of the conservation of reptiles and amphibians in the Netherlands, one of which (Chapter 6) has yet to be published. They serve as examples of studies that are needed for improving our knowledge of the ecology of reptiles and amphibians, which is the basis for practical habitat management. Moreover, they are also meant to illustrate the effort needed for improving this knowledge.

Concise information about the distribution, status, and conservation needs of all species of indigenous reptiles and amphibians are presented in boxes throughout Chapter 7.

But before going any further, what are reptiles and amphibians, or, as they are collectively known, the herpetofauna, a word that literally means creeping animals? Herps, as the specialists call them, are largely unknown in the Netherlands, which in a sense is understandable, because they are inconspicuous, and many are rather rare. Although everybody knows that snakes exist, only few people have seen them in the wild, and almost nobody can tell lizards from salamanders or frogs from toads, many biologists included. Unfortunately, in general, people find snakes dangerous and toads disgusting, which means that they find more reason to persecute than to protect them.

Reptiles and amphibians are declining not only in the Netherlands, but also all over the world. BAILLIE & GROOMBRIDGE (1996) suggested that at least 20-25% of all reptiles and amphibians are threatened worldwide, albeit there are insufficient data for assessing the conservation status of many species reliably. Although preliminary reviews of threatened European herpetofauna have been made by HONEGGER (1981) and CORBETT (1989), an official Red List does not yet exist. However, various European states have published national Red Data books, e.g., Ukraine (SCERBAK, 1994), Germany (BEUTLER *ET AL.*, 1998). When Europe is taken to include Asiatic Turkey, Cyprus, Transcaucasia, the Canary Islands, Salvagens Islands, and Madeira, its herpetofauna consists of 219 reptile and 86 amphibian species according to present taxonomy. (STUMPEL & CORBETT, 2003A, 2003B; TABLE 1). A preliminary European Red List of vertebrates was recently brought out by the Council of Europe (ANONYMOUS, 2001).

TABLE 1. Numbers of European species of reptiles and amphibians (from STUMPEL & CORBETT, 2003A, 2003B). Numbers are approximate, due to recent new discoveries and changes in taxonomy.

Vernacular name	Scientific name	Number of species
REPTILES	REPTILIA	219
Turtles	Testudines	15
Lizards	Sauria	135
Snakes	Serpentes	69
AMPHIBIANS	AMPHIBIA	86
Tailed amphibians	Urodela	35
Tailless amphibians	Anura	51

Concerning their conservation, it should be stressed that amphibians and reptiles are particularly vulnerable animals, as they are confined to a particular part of an area during certain periods of the year in connection with reproduction or hibernation. Most species have small territories or home ranges, in which they are relatively sedentary. Having very limited ability and instinct for movement over long distances, and thus, little possibility for dispersal over a large area, these animals are usually poor colonisers. They thus have little scope to avoid even temporary threats or adverse changes to their habitats, not being able to move out and return when conditions improve. This is what makes them particularly vulnerable: once their habitat is lost, they have no other place to go. In places, such as the more temperate parts of the world, where temperature is a limiting factor for ectothermic animals, they may spend up to six months or more in hibernation, and thus fixed to one site, they are even more sensitive to change. Furthermore, there is much variety in the structure of the vegetation of a good reptile habitat; many have taken years to get to maturity. It will be obvious that new habitats cannot be developed within a short time, which has consequences for the practice of habitat creation. It should be said that there are exceptions to the sedentary behaviour, shown in species, such as marine turtles, some water snakes and some amphibians, that travel several kilometres or much further, finding their way to their breeding places.

When designing measures to protect reptiles and amphibians, all these facts must be known, so that they can be taken into account. It is therefore essential to identify key habitats and prevent their loss or deterioration. Although public and political interest in nature conservation is increasing, reptiles and amphibians tend to stay in the shadow of the more popular groups such as flowering plants, birds, butterflies, and mammals. As a consequence, the worldwide decline of many species of herpetofauna has largely gone unnoticed, and has certainly not been addressed. Moreover, in habitat conservation, minimal use has been made of their significance as indicator species for many important habitat types, a missed chance (CORBETT, 1989; STUMPEL & CORBETT, 2003B). This is extra regrettable, as the habitats of both reptiles and amphibians, are generally speaking, of the same order of magnitude as the scale on which practical measures are carried out in nature management. This will become clear in Chapter 7. I am concerned with getting the right approach, so that herpetofauna can be conserved before it is too late.

The Conservation Committee of *Societas Europaea Herpetologica* (SEH), the European herpetological society, have been investigating the status of the European reptiles and amphibians from their beginning in 1981. Already the first results revealed many serious threats to both reptiles and amphibians, which were hitherto unknown. There was an obvious trend of decline in numbers and deterioration of habitats; many species were in urgent need of conservation. Consequently, special surveys were made of Europe’s rarest herpetofauna (e.g., GROSSENBACHER *ET AL*., 1983; VOESENEK & VAN ROOY, 1984; CORBETT *ET AL*., 1985A, 1985B, 1985C; GROOMBRIDGE, 1985; GROSSENBACHER, 1985; HELMER & SCHOLTE, 1985; STUBBS, 1985; VAN MOOK, 1986), which led to the identification of key sites and areas for threatened species (CONSERVATION COMMITTEE, 1987; CORBETT, 1989).

At the same time during the mid 1980s, the Conservation Committee became active on the policy front under the auspices of the Bern Convention. We assessed the habitats of most of the threatened species by visiting them all over Europe, and reported to the Council of Europe (e.g., CORBETT *ET AL*., 1990; ANDRÉN *ET AL*., 1991, 1993). On the basis of these reports, the Ministers concerned accepted no less than twenty-one Recommendations for the conservation of herpetofauna (EDGAR & STUMPEL, 2004). I was personally involved in what are called On-the-spot-appraisals, which brought me to Sardinia, where the unique herpetofauna lacked appropriate conservation (STUMPEL, 1992; VAN ROOY & STUMPEL, 1995). Furthermore, I chaired a group of experts on behalf of the Bern Convention, and we examined the problems confronting endangered species in greater detail. During this period, a solid co-operation came about with many European herpetologists and they have strongly influenced my views on conservation.

This work is all connected with international legislation, which forms the basis for nature conservation policy in the different countries that agree to take part. At the European level, reptiles and amphibians are legally protected by two international treaties. The Bern Convention was the first (ANONYMOUS, 1979). It was drawn up in 1979 under the auspices of the Council of Europe, and ratified by the Netherlands in 1982. This agreement is concerned with "the conservation of European wildlife and natural habitats". The Bern Convention covers all European species of reptiles and amphibians; the most threatened species are included in Annex II "strictly protected fauna species", and all other herpetofauna species come under Annex III "protected fauna species". According to the category, there are different obligations for those who sign the treaty, that is, the contracting parties who, as well as states, may be non-governmental organisations. They may be committed to protect special habitats and to manage them appropriately.

The second treaty is the European Habitat and Bird Directive (Directive 92/43/EEG; ANONYMOUS, 1992) of 1992, concerning "the conservation of the natural habitats and the wild flora and fauna". Reptiles and amphibians may be listed either in Annex II as "animal and plant species of community interest whose conservation requires the designation of special areas of conservation" or in Annex IV as "animal and plant species of community interest in need of strict protection". In contrast with the Bern Convention, not all European species of reptiles and amphibians are included. Some endangered species are missing from Annex II, as, for example, the Sardinian brook salamander *Euproctus platycephalus*. This makes it difficult to designate areas for conservation of such species.

Many members of the Conservation Committee of the SEH had joined the I.U.C.N. Species Survival Commission's Group for European Herpetofauna in the early 1990s. This group started to compile a set of Action Plans for threatened amphibians and reptiles (CORBETT *ET AL.*, 1987, 1990; ANDRÉN *ET AL.*, 1991; STUMPEL *ET AL.*, 1992; ANDRÉN *ET AL.*, 1993). This work was to take a long time, but since 1998, many of the draft texts have been adopted by the Council of Europe for the Bern Convention. However, they still have to be put into action.

Other relevant developments on the European front included the publication of the atlas of the European herpetofauna by the SEH (GASC *ET AL.*, 1997), which provided a useful overview of distribution patterns for non-specialists involved in policy-making. The Pond *Life* Project of the European Union (HULL *ET AL.*, 1997; BOOTHBY, 1999) was a new stimulus for conservation that raised much awareness concerning ponds as a habitat for wildlife in Europe, and furthermore, their importance as a habitat for amphibians.

International programmes, such as the Pan European Ecological Network (PEEN) (NOWICKI, 1998; VAN OPSTAL, 2000) and Natura 2000 (EUROPEAN COMMISSION, s.a.), which designate areas for nature conservation, show that mapping of the most important habitats of reptiles and amphibians is a prerequisite for good nature conservation. Recently, at the initiative of the Netherlands' *Ministerie van Landbouw, Natuur en Voedselkwaliteit* (LNV; Ministry of agriculture, nature and food quality), the project Important Herpetofaunal Areas in

Europe (IHAs) was started (STUMPEL & CORBETT, 2003A), mapping the most important areas in Europe for the survival of threatened herpetofauna and rich assemblages of different taxa. According to defined criteria that take their known conservation status into account, sixteen amphibian species and thirty-nine reptile species and subspecies have now been listed as international target taxa. This is about one-fifth of the European herpetofauna (TABLE 1). IHAs are also being established for each separate European country. The project is being carried out with the co-operation of herpetologists all over Europe, using their expertise to point out such areas. We hope that the atlas of these IHAs will provide policy makers with a tool for conservation planning. Publication is planned for 2005.

Other examples of co-operation between more than one country can be seen in conservation activities of private organisations, such as MEDASSET, the Mediterranean Association to Save the Sea Turtles and SOPTOM, the *Station d'Observation et de Protection des Tortues des Maures*, the latter concerned with the conservation of tortoises in southern Europe.

However, before we can take appropriate conservation measures, despite all that has been done, we still do not have enough details about the habitats to be protected. The identification and delimitation of key habitats should have priority. Moreover, key habitats must be continuously monitored in order to be able to adjust conservation measures if necessary.

Internationally, a lot has been achieved in raising awareness, which has led to national legislation and local conservation successes. However, the international treaties do not bear enough weight. Many countries do not take the obligations seriously; they try to get out of them, minimising their efforts in favour of economic interests, or do not keep to them at all. Violations are rarely sanctioned. Meanwhile, the threatened reptile and amphibian species are becoming more and more rare.

In the Netherlands, all indigenous reptiles and amphibians have been legally protected since 1973 under the Nature Conservation Act. As well as naming species, this act also designated some sites as *Beschermd Natuurmonument* (Protected Nature Monument). Since then, a national Red List for reptiles and amphibians has been published (CREEMERS, 1996; HOM *ET AL.* 1996). Recently, the Flora and Fauna Act (BACKES & VERSCHUUREN, 2001) provided an update of the Nature Conservation Act and included the provisions of the Bern Convention and the Habitat and Bird Directive. Yet, the new Act has exemptions that provide loopholes, leading to a political tug-of-war when people apply for planning permission. It is difficult to assess whether the conditions for exemption, namely, a. there is a national interest; b. there is no alternative; c. the sustainable survival of the regional population involved can be guaranteed, are met. Judgements based on ecological arguments are difficult to make and may include many uncertainties, due to lack of population studies (CAPPELLE & STUMPEL, 2003). This can lead to important habitats being destroyed. In order to set priorities for conservation, the policy makers have developed a system with target species (BAL *ET AL.*, 2001); all reptiles and amphibians from the Red List are included (TABLE 2). Furthermore, a series of Species Action Plans has been started by the Netherlands Ministry of Agriculture, Nature and Food Quality (LENDERS, 2000; CROMBAGHS & CREEMERS, 2001; CROMBAGHS & LENDERS, 2001; LENDERS *ET AL.*, 2002).

TABLE 2. National and international legal protection, Red List category and national policy appreciation of all the reptiles and amphibians of the Netherlands. BC: Bern Convention Annex; HD: Habitat Directive Annex; FF: Flora and Fauna Act; RL: national Red List category (E: endangered; T: threatened; V: vulnerable); TS: target species in Netherlands nature conservation policy. English nomenclature according to STUMPEL-RIENKS (1992). Species ordered phylogenetically per class to genus level.

English vernacular name	**Scientific name**	**Dutch vernacular name**	**BC**	**HD**	**FF**	**RL**	**TS**
REPTILES							
Slow-worm	*Anguis fragilis*	Hazelworm	III	-	●	V	●
Sand lizard	*Lacerta agilis*	Zandhagedis	II	IV	●	V	●
Wall lizard	*Podarcis muralis*	Muurhagedis	II	IV	●	E	●
Common lizard	*Zootoca vivipara*	Levendbarende hagedis	III	-	●	-	-
Smooth snake	*Coronella austriaca*	Gladde slang	II	IV	●	T	●
Grass snake	*Natrix natrix*	Ringslang	III	-	●	V	●
Adder	*Vipera berus*	Adder	III	-	●	V	●
AMPHIBIANS							
Fire salamander	*Salamandra salamandra*	Vuursalamander	III	-	●	T	●
Alpine newt	*Triturus alpestris*	Alpenwatersalamander	III	-	●	-	●
Great crested newt	*Triturus cristatus*	Kamsalamander	II	II & IV	●	V	●
Palmate newt	*Triturus helveticus*	Vinpootsalamander	III	-	●	V	●
Smooth newt	*Triturus vulgaris*	Kleine watersalamander	III	-	●	-	-
Midwife toad	*Alytes obstetricans*	Vroedmeesterpad	II	IV	●	V	●
Yellow-bellied toad	*Bombina variegata*	Geelbuikvuurpad	II	II & IV	●	E	●
Common spadefoot	*Pelobates fuscus*	Knoflookpad	II	IV	●	T	●
Common toad	*Bufo bufo*	Gewone pad	III	-	●	-	-
Natterjack toad	*Bufo calamita*	Rugstreeppad	II	IV	●	-	●
European tree frog	*Hyla arborea*	Boomkikker	II	IV	●	T	●
Moor frog	*Rana arvalis*	Heikikker	II	IV	●	V	●
Edible frog	*Rana* kl. *esculenta*	Middelste groene kikker	III	-	●	-	-
Pool frog	*Rana lessonae*	Poelkikker	III	IV	●	V	●
Marsh frog	*Rana ridibunda*	Meerkikker	III	-	●	-	-
Common frog	*Rana temporaria*	Bruine kikker	III	-	●	-	-

There has been a lot of work in getting reptiles and amphibians on the map in this country. In the Netherlands, there are two societies for people interested in the herpetofauna; members are both professionals and amateurs. The society *Lacerta* puts a strong accent on keeping herpetofauna in a terrarium, and publishes a bimonthly journal of the same name. *RAVON*, which stands for *Reptielen Amfibieën Vissen Onderzoek Nederland* (Society for the study of reptiles, amphibians and fish in the Netherlands), is more orientated towards conservation. Its journal also has the same name, appearing every two months as well. Both societies have made a large effort to map the distribution of the Netherlands' herpetofauna, by setting up national databases (VAN DE BUND, 1964; BERGMANS & ZUIDERWIJK, 1986). In 1993 RAVON set up a national network of field workers, *Meetnet Reptielen en Amfibieën* (Monitoring workgroup for reptiles and amphibians), comprising both professionals and voluntary workers. Counting herpetofauna along transects, they have provided data that enables us to calculate trends in population development. The databases of the two societies have recently been merged, and the data are being used to prepare a scientific atlas that RAVON will shortly be publishing. Through this work, the distribution of the herpetofauna in the Netherlands is now well known. However, the areas with key habitats for many threatened species (IHAs) have not yet been officially identified.

Furthermore, various publications have brought attention to the many ways in which the herpetofauna is threatened in the Netherlands (VAN DE BUND, 1964; STUMPEL, 1981A, 1981B, 1981C, 2000; BERGMANS & ZUIDERWIJK, 1986; FOG *ET AL.*, 1996; TABLE 3), and the *Werkgroep Amfibieën en Reptielen Nederland* (WARN; Working group on amphibians and reptiles in the Netherlands) organised workshops on this subject annually. The loss of ponds has long been recognised as a major threat to amphibians. From 1982 onwards, a number of Pond Action Plans have been carried out (e.g., BOSSENBROEK *ET AL.*, 1982; BOSSENBROEK & LENDERS, 1985; LAAN & VERBOOM, 1986; CONSULENTSCHAP, 1987, 1992; CROMBAGHS *ET AL.*, 1989; SCHROFER & STOOKER, 1991). Furthermore, manuals for pond management have appeared (VAN BERKEL & STEINHAUER, 1988; HANEKAMP, 1997), and in order to help the general public make garden ponds into a habitat suitable for amphibians, educational information has been provided (STUMPEL & WEZEMAN, 2000).

After the Second World War, the government carried out a national programme for consolidating and re-allocating land, known in Dutch as *ruilverkaveling*, in order to rationalise agriculture. Large-scale, modern and highly mechanised farming replaced the small-scale, low-impact traditional farming practices (LAMBERT, 1985), resulting in loss of wildlife and natural and semi-natural habitats. Over the years, together with the explosive growth of towns and infrastructure, this has led to the destruction and degradation of nature and the landscape on a disastrous scale. Relatively few sites were safeguarded as nature reserves; these were often small and isolated, and moreover, buffering zones were absent (e.g., STUMPEL, 1997). Today, manuring and drainage of agricultural land continue to have their effect both in nature reserves and other natural areas; they remain the most serious threat to nature in the Netherlands.

Intensive land use is still common practice, and reptiles and amphibians are generally unable to cope with the speed of today's man-made changes, being unable to find alternatives in the face of loss, deterioration and fragmentation of their habitats. The threats that bring this about are the most serious (e.g., STUMPEL, 1981A; BERGMANS & ZUIDERWIJK, 1986; CORBETT, 1989; CREEMERS, 1996). Many other threats may only be temporary or have an effect at local level. Among these are illegal sale of animals or their disappearance into private collections (e.g., WARWICK, 1990; LENDERS, 2004). An overview of the most serious ways in which the herpetofauna are threatened in the Netherlands is given in TABLE 3; threats concerning the physical well-being of individuals have been left aside. I am aware of the shortcomings of such an overview; it is difficult to name and list threats separately, as some overlap, or have more than one effect. Yet, I thought it useful to give the reader an idea of how drastic the effects are of our way of life here in the Netherlands, how much we are encroaching upon what is left of our nature. It should be realised that evaluating the impact of each threat separately is complicated, if not impossible. In Chapter 7 the threats are handled in context of the habitat type they apply to, and the way in which they work will be more apparent.

TABLE 3. Main threats to reptiles and amphibians in the Netherlands and their effect on the animals and habitats.

Threat as a result of:	**What happens in the landscape?**	**Effect on herpetofauna and habitat:**
modern agricultural, horticultural or forestry practices:		
large-scale land use	parcels bigger: distances between field edges increased, and also between natural areas; area of wild vegetation at field edge reduced	reduction of habitat; isolates populations
intensive animal husbandry	acidification of aquatic habitats; eutrophication leading to uniform, tall vegetation; trampling of vegetation	reproduction failure; deterioration of habitat
drainage	groundwater table lower; microclimate less humid; ditches and ponds dry up	animals in danger of desicca-tion; loss or deterioration of habitat; loss of aquatic habitat for amphibians
mechanical cutting	complex vegetation structure lost, uniform vegetation; sharp boundaries between parcels	prevents optimal development of habitat
frequent crop rotation	frequent change in land use, with ploughing, etc.; loss of grassland to arable land	loss or disturbance of habitat; animals killed by plough; reduces population
use of fertilisers	contamination of reproduction waters; eutrophication leading to uniform, tall vegetation or more grass in heathland	reproduction habitat lost; lacking of structure in habitat
frequent mowing or cutting	no development of vegetation structure; in their active season, animals get in the way of machinery	optimal development of habitat prevented; killing of animals during active season reduces population
overgrazing	heterogeneity of the vegetation lost; no structure variation in vertical direction	optimal development of habitat prevented; makes habitat unsuitable
burning	mature vegetation structure lost, re-growth uniform; animals cannot move quickly enough to escape fire	prevents optimal development of habitat; affects hibernacula; animals killed; reduces population

Threat as a result of:	What happens in the landscape?	Effect on herpetofauna and habitat:
use of herbicides and pesticides	poisonous substances in aquatic and terrestrial habitat; invertebrates they feed on die	animals die; abnormalities occur; reproduction decreases; food shortage; reduces population
urbanisation:		
building activities	wild places in towns are lost; building encroaches on countryside	loss or isolation of habitat
recreation	disturbance of nearby natural areas; trampling of vegetation; collecting or killing animals; predation by pets	habitat deteriorates; vegetation structure spoilt; animals disturbed, injured or killed; reduces population
infrastructure:		
construction of roads, railways or canals	splitting up of natural areas;	fragmentation of habitat; isolation of populations; traffic casualties when migration route is obstructed; reduction of population
modern management of waterways:		
frequent mowing and dredging	development of vegetation structure on shores and under water suppressed; animals get in the way of machinery	prevents optimal development of habitat; interference with animal activities; kills animals; reduces population
straightening of watercourses	vertical banks; loss of diversity in vegetation structure	animals cannot leave water and die or get eaten; prevents optimal development of habitat
mismanagement:		
lack of management	succession of vegetation proceeds too far; arrival of alien species not controlled	habitat deteriorates and gets lost; harmful effect on population
bad timing of measures	machinery in use in active period of animals	interference with animal activities; disturbance of reproduction
too frequent intervention	no development of mature vegetation structure; in their active season, animals get in the way of machinery	optimal development of habitat prevented; killing of animals during active season; reduces population

Threat as a result of:	What happens in the landscape?	Effect on herpetofauna and habitat:
mechanical cutting	uniform vegetation; sharp boundaries between parcels; animals get in the way of machinery	prevents optimal development of habitat; makes habitat unsuitable; kills animals; reduces population
overgrazing	heterogeneity of the vegetation lost; no structure variation in vertical direction	optimal development of habitat prevented; makes habitat unsuitable
burning	mature vegetation structure lost, uniform re-growth; animals cannot move quickly enough to escape fire	prevents optimal development of habitat; affects hibernacula; animals killed; reduces population
other causes:		
pollution	water or soil contains noxious substances	animals die; population becomes extinct
diseases	sick animals released into wild populations	animals die; population decreases or becomes extinct
keeping of fish and waterfowl in ponds and pools	predators in unnatural densities; water vegetation disappears; water gets turbid	habitat deteriorates; disturbance of amphibian reproduction; animals get eaten; reduces population
introduction of wild boars and pheasants for hunting	predators in unnatural densities	reptiles get eaten; reduces population
predation by pets	cats hunt reptiles and amphibians	animals are killed or maimed; population decreases or becomes extinct
persecution	deliberate killing and systematic hunting down of wild animals or whole populations	animals killed and habitat destroyed; population becomes extinct
collection	fewer wild animals	population decreases or becomes extinct

During the 1980s, it became apparent, although perhaps rather late in the day, that we needed a structural rather than an *ad hoc* approach to improve the quality of nature in the Netherlands. As a consequence, the National Nature Policy Plan (NNPP) was drawn up. It came into force in 1990 (MINISTERIE *ETC*., 1990; VAN ZADELHOFF & LAMMERS, 1995), and spans a thirty-year period (1990-2020), during which time its objectives are expected to be met. The main aim is “the sustainable preservation, restoration and improvement of nature and the value of the landscape". Although primarily directed at the ecosystem, the plan is also valuable for developing conservation objectives for animal and plant species, and for increasing awareness of geological features, local cultural history and the environment. Prioritisation at the species level has been carried out by identifying target species using three criteria: a. international importance; b. evidence of a decline at the national level; and c. rarity at the national level. Species meeting two or more of the criteria were selected to produce a list of target species (BAL *ET AL*., 2001; TABLE 2). Among these are eleven amphibians and six reptiles. They will be the target species for the IHAs of the Netherlands.

The NNPP is a strategic plan at national level that resulted in the National Ecological Network (NEN). This network consists of core areas, these are larger than 500 ha, stepping stones of between 50 and 500 ha, areas for future nature development, and corridors with a recommended width of 1 km for connecting them. The purpose of the Network is to counteract the effects of fragmentation on the one hand, and to prevent further fragmentation of the landscape on the other hand, in order that plants and animals have a better chance to survive.

The first step in putting a stop to fragmentation is the protection of certain areas by environmental planning. Next, the land has to be acquired, and thus money has to be allocated for this purpose. Finally, management agreements need to be drawn up; they are essential for maintaining and enhancing the value of the NEN areas. These agreements are the responsibility of the *Programma Beheer* (Programme Nature Management), which has the responsibility for dispensing the financial means in an effective way.

Plans, however good they look on paper, only have value if they produce benefits in the field. The great disadvantage of the structural approach is that not all habitats of threatened herpetofauna are included in the NEN, and moreover, it is impossible to fund the acquisition of new areas outside the National Ecological Network both now and in the future.

But next to information on habitats, more data on population sizes of reptiles and amphibians are needed urgently. We must have up-to-date data on the presence and abundance of herpetofauna species from all over the country. We need a system with sampling methods based on the ecology of the different species, using methods designed for investigating a particular species (STUMPEL & SIEPEL, 1993). The first step towards a national monitoring system has already been made by the Monitoring workgroup of RAVON that has been counting reptiles and amphibians along fixed routes for the last ten years (ZUIDERWIJK, 2003B).

Under the auspices of the European Habitat Directive, the designation of Natura-2000 areas is now underway through the creation of a network of so-called Special Protection Zones (SPZs), which include areas for the Bird Directive (Directive 79/409/EEG). By 2003, the Netherlands had registered a hundred and forty-one of such areas. Unfortunately, the habitats of reptiles and amphibians have been a secondary consideration, the selection being based on plant communities and landscape types (JANSSEN & SCHAMINÉE, 2003). This shows that the final decision is often a compromise at the cost of a certain species. For example, the location of the best habitats of the Great crested newt, a species placed in both annexes of the Habitat Directive, has not been the leading argument for the designation of SPZs (ZOLLINGER *ET AL.*, 2003).

Despite all the above regulations and efforts, reptiles and amphibians, including the commoner ones, are still declining in the Netherlands due to habitat loss and habitat change (e.g., VAN DELFT & KUENEN, 1998; WITMER *ET AL.*, 2002). Although some populations show an increase in numbers through the enthusiastic efforts of professionals and voluntary workers alike (OVERLEG DUINHAGEDIS, 1999; BRAAD, 2000; MOORS, 2003; ZUIDERWIJK, 2003A), there is no reason for overall optimism. There is clearly a discrepancy between policy and practice in nature conservation in the Netherlands. Policy plans are necessary, but their profusion is out of all proportion. Paperwork does not mean that the practical work of management is really done. Only by carrying out effective measures can we ensure the long-term survival of populations; the real work of conservation is carried out in the field.

My contribution is therefore about management practice, based on my own experience working for the conservation of reptiles and amphibians in the Netherlands and abroad for a period of over 30 years. I highlight the most relevant measures in conservation management for each group of the herpetofauna. Moreover, I have looked for solutions to current management problems and have recommended appropriate measures, if possible at the species level. As each site needs a conservation and management plan tailored to the local situation (e.g., CROMBAGHS & BOSMAN, 2003), it would be impossible to describe all management details in this study, but many measures can be deduced from the framework I describe. Financial implications, even though they may be considerable in some cases, are not discussed in this study. Furthermore, although they all play a part in safeguarding these animals, policy development, education, laws and regulations, the modern techniques of the restoration of inbred populations (e.g., MADSEN *ET AL.*, 1999), and animal welfare, are also not discussed.

Special attention has been paid to the situation in the Netherlands, but where relevant, reference is made to Europe as many problems are shared. Two important problems in conservation management are dealt with in detail: how best to maintain heathland as a habitat for reptiles, and how to create, restore and manage ponds as a reproduction habitat for amphibians in a modern agricultural landscape.

It is important to realise that each species of reptile and amphibian has its own survival strategy and conservation needs. Nevertheless, some of these needs are shared, applying to a number of species from the same class or to a number of species from an assemblage of reptile and amphibian species (e.g., STRIJBOSCH, 1991). They can be used as a framework for other measures that are more species specific. Measures, both general and specific, form the main subject of Chapter 7.

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2 Biometrical and ecological data from a Netherlands population of *Anguis fragilis* (Reptilia, Sauria, Anguidae)

Abstract. Slow-worms (*Anguis fragilis*) were caught, measured, marked and released over a period of three years. A number of them was recaptured. In this way information was gathered about biometry, tail loss, above-ground presence, movements, and habitat selection. Animals were present above ground in the daytime. Most captures were made during the mid-afternoon hours in August, mainly of females. The Slow-worms showed a high site tenacity. They prefer certain vegetation types in the forest area.

Introduction

Most information about Slow-worms (*Anguis fragilis* L., 1758) originates from captive animals (e.g., HORNUNG, 1896, 1897), or from specimens in museum collections from different populations (e.g., WERMUTH, 1950). Also reports have been made of finds of great numbers in winter habitats (COLLETT, 1918; MERTENS, 1947; SMITH, 1973) or under objects in the vegetation (SIMMS, 1970); however, no animals were measured. Detailed information about habitat requirements is scanty. General views of the Slow-worm's life history and ecology are given by ROLLINAT (1946), PETZOLD (1971), SMITH (1973) and DELY (1981).

It proves hard to establish the presence and abundance of this very secretly living species (partly fossorial). I know of only one field survey that has been carried out rather systematically (FELLENBERG, 1981).

During the period 1978-1980 the author made a survey of the distribution and habitat selection of Lacertid lizards, aimed at nature conservation and management. Attention was also paid to the Slow-worm, casually though. Yet, in view of the hidden way of life of this species, the number of specimens caught was surprisingly high, so that it was possible to gain information about biometry, tail loss, above-ground presence, movements, and habitat selection. The data presented in this paper come from one single wild population.

Study area

The study area of about 500 ha (a part of the forest Amerongsche Bosch) is situated in the southeastern part of the Utrechtse Heuvelrug, a hill ridge in the province of Utrecht in the centre of the Netherlands. It consists of a mainly wooded push moraine with podzolic soils. Highest and lowest point respectively are 69.2 and 8.2 m above sea level. All vegetations in the Amerongsche Bosch are climax, developing, substitute, or degradation stages of the oak-birch forest (*Querco roboris-Betuletum*). The major part of the area is covered with conifer plantations in small plots, and as a result the study area has a very dense system of paths. The structure of the study area is fairly varied in consequence of the present management, which aims both at wood exploitation and at natural forest development: in some parcels conifers (*Picea, Pinus* and *Pseudotsuga*) are grown in cycles of 80-120 years, while in others conifers are cut down in favour of birch and oak. One can find side by side most stages in the succession from bare grounds to mature forest.

Material and methods

From the beginning of April until half October the study area was visited almost daily. Field work was done from sunset until sundown and spread over the hours of the day as evenly as possible. Slow-worms were localized by eye sight and caught by hand. All captures were made above ground, no animals were dug up. For individual recognition the animals were branded with a cordless soldering iron (Isotip, Wahl Clipper Corp.), provided with a micro tip. According to a code, tiny point-shaped marks were placed on the ventral scales. The conspicuity of the marks decreased strongly in the course of time. However, they remained observable throughout the survey period. Slow-worms were treated at the catching site and released immediately afterwards at the same spot. At each capture the following data were recorded: sex, mark, pregnancy, length (snout-vent, tail, tail regeneration), state of the tail (complete or broken), date, time of day, locality (according to a coordinate system with an accuracy of 1 m), and vegetation characteristics.

Weather data were obtained from a station, situated along the same hill ridge, at a distance of 24 km.

Time was recorded as or converted into Central European Summer Time.
The nomenclature of plants follows VAN DER MEIJDEN *ET AL*. (1983).

Results and Discussion

Numbers

During the survey period 110 different specimens of Slow-worms were captured (99 adults and 11 subadults). Only once the blue-spotted form was found: a male of 160 mm snout-vent-length (SVL).

The total time spent on the reptile field work was 1686 hours. This is rather low, because of long periods of cold weather and rain. Consequently, the mean capturing success of Slow-worms was one capture in 9.9 hours of field work.

All animals of SVL < 120 mm were considered subadult, because most of the Slow-worms of ≥ 120 mm could be sexed. SCHREIBER (1912) considers Slow-worms of ca. 250 mm body length (BL, BL = SVL + tail length TL) as sexually mature. SMITH (1973) gives a maximum BL of 230 mm for animals at the end of their 3rd year.

It is known that the sexes cannot always be distinguished on the basis of external characteristics only (cf., WERMUTH, 1950). In my study mostly the colour pattern of the scales combined with the shape of head and trunk was used for sexual determination (the pileus length was not measured). In many cases, sexual determination was facilitated by males extruding their hemipenes and by females being visibly gravid. Sometimes it was not possible to determine the sex with 100% certainty.

The group of adults consisted of 19 males, 66 females and 14 individuals of unknown sex. So for the sexed animals the sex ratio was 0.29 for the first captures. Also GREGORY (1980), SMITH (1973), SPELLERBERG & PHELPS (1977), STREET (1979) and VAN DE BUND (1964) observed more females than males above ground.

The total number of captures was 170 (73 in 1978, 22 in 1979 and 75 in 1980), respectively on 44, 21 and 49 specimens; among these were 60 recaptures of 30 different specimens. All recaptures were adult females, except for 1 adult animal that could not be sexed. Two Slow-worms were recaptured 5 times. Of all females caught (66), 33 were visibly gravid at the first capture. However, it should be noted that determination of pregnancy only by sight may have been difficult in females with a low number of embryos (especially the young ones, cf., ROLLINAT, 1946).

No explanation can be given for the difference in number of captures between the three years, because the searching intensity was equal in every year. No relationship could be demonstrated with the weather conditions. Also within the group of females, the percentage of specimens that is gravid in one year is different over the three years: 0.31, 0.43 and 0.87 respectively in 1978 (n = 32), 1979 (n = 7) and 1980 (n = 31) (3x2 test of independence using the G-test, $P<0.005$). As the number of captures in 1978 and 1980 were almost equal, these data lead to some doubt if all Slow-worms in this population have a one-year reproduction cycle, as mentioned for central France by ROLLINAT (1946) and SAINT GIRONS (1963). Because in 1980 only 4 out of 31 adult females never were visibly gravid, it is likely that the greatest part of the adult females joined in the reproduction in 1980.

The number of recaptures is too low for estimating the population density. Remarkably few juvenile and subadult Slow-worms have been observed. Only once a newly born animal was caught, in spite of special searching activities at places where late in the season gravid females were found. The small number of young Slow-worms observed may indicate a more hidden way of living of this group, which was also mentioned by DELY (1981), HORNUNG (1896, 1897) and SMITH (1973). On the other hand, as Slow-worms can get very old - up to 46 years (FUHN & VANCEA, 1961) - , only few juveniles would be expected.

Length, weight and tail loss

Data about lengths are presented in TABLE 1. For both SVL and BL, males are significantly smaller than females (Mann-Whitney U-test; in both cases $P<0.001$). There are no differences in SVL/TL ratio between males and females with a complete tail.

Little information was obtained about growth. Between the first and the last capture, growth was generally less than 5 mm (SVL), which was within the estimated measuring error of 2-5%. Only two females showed clear growth: one increased 12 + 6 mm (SVL + TL) (from 165 + 175 to 177 + 181 mm) in 672 days; the other 13 + 13 + 0 mm (SVL + TL unbroken part + TL regenerated part) (from 134 + 112 + 5 to 147 + 125 + 5 mm) in 709 days.

In literature, relatively much information exists about scalation, blue-spotted morphs and systematics of the Slow-worm. Also many records have been made of the maximum sizes of Slow-worms in different geographic areas (summarized in DELY, 1981). Other data about lengths are very scarce and they mostly concern single specimens, never populations. Compared with the available data, the lengths as well as the SVL/TL ratios recorded in this study, do not essentially differ from those, mentioned in literature about the nominate race (e.g., WERMUTH, 1950; STUGREN *ET AL*., 1962; DELY, 1981; FELLENBERG, 1981).

TABLE 1. Lengths at first capture. SVL = snout-vent-length, BL = total length of Slow-worms with a complete tail, SVL/TL = ratio SVL/tail length of Slow-worms with a complete tail.

	n	mean SVL in mm	maximum	minimum
adult males	19	142.7 ± 14.9	179	120
adult females	66	156.4 ± 11.9	185	131
adults, sex unknown	14	144.9 ± 11.1	168	121
	n	mean BL in mm	maximum	minimum
adult males	12	282.1 ± 14.1	301	258
adult females	27	330.2 ± 25.3	385	270
adults, sex unknown	5	299.0 ± 17.3	330	279
	n	SVL/TL	maximum	minimum
adult males	12	0.922 ± 0.033	0.993	0.870
adult females	27	0.922 ± 0.040	1.000	0.843
adults, sex unknown	5	0.935 ± 0.037	1.000	0.888

Slow-worms were weighed in 1980 only. FIGURE 1 gives the weights in classes of 1 g. Mean weights of animals with a complete tail are shown in TABLE 2. Females are heavier than males (the lightest female is heavier than the heaviest male). However, this is based on only 5 males, and they were all very young (SVL 120-140 mm). Between first and last capture no difference of weight could be measured. Adult females and adults of unknown sex showed a significant correlation between SVL and weight (animals with complete tails) (Spearman rank correlation coefficient; for females $P < 0.01$, for the other group $P < 0.02$), which was actually expected for the adult males too.

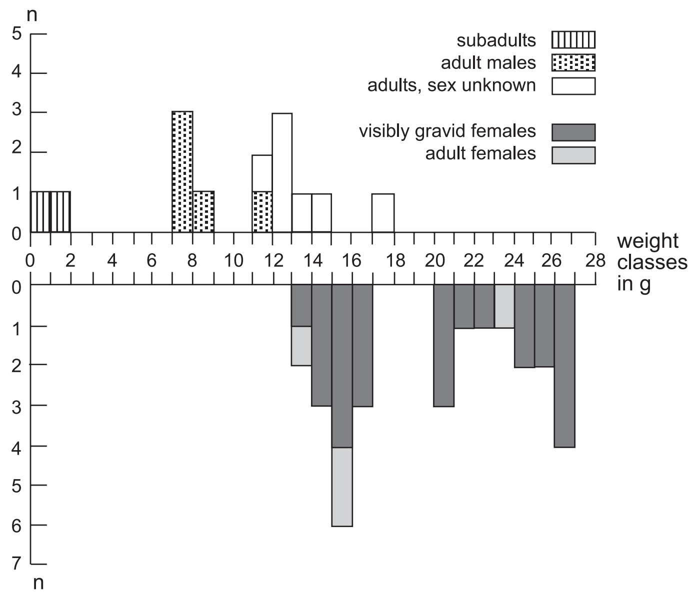

FIGURE 1 Frequency of weight classes of 1 g. All Slow-worms with a complete tail, caught in 1980.

The males in my study area have a very low weight, due to their young age. In TABLE 2, only the Slow-worms with a complete tail are presented. The maximum weight for males with a broken tail is somewhat higher: 13.7 g (SVL = 165 mm, BL = 295 mm). However, these values are normal for the Netherlands. VAN BUGGENUM & LEVELS (1980) found a range of 7.5-30 g in males from another Netherlands study area. Apparently, I did not catch old males. In literature, there are almost no further data about weights. Two records have been found: FELLENBERG (1981) mentions a female of 28.5 g from Westphalia (BL = 43.6 cm), and MCCARTHY (1977) got a male of 13.7 g (BL = 34 cm) from Ireland (the values in his paper have been misprinted; McCarthy, pers. comm.). Both weights are about the same as the maximum weights recorded here.

TABLE 2. Mean weights of adult Slow-worms with a complete tail, caught in 1980 (all captures).

	n	mean weight in g	maximum	minimum
adult males	5	8.5 ± 1.5	11.4	7.4
adult females	28	19.4 ± 4.6	26.0	13.4
adults, sex unknown	7	13.2 ± 1.8	17.0	11.3

At the first capture, 56 Slow-worms (= 50.9%) had a broken tail (TABLE 3). Once a female was recaptured after 24 days with a newly broken tail; all other Slow-worms recaptured kept their primary tail during the survey period. From the group of animals with a broken tail at the first capture, only once a female with a newly broken tail was recaptured. During the survey tail breakage was never brought about. Relative numbers of primary tails at first capture of males and females do not differ significantly (Fisher's exact test for independence, P>0.05).

TABLE 3. Number of Slow-worms with a complete tail at first capture.

	number of captures	number with a complete tail	percentage
adult males	19	12	63.2
adult females	66	27	40.9
adults, sex unknown	14	5	35.7
subadults	11	10	90.9
total	110	54	49.1

From the 56 Slow-worms with a broken tail, 50 had a regenerated part of the tail. Maximum length of that part was 11 mm in two gravid females of 175 + 56 mm and 170 + 44 mm (SVL + TL). These Slow-worms had lost more than half of the original tail (cf., TABLE 1). BRYANT & BELLAIRS (1967) found the same in their Slow-worms with maximum regrowth. The second female was recaptured after 731 days; only 1 mm growth of the regenerated part could be assessed. Another female showed no increase in length of that part: it stayed 5 mm long in a period of 724 days. A significant correlation was found between the SVL and the length of the regenerated part of the tail (Kendall rank correlation coefficient test, P<0.01), which indicates that Slow-worms regain a longer regenerated part of the tail as they grow older, or, more likely, that the regenerated part keeps growing along with the animal. BRYANT & BELLAIRS' study was directed to tail regeneration. My results correspond well with theirs on captive animals: tail regeneration is very slow and yields only a short stump; in fact the wound only heals. The question arises why there is no tail regrowth such as in other lizards. A shortened tail certainly influences the locomotion of the Slow-worm on bare soils. But as the Slow-worm mostly lives inside the vegetation where it can quickly disappear (this paper), it may have less need for a long tail. Apparently, the tail does not have an essential function for fat storage.

During the survey period only two animals lost a piece of tail, while the tail breakage percentage over all Slow-worms is rather high (50.9%). This may reflect the longevity of the Slow-worm. Tail breakage may be attributed to the sexual activity of the Slow-worms. Fighting often occurs among males (SMITH, 1973;

STREET, 1979), and the female is bitten by the male during copulation (ROLLINAT, 1946). In both activities, there is a great risk for tail breakage. Therefore, the animals have a great chance losing their primary tail during the first years of sexual activity. Indications for this were found in testing a correlation between the length of the adults and the proportion of broken tails (t-test, $0.05<P<0.125$). In addition to a more hidden way of living, also this may explain the high proportion of complete tails in subadults. The impact of tail breakage, caused by predators, is supposed to be rather constant during the Slow-worm's life.

Above-ground presence

The Slow-worms observed in this study were visible in or on the vegetation or on the bare soil. When they were inside the layer between the soil and the top of the (dense) vegetation (e.g. for chasing), they have not been noticed.

Animals were caught throughout the whole season. Mating was never observed. In TABLE 4 the number of captures is given per month, per hour class, and for the distinguished group of animals. The mid-afternoon hours in August provided most captures, mainly females.

No correlation could be demonstrated between above-ground presence and weather (monthly data of air temperatures, hours with sunshine, mm rainfall).

Captures were made from March 22nd until October 9th. This agrees well with data from DELY (1981), PETZOLD (1971), ROLLINAT (1946) and SMITH (1973). As my main survey period covered the beginning of April till half October, I have only little information about Slow-worm activity in the rest of the year. DELY and PETZOLD, writing about animals from western Europe mention activity in the beginning of November, and Smith observed many Slow-worms in March. In this respect, it is remarkable that in this study so few Slow-worms were caught in April. The length of the hibernation period appears to be comparable to that of the sympatric lizards *Lacerta agilis* and *L. vivipara* (VAN NULAND & STRIJBOSCH, 1981). My study suggests that after hibernation the males are first in above-ground activity.

In contrast with its English name “Slow-worm” and in spite of its osteoderm armour, the Slow-worm really can be fast. Several times I observed that on warm days Slow-worms disappeared into the vegetation in a flash, a behaviour that can be compared with the fleeing behaviour of the skink *Chalcides chalcides*. Also SIMMS (1970) and STREET (1979) mention a sometimes surprising speed. This behaviour may lower the chance of observation on warm days.

TABLE 4. Number of captures (recaptures included) per hour class per month, and per sex per month.

month	hour class 9	10	11	12	13	14	15	16	17	18	19	20	total	adult males	adult females	adults, sex unknown	sub-adults
March	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-
April	-	1	-	1	-	-	-	-	-	-	-	-	2	1	-	1	-
May	1	1	1	2	-	-	-	-	3	1	2	-	11	7	1	-	3
June	1	1	-	2	1	1	1	1	2	1	-	-	11	4	5	2	-
July	-	-	-	5	4	6	5	7	8	3	2	1	41	1	35	4	1
August	1	2	6	8	6	10	11	19	9	5	-	-	77	4	67	2	4
September	-	2	1	2	1	6	1	5	4	1	2	-	25	2	16	5	2
October	-	-	-	-	1	-	-	1	-	-	-	-	2	-	-	1	1

The above-ground absence of Slow-worms during the 'warm hours' on summer days, as mentioned by GISLÉN & KAURI (1959), PETZOLD (1971) and DELY (1981), and the nocturnal way of life by SAINT GIRONS & SAINT GIRONS (1956), does not appear from my data. When searched carefully, Slow-worms really are found on 'warm hours', even more than in the early and the late hours. During the field work the Slow-worms appeared to be above-ground between 8.45 and 19.45. These times are influenced by the researcher's activities because little time was spent before 8.00 and after 20.00. However, during these early and late hours Slow-worms never were observed. In this respect, also the remark of HORNUNG (1891), that the animals he held in captivity, were no longer visibly active at the beginning of the dark, shows the probability of a diurnal above-ground activity.

The annual cycle of the Slow-worm (ROLLINAT, 1946; SAINT GIRONS, 1963), makes clear that the above ground presence, as recorded here, must be explained in terms of thermoregulation. After hibernation, the males are in need of heat energy for finishing their spermatogenesis before the mating starts. In summer, the females bask in full sunshine for stimulating development of the embryos. This also can be found from my data: 37% of the males was observed in May, 82% of the females in July and August (most of them were visibly gravid by then), and very few juvenile and subadult animals have been observed.

For thermoregulation, the weather must play an important role. Therefore, it will determine, apart from internal factors, the above-ground presence of the Slow-worm. The three summers of this survey were gloomy and cold. One might speculate that, as a result, the Slow-worms were in need of emerging any time the sun was shining, so that the numbers observed were relatively high. On the other hand, if they react on warm weather, more animals might have been seen in warmer summers. So it remains hard to judge about the abundance of the Slow-worms in the study area.

Movements

All recaptures were made within the same year of the preceding capture, except 4, which were made of animals marked in 1978 and recaptured in 1980. Never two or more individuals were found together. The number of all recaptures with relation to movements and time intervals is given in FIGURE 2. Distances were measured as the crow flies. The largest distance recorded was 130 m (after 672 days); the fastest displacement was 80 m in 7 days. The movements of the Slow-worms indicate high site tenacity in this area.

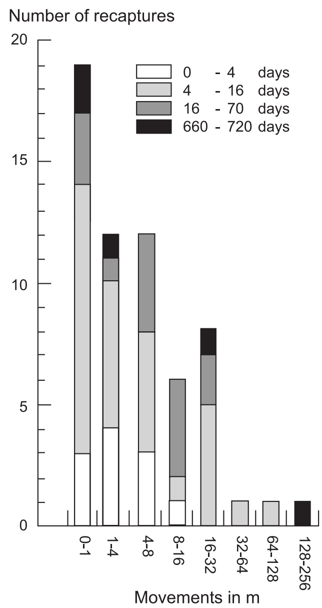

FIGURE 2 Number of all recaptures at different distances from the preceding site, at different time intervals.

Habitat

In the Netherlands, the Slow-worm mainly lives in wooded parts of the diluvial territory (Central, East and South Netherlands). Most records of the Slow-worm originate from the *Utrechtse Heuvelrug* (where the study area is situated), the *Veluwe* and Southern Limburg (VAN DE BUND, 1964). His data demonstrate a strong relationship between the Slow-worm records and the distribution of forests: 57% of all records were made inside forests, in forest edges or on coppice banks (he does not mention the forest types), 16% concerned dry heath. The remaining records came from wet heaths, road verges, slopes with grass vegetation, gardens, railroad embankments and unkempt places.

The captures in the study area were made inside as well as in the edges of the parcels. All recaptures were made within the same parcel and vegetation type as the first capture of the same specimen. The majority of the observations (85%) was made in plantations of *Picea* (several species, *P. abies* or *P. sitchensis* or *P. omorika*) or *Pseudotsuga menziesii*. From this group, 97% was found in young, rather open plantations of ages varying from 4 to 15 years (FIGURE 3).

FIGURE 3. Characteristic habitat of the Slow-worm: very young plantation of *Picea abies* (foreground). Most records were made in this vegetation type.

The trees are mostly lower than 5 m and at such a distance from each other (1-3 m), that the ground between the trees is directly shone upon by the sun on many places. The herb layer locally consists of very dense vegetation of *Deschampsia flexuosa*, which grows very tussocky, or of *Calluna vulgaris*. Also *Vaccinium myrtillus* is found. Between the conifers there is a fast growing of *Betula pendula*, which is cut down in winter time. There are also bare spots between the conifers with dead branches or with some low mosses which hardly contribute to the vegetation structure. In many places sods of *Carex pilulifera* occur.

The remaining Slow-worms from the spruce-fir forests were found in an older developing stage of this type of plantation of ages from 13 to 30 years. The trees are much higher (ca. 10 m) and form very dense vegetation. The lowest tree branches form an almost closed layer close to the ground, but here and there still glades occur. In general, the herbs have been substituted by mosses.

In the conifer plantations the developing series of the vegetation varies from bare ground to dense forest. Slow-worms never were caught in both extreme stages, but right in the intermediate stages. Sometimes extra light is provided in the somewhat older stages by clearcutting of trees. As a result of earlier tillage, extra structural variation occurred in the soil as well as in the vegetation, which makes that this burrowing species may have favourable conditions of life.

11% of all observations were made in a vegetation of composite structure, dominated by *Rubus*. It is an abandoned garden, where the vegetation consists of grasses, annual and perennial herbs and very dense, up to 2 m high shrubs of brambles.

The remaining captures (4%) were made at the edges of other forest types, such as mixed forest of *Betula pendula* and *Pinus (P. sylvestris* or *P. nigra*), young plantation of *Larix kaempferi*, oak coppice (*Quercus robur*), and at the edge of a heathland of *Calluna vulgaris, Erica tetralix* and *Molinia caerulea*. It is quite interesting that this last vegetation type has such a low score here. In other areas in the Netherlands I have made many observations of Slow-worms in open heathland vegetation.

From all captures, 71.3% was made in or near *Deschampsia flexuosa* (57.9% pure and 13.4% in combination with other plant species). Eight Slow-worms were caught on bare soil, six of them near *Calluna* and two near *Deschampsia*. Once, in September, a live Slow-worm was caught on a nest of wood ants (*Formica* species).

I did not find indications that males, females and subadults differ in selecting special vegetation types.

In conclusion, the Slow-worm's habitat in the area is characterized by forests of low trees (< 5 m), or higher trees with glades in between, or by forest edges with a south to southwest exposition. Inside the forests a bush layer fails and in the herb layer is a variety of open spots and dense plant growth. A strong preference exists for places with Wavy Hair-grass (*Deschampsia flexuosa*).

It should be noted that within the study area Slow-worms were not found in all potential forest habitats. In the summer of 1981, a ten of adult Slow-worms was found together under a pile of beech leaves at the edge of a dense beech forest, situated at ca. 5 km from the study area. This type of forest, dark without bush and herb layer (*Fagetum nudum*) also occurs in the Amerongsche Bosch, but Slow-worms never were observed there. Maybe the exposure of a vegetation type to sun and wind plays an important role in determining the suitability of a certain type as habitat for Slow-worms.

An important relationship exists between the actual forest management in the area and the distribution of Slow-worm habitats since the forest management (unconsciously, in respect of its effects on Slow-worms) takes care of the maintenance of the intermediate stages in the development of conifer forests: by clearcutting and by spreading the ages of the plantations. In this way always appropriate stages are available for the Slow-worm population.

If we assume that the Slow-worm's above-ground activity in the daytime is a criterion for its presence, the data presented here indicate that they do not inhabit the whole territory surveyed, but that they prefer certain vegetation types.

Conservation

Most of the Netherlands species of reptiles have been found to decrease in number (STUMPEL, 1981). However, this could not be established for the Slow-worm, as the distribution data are very fragmentary (BERGMANS, 1981; VAN DE BUND, 1964). I have the impression that on a national level this species is not yet threatened, although modern land use by man dissipates populations locally. FELLENBERG (1981) comes to the same conclusion for the neighbouring German state of Westphalia. More knowledge about the habitat selection aspects will provide a nature management with special emphasis on the Slow-worm's habitat.

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3 Habitat selection and management of the Sand lizard, *Lacerta agilis L.*, at the Utrechtse Heuvelrug, Central Netherlands

Abstract. A survey was made of the Sand lizard (*Lacerta agilis*) on the Utrechtse Heuvelrug in an area of 540 ha, which was nearly all heathland a century ago. Nowadays, the area is covered by forest, and only some small remnants of heathland are left. The present distribution of *L. agilis* is a relict of the former large population. The lizards were most abundant in spruce (*Picea*) plantations of 4-15 years old, with an undergrowth of Heather (*Calluna vulgaris*) or Wavy hair-grass (*Deschampsia flexuosa*). Remarkable was their low presence in open heather vegetation. The relationship between the distribution of *L. agilis* and the forest management carried out in the area is discussed. Heather plays an important role in the distribution of this lizard. It is recommended taking reptiles into account in the management of forests and heathland, ensuring that habitats favourable for *L. agilis* are present.

Introduction

In the Netherlands, Sand lizards (*Lacerta agilis*) are found only on sandy soils. Suitable habitats occur mainly on inland heathlands and in coastal dunes with open shrub vegetation (VAN DE BUND, 1964; VAN LEEUWEN & VAN DE HOEF, 1976; STUMPEL, 1985/1986). In former heathland areas, forested with conifers, small Sand lizard populations may survive. Within such an area Sand lizards have been studied with respect to habitat selection. This study was part of a three years ecological landscape project focusing on relationships between distribution patterns of animals and vegetation structure (OPDAM *ET AL.*, 1983, 1984), and aiming at guidelines for nature management.

Study area and Methods

The 540 ha study area is situated 1 km north of the village of Amerongen (province of Utrecht; FIGURE. 1) on a ridge. The vegetation on the podzolic soils consists of various stages of the oak-birch forest (*Querco roboris-Betuletum*). The major part of the area is covered with conifer plantations planted in small plots. As a result, the study area has a very dense system of rides.

Four species of reptiles are found within the study area: *Lacerta agilis*, *Lacerta vivipara*, *Anguis fragilis*, and *Natrix natrix*.

The area is managed for forestry, natural forest development, and recreation. This results in a fairly varied landscape: in certain plots conifers (*Picea*, *Pinus* and *Pseudotsuga*) are grown in 80-120 year cycles, while in others conifers are cut down in favour of birch and oak. One can find side by side most stages in the succession from bare ground to fairly mature forest.

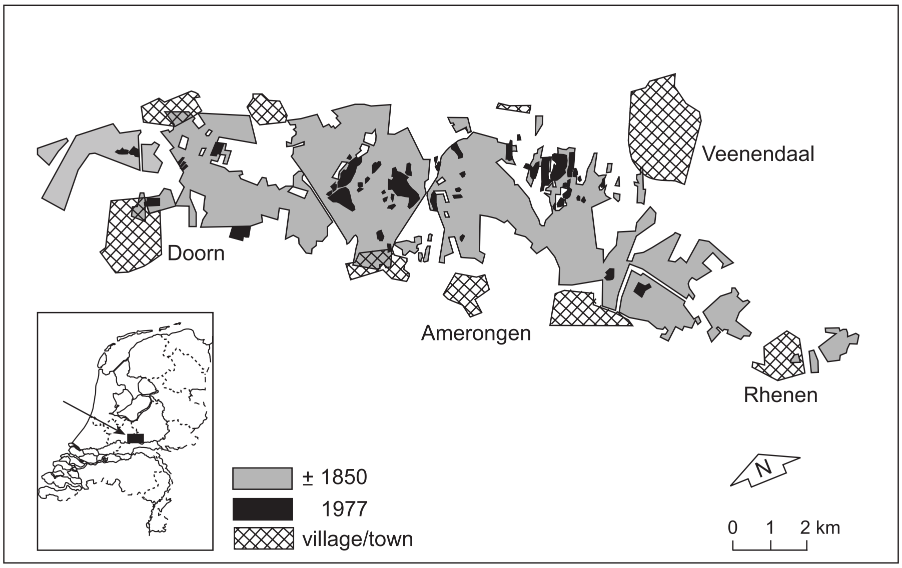

FIGURE 1. Heathland presence in the southern part of the Utrechtse Heuvelrug. Grey: situation of ± 1850; black: 1977 (LINKER, 1977).

Within the area many changes are happening regularly, which have consequences for the presence of the Sand lizard, such as - clearcutting for timber; - chopping of conifers; - chopping for scenic views; - cutting of birch twigs for brooms; - bulldozing paths for fire breaks, walking paths, forestry roads, bridle paths; - planting young trees; - piling up of chopped trunks. In addition, there is a high pressure of recreation. The area is visited by crowds of people and used for letting out dogs.

No management measures have been taken in favour of Sand lizards or other reptile species. The present population survives as a side effect of management practices as referred to above.

During our study vegetation was classified on the basis of the species composition and structure of tree-layer, bush-layer and undergrowth. Vegetation maps were drawn on a 1 : 5000 scale. The total area was searched, irrespective of whether or not Sand lizards were expected to occur. Observations of lizards were recorded as sightings, not as individuals, which resulted in a relative measure of population density in order to compare the different sub-habitats. Nesting sites were recorded as well. For all sightings the sex or age groups were determined: males, females, first calendar year juveniles, and subadults including second calendar year juveniles. It was also noted in or close to which plant species the Sand lizards were present. Corrections were made for differences in searching intensity per plot.

For reasons of comparison, reference areas have been studied in other parts of the *Utrechtse Heuvelrug* and at the *Veluwe* area (a push moraine landscape in the province of Gelderland).

Results

Mapping of the vegetation showed 24 vegetation types: forests which differed in structure of trees, bushes, herbs and heather vegetation. Sand lizards were observed in 6 of these types, covering 39% (210 ha) of the study area. Within these types, the lizards were exclusively found on places exposed to the sun. Such places mostly occurred at the edge of the plots. The other vegetation types were more dense, having a closed canopy or bush-layer. Sand lizards occurred in (FIGURE 2):

1. Type YS. Young, open plantations of firs (*Picea abies*, *P. sitchensis*, *P. omorika* or *Pseudotsuga menziesii*) varying in age from 4 to 15 years. The trees are mostly lower than 5 m and at a distance of 1-3 m from each other. In clearings Wavy Hair-grass (*Deschampsia flexuosa*) dominates, but also Heather (*Calluna vulgaris*) and Bilberry (*Vaccinium myrtillus*) are present.
2. Type OS. An older developing stage of the former type with trees varying in age from 13 to 30 years. The trees are up to 10 m high, with the lowest tree branches forming an almost closed layer low to the ground, but here and there glades still occur. In general, the grasses and dwarf bushes have been substituted by mosses.
3. Type B. Young birch (*Betula pendula*) forests of 10-20 years, with an open canopy and scattered deciduous bushes. Some Pine trees occur. *Calluna vulgaris* dominates the floor.
4. Type OP. Old pine (*Pinus sylvestris*, *P. nigra*) forests of 40-80 years. The canopy is closed at many places and only few bushes occur. The lower vegetation consists of Bilberry, Wavy Hair-grass and/or Heather.
5. Type MF. Old mixed forest of birch and pine of 60-100 years. The canopy is rather open. On many places Heather or Bilberry dominate.

6. Type H. Heather vegetation, mainly consisting of Heather. Locally Cross-leaved Heath (*Erica tetralix*) and Purple Moor Grass (*Molinia caerulea*) occur. Open vegetation with few or no trees.

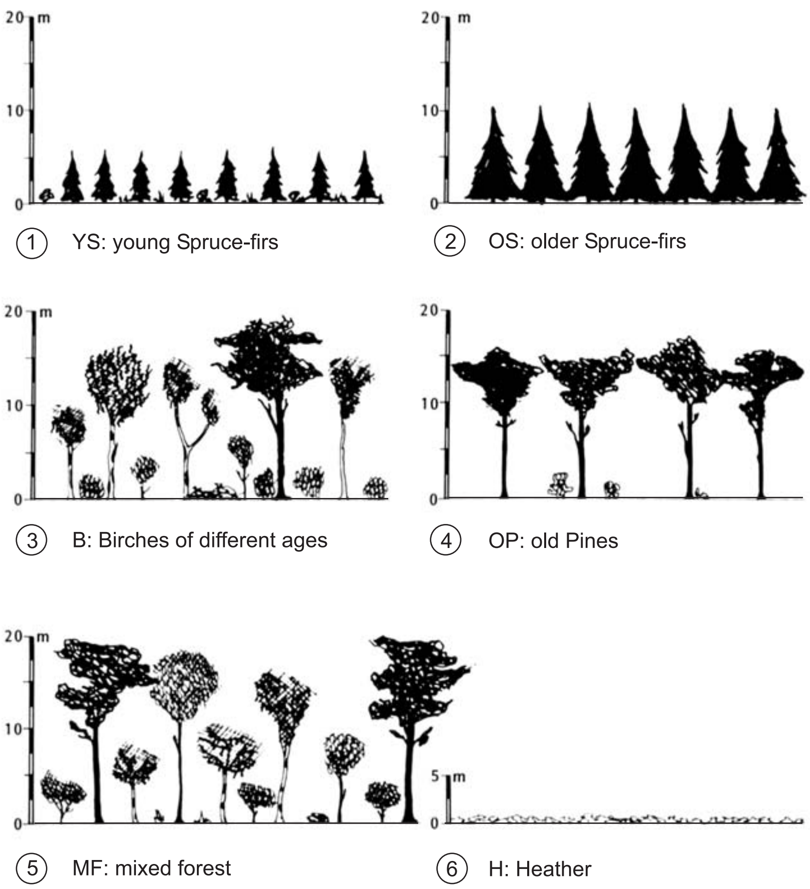

FIGURE 2. Vegetation types with Sand lizard presence.

Over a period of three years, in total 843 sightings of Sand lizards were made. Over 90% were made in type YS. In FIGURE 3 the observations are summarized and expressed as the number of sightings per hectare per vegetation type. Sand lizards showed a clear preference for type YS. In types OS and B more lizards were found than in types OP and MF. Very few lizards were found in type H. The occurrence of the lizards in the different vegetation types was constant over the three years.

Five plant species dominated in the undergrowth of the area: Heather, Wavy Hair-grass, Bilberry, Cross-leaved Heath, and Purple Moor Grass. Only among the first three species Sand lizards were found to be present. FIGURE 4 shows the relative presence of the lizards per ha of the three preferred plant species. Bilberry had the lowest number of lizards, but it should be noted that most vegetation of this species was found in shaded places.

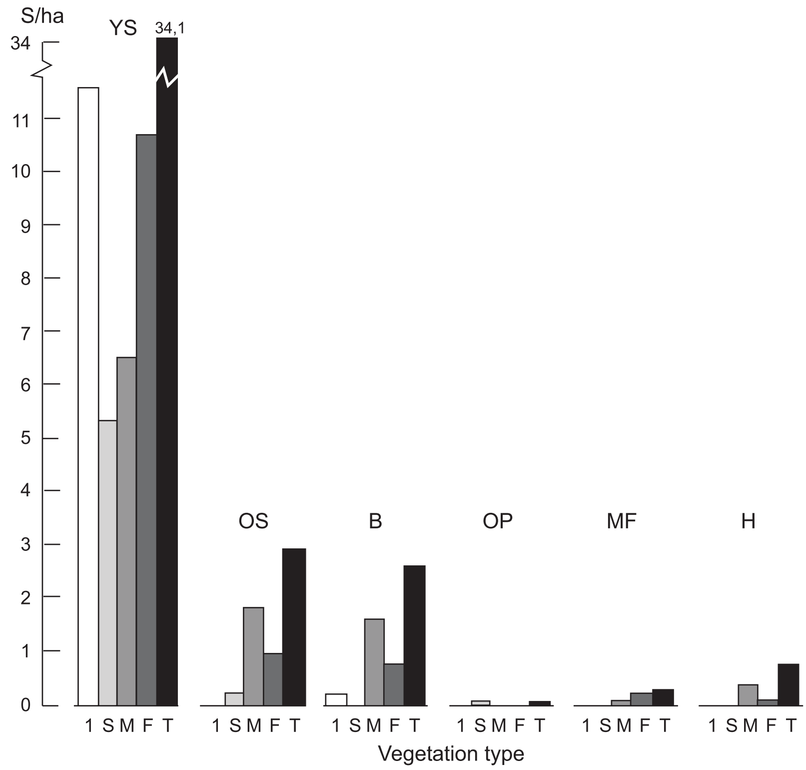

FIGURE 3. Relative densities of Sand Lizards in the different vegetation types (see text). S/ha: number of sightings per ha; 1: first calendar year juveniles; S: subadults, including second calendar year juveniles; M: males; F: females; T: total.

Nesting sites of Sand lizards were all found at the edges of or inside type YS. They were situated along south facing slopes and in places with digging activities of rabbits. These rides are being treated mechanically at intervals of some years: a machine flattens the ride and at the edges low "sand dunes" (20 cm) develop.

In conclusion, the suitability of a Sand lizard habitat is determined by the quality of the low vegetation layer: it consists of grasses and/or dwarf bushes on sunny places and nesting sites must be present.

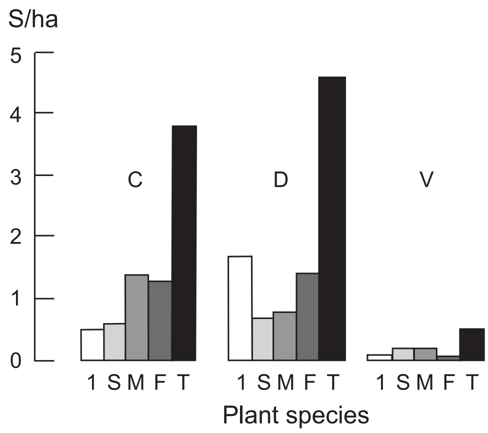

FIGURE 4. Relative densities of Sand Lizards in undergrowth plant species. C: *Calluna vulgaris*; D: *Deschampsia flexuosa*; V: *Vaccinium myrtillus*.

Preceding this study the area had also been examined regularly for the presence of Sand lizards over a period of ten years. Comparing the former with the latter study, at some places a shift in the presence of the lizards could be established, which was caused by vegetation succession. Sand lizards colonized sites about four to six years after clearcutting, and only when a vegetation of dwarf bushes or grasses had developed. They disappeared when the canopy closed and/or too much shade was formed. Viviparous lizards (*Lacerta vivipara*) colonized at least one year earlier (cf. OPDAM *ET AL*., 1983).

A survey of remnants of heathland in other forested parts of the *Utrechtse Heuvelrug* and parts of the *Veluwe* area revealed the presence of *Lacerta agilis* only at places with a well-developed Heather vegetation, mostly on south-facing slopes, and with patches of bare sand in the vicinity. The majority of those sites were very small (some acres), and only formed a small fraction of the heathland concerned.

Discussion

Heather vegetation forms the typical habitat of Sand lizards in northwestern Europe, provided that the heather is well-developed (i.e. plants of old age with differences in height; litter on the floor) and that open sandy patches are present (CORBETT & TAMARIND, 1979; GLANDT, 1979; STUMPEL, 1981; CORBETT, 1983; HOUSE & SPELLERBERG, 1983). Also in the Netherlands, Sand lizards prefer heather vegetation. The highest known densities are approx. 100/ha (STRIJBOSCH & CREEMERS, 1988).

During the last centuries in the Netherlands heather vegetation occurred as extended heathlands. Nowadays, many heathlands have been reclaimed or planted with conifers. In such situations heather survived at the edges of forests and on glades.

Our study dealt with an area planted with conifers. The results show that Sand lizards can survive in a forest area by selecting vegetation types with temporary suitable conditions. Young plantations of Spruce-fir and Douglas-fir offer these conditions for a period of approx. ten years, with an optimum at an age of five to six years (FIGURE 5). The other forest types provide suitable vegetation locally, mostly at the edges.

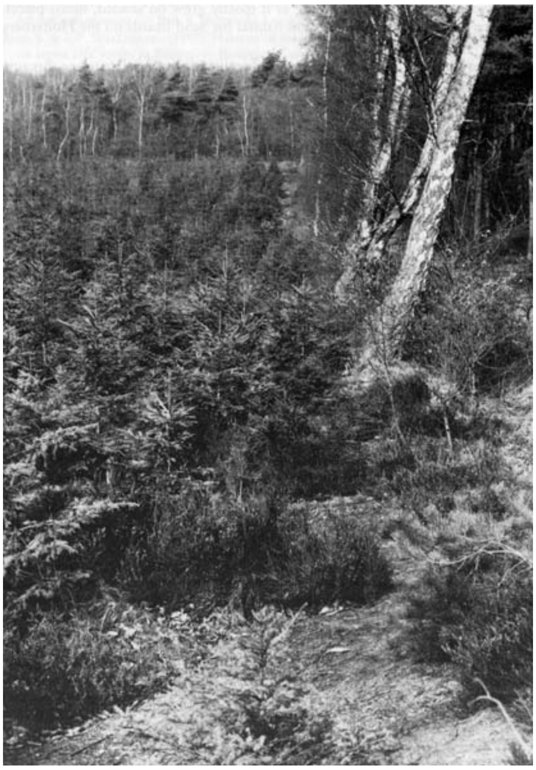

FIGURE 5. Sand Lizard site in type YS (see text).

The low numbers of Sand lizards in the open heather vegetation in our study area is remarkable, because at some kilometres a small dry heathland survived (*Remmerdense Heide*), which harbours the highest population density of Sand lizards in the eastern part of the *Utrechtse Heuvelrug*. Another interesting feature is the abundance of Wavy Hair-grass in the Sand lizard habitats. These grasses were always in the vicinity of tree branches, and I suggest that those branches provided the appropriate conditions for thermoregulation. Besides, the tussocky shape of the grass sods (a result of former tillage) provided extra variation in vegetation structure. A relatively high density in grassy vegetation may have to do with the bad quality of the Heather in the study area: locally it grew in high, but thin plants with little litter (moist and dark situations), or very short (after fire or trampling). More extensive heather vegetation in the forest area only occurred as small pockets in a drifting sand area. Bilberry seems to be less important as a Sand lizard habitat. This is not surprising as it mostly grew on shaded, moist places. However, Bilberry forms an excellent habitat for Sand lizards on the *Holterberg* (Overijssel province).

The lizard population in the study area is a relict of a former larger one. Because of the relatively low numbers of Sand lizards, the forest at the *Utrechtse Heuvelrug* may be called a marginal Sand lizard habitat. The forest management unconsciously includes the maintenance of lizard habitats, because it maintains the intermediate stages in the development of conifer forests by clearcutting and by creating plantations of different ages. However, an active habitat management could provide better conditions for Sand lizards (cf., CORBETT, 1983): creation of wide verges with open heather vegetation between ride and plantation, particularly those south-facing, and maintenance of glades inside the plantation areas (STUMPEL, 1985, 1985/1986; DENT & SPELLERBERG, 1987); chopped trunks should not be piled in the verge vegetation nor should those places be trampled or driven on.

Within the forest areas of the *Utrechtse Heuvelrug* and the *Veluwe*, some small heathlands still occur. They are supposed to be essential for the long-term survival of Sand lizards. However, heathlands are subject to a variety of management practices, such as turf-cutting, mowing, burning, and grazing. These measures generally do not consider reptiles (STUMPEL, 1987). Since in the Netherlands heathlands suffer strongly from encroachment with grasses, the measures mentioned are frequently practiced and often on a large scale. As a consequence, old heather cannot develop and so the habitat requirements of Sand lizards and other reptiles are not fulfilled.

The Sand lizard is an indicator species for well-developed dry heather vegetation. Its presence often includes that of other reptiles (CORBETT & TAMARIND, 1979; CORBETT, 1983; STUMPEL, 1985/1986). Therefore, the conditions for the Sand lizard should be incorporated in management plans for forestry areas.

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4 Distribution and present numbers of the tree frog *Hyla arborea* in Zealand Flanders, the Netherlands (Amphibia, Hylidae)

Abstract. A distribution survey of *Hyla arborea* has been carried out in the western part of Zealand Flanders over a period of six years. Additional data on the eastern part and the neighbouring Belgian area have been collected. The relationship between the maximum number of males calling on one evening/night and the estimate of their population size is a suitable basis to predict the total number of males in other pools during a season. Methodological aspects of the fieldwork are discussed. Great fluctuations in presence and activity of the Tree Frog illustrate the need for long-term surveys. *Hyla arborea* is declining, and nowadays its distribution is restricted to some localities in the western part of the region. These localities are classified according to the number of males and their importance for conservation.

Introduction

In the Netherlands, the Tree Frog *Hyla arborea* (LINNAEUS, 1758) reaches the northwestern border of its distribution area. Its range is limited to parts in the east and south of the country. During the last few decades, the Tree Frog decreased markedly and became a threatened species (VAN DE BUND, 1964; LUIKEN, 1970; VAN ROON, 1973; BURNY, 1976; BERGMANS, 1981; STUMPEL, 1981A, B; BROEN & VERGOOSSEN, 1983; STUMPEL & HANEKAMP, 1984; STORTELDER & REYRINK, 1985; BERGMANS & ZUIDERWIJK, 1986). At present, the Tree Frog can be found in four isolated areas: the region of Achterhoek and Twente (provinces of Gelderland and Overijssel), the central part of the province of Limburg, the central part of the province of North Brabant, and the western part of Zealand Flanders (province of Zealand) (BERGMANS & ZUIDERWIJK, 1986). The Tree Frog area in Zealand Flanders extends for some kilometres to the west across the Belgian border.

Since 1981 a field study has been carried out in Zealand Flanders, focusing on the distribution, ecology, population dynamics, and habitats of the Tree Frog (STUMPEL & HANEKAMP, 1986). The field study is to lead to directives for conservation and management of its habitats. This is the first report, dealing with the results of the distribution survey during the period 1981-1986.

Survey area

Zealand Flanders is the southernmost part of the province of Zealand, situated in the southwest of the Netherlands (FIGURE 1). It covers 880 km^2, and is isolated from the rest of the Netherlands by the West Scheldt (a part of the Rhine-Scheldt estuary). In the south it borders on the Belgian provinces of West and East Flanders. The area is rich in salt and brackish waters, particularly land-locked creeks. Fresh water is rather scarce, a reason for man to dig many pools in the past.

Fieldwork has been carried out almost exclusively in a study area (approx. 250 km^2) west of coordinate x = 30 of the Amersfoort grid (FIGURE 2). This report considers the whole area of Zealand Flanders, although no systematical fieldwork has been carried out in the eastern part. Some additional searching has been done in the neighbouring Belgian area, so as to cover the total distribution range in this part of the Netherlands and Belgium.

Methods

Before the fieldwork started, the potential spawning sites, such as cattle drinking pools, ponds, shallow parts of canals, and other small waters, were mapped. Not all the pools were reproduced on the topographical maps, particularly small cattle drinking pools were lacking, and moreover, some were well hidden in the landscape. This meant that some pools were only found later during the survey. The direct surroundings of these sites were considered potential land habitats. Salt waters were not taken into account.

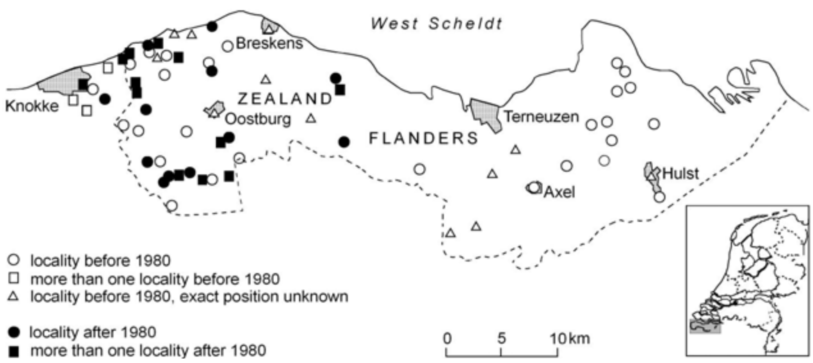

FIGURE 1. Present and former distribution records of *Hyla arborea* in Zealand Flanders. Data from different origins; see text.

During the years 1981-1983 and 1986, the presence of the Tree Frog was recorded systematically. The majority of the potential reproduction sites were visited at least three times yearly during the reproduction period. In the period 1984-1986 only a number of selected localities were studied, but those were more intensively, and particularly so in the village of Retranchement, situated against the Belgian border. Additional data were collected on other waters and land habitats in Zealand Flanders for that period.

The presence of the Tree Frog was recorded by three methods:

- searching for males calling spontaneously or in reaction to tape-recorded mating calls;
- searching in the water for eggs, tadpoles, juveniles and adults;
- searching in the terrestrial vegetation for juveniles and adults.

To be able to make quantitative comparisons, these methods were used as evenly as possible for all the potential reproduction sites. All the waters where one calling male was recorded were considered to be Tree Frog sites, even if eggs, tadpoles or juveniles were never found there.

By catching as many males as possible on evenings with high calling activity and adding up the remaining non-catchable calling males, the minimum numbers of Tree Frogs present on a spawning site were established.

All Tree Frogs caught were marked individually, with the exception of first-calendar-year juveniles. After every capture the animals were released at the very spot where they had been caught.

For additional distribution data on Zealand Flanders for the period before the distribution survey, literature and files were searched and people interviewed.

Results

Distribution

TABLE I gives the position of the sites, and the years in which Tree Frogs were found. All the Tree Frog waters were situated in grassland or arable land that had recently been converted from grassland, except for one site in a marsh, one in a dune shrub vegetation, and one in a cellar. The majority of the waters were used as cattle drinking pools. In the western study area 471 potential spawning waters were localized, but in only 52 (= 11%) was the presence of Tree Frogs established at least once (STUMPEL, 1987).

The Tree Frogs were observed in and at the edges of the spawning water, or in the nearby vegetation. As a rule they were found within about 300 m from a spawning site. In view of this distance a grid with quadrats of 500 x 500 m was chosen to match the distribution pattern (FIGURE 2). Actual water and land habitats together covered 35 out of the 952 quadrats (= 4%). (In four of these quadrats observations were only made in the terrestrial vegetation, but always near spawning sites.) The sites were both inland and close to the coast. Some Tree Frogs were found on the seaward side of the dunes up to 2 m from the beach.

Not all Tree Frog sites were localized during the survey. R. BEIJERSBERGEN (pers. comm.) observed five calling males in the Groedse Duintjes area (cf., TABLE I) during the survey period, a site also visited several times within the scope of the survey, but always without success. An unconfirmed record of one calling male came from Oostburg for 1983 and 1984.

A remarkable situation arose in Retranchement where Tree Frogs were found regularly in a cellar hole with some centimetres of water at the bottom. This site was in the pavement in front of a house in a street without any vegetation, with the land habitats at the back of the same house, Up to 17 adults at a time were found there during the reproduction period.

About 5 km eastward of the study area BEIJERSBERGEN discovered Tree Frogs on three sites near Driewegen in 1981 (pers. comm.). Two calling males were heard in a pool that has been infilled meanwhile (Amersfoort coordinates 33.060/374.850); and ten specimens were perceived in a cattle drinking pool (no. 596). In a complex of three pools (nos. 302,303 and 304) inside the hamlet of Driewegen, 15 calling males were found. The presence of Tree Frogs in these four pools could be reconfirmed in 1986. One adult was found in 1985 in a garden at Pyramide, 5 km south of Driewegen (MRS. L. BUTLER, pers. comm.).

Some additional searching in eastern Zealand Flanders up to 1986 failed to reveal any Tree Frog (this survey; G. SPONSELEE, pers. comm.; LENDERS, 1986).

Across the Belgian border, between Knokke and Retranchement, Tree Frogs were found in three pools in 1986 (TABLE I).

TABLE I. List of waters and one isolated land habitat with Tree Frog records during the survey. Number of the waters according to the RIN files, coordinates to the Amersfoort grid (cf., FIGURE 2).

Locality	Water no. or site	Coordinates	Year of record	Remarks
Retranchement	1	15.640/375.050	80, 81, 82, 83, 84, 85, 86	
	2	15.110/375.350	81, 83, 85, 86	
	3	15.150/375.275	86	
	4	15.020/375.300	85	
	25	15.340/375.000	85, 86	
	26	15.620/374.590	81, 83, 84, 85, 86	
	27	15.560/374.550	85	
	28	15.550/374.630	85	transformed by excavation in 85
	234	15.500/375.450	82, 83, 84, 85, 86	
	255	15.920/375.300	85	
	Veste	15.575/374.540	83, 85, 86	partially transformed in 85
	cellar	15.530/375.030	81, 82, 83, 84, 85, 86	
Terhofstede	30	15.640/373.960	83, 85	infilled in 86
	256	15.840/374.025	85, 86	
Oudelandse Polder Northwest	9	14.810/377.720	79, 81, 82, 83, 85, 86	
	10	15.050/377.820	81	infilled in 82
Kievittepolder	11	15.140/378.010	81, 82, 83, 85, 86	
	217	15.170/378.130	82	
Vlamingpolder	13	16.630/378.710	78, 79, 80, 81, 82, 83, 84, 85, 86	
	246	17.430/378.930	83, 84, 85, 86	
Cadzand-Bad	14	16.580/378.620	82, 86	
Knokkert	19	19.260/376.910	80, 81, 82, 83, 84, 85, 86	
	20	19.210/377.125	83, 84, 85	
	218	19.350/376.910	83, 85	restored in 82
Marolleput	57	22.440/375.630	83	
Groedse Duintjes	221	22.600/380.300	81	
Kasteelpolder	32	16.590/372.360	83	
Kruisdijk	44	16.390/367.950	81, 82, 83, 85, 86	
Aardenburg	47	19.975/366.620	81, 82, 83, 86	
	174	19.550/366.280	81, 82, 83, 86	
	175	19.610/366.225	81, 82, 83, 86	
	176	19.675/367.000	81, 82, 86	
	177	19.730/366.930	81	infilled in 82
	179	19.860/366.820	81, 82	reduced yearly by infilling
	181	20.340/366.630	81, 82, 83, 86	
	182	20.180/366.960	81, 86	
	202	19.440/366.420	81, 82, 86	reduced in 83
	203	19.400/366.360	81, 82, 83, 86	
	211	19.220/366.360	82, 86	
	299	19.890/366.290	83, 86	reduced in 83
	ditch	18.550/366.750	86	
Heille	472	17.730/366.275	86	
Sint Kruis	186	21.930/366.400	86	
	195	23.900/366.410	82	
	197	24.375/366.360	81, 82	transformed by excavation in 82
	198	24.430/366.280	81	infilled in 82
	380	21.530/366.130	86	

TABLE I, continued

Locality	Water no. or site	Coordinates	Year of record	Remarks
Margueritepolder	109	23.980/369.590	81, 82, 83	
Nieuwe Passageule				
Polder West	110	23.410/369.475	83	
	112	23.450/369.670	83	
	113	23.210/369.530	83	
	117	23.460/369.200	83, 86	
Driewegen	302	34.270/374.230	81, 86	
	303	34.370/374.300	81, 86	
	304	34.220/374.280	81, 86	
	596	33.860/375.130	81, 86	
Pyramide	garden	34.880/369.500	85	close to pool 620
De Vrede (Belgium)	pond	12.950/373.880	86	
Het Kalf (Belgium)	pond	10.875/374.680	86	
	pond	10.875/374.325	86	

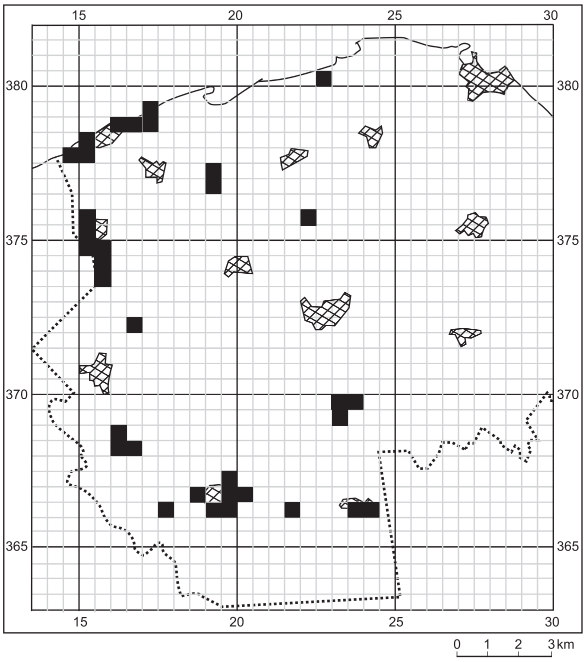

FIGURE 2. Distribution of *Hyla arborea* (aquatic and terrestrial habitats, black quadrats) in the study area in western Zealand Flanders for 1981-1986. Coordinates according to the Amersfoort grid (quadrats of 0.25 km^2). Hatched areas indicate urban environments.

During the survey period six spawning sites were abandoned as a result of infilling, whereas two others became strongly polluted by dumping dung and rubbish. One overgrown pool was restored for the Tree Frogs.

As to the former distribution of *Hyla arborea* in western Zealand Flanders, J. M. BURNY carried out a survey in the area during the years 1975-1977. He recorded 26 spawning sites (BURNY, 1976); in nine of these, Tree Frogs were never found in the present survey (BURNY, correspondence; TABLE II). Apart from BURNY's data only few concrete old data are available (SCHOUTEN 1899; VAN MALE, 1926; HEIMANS, 1926, 1928; VAN KAMPEN & HEIMANS, 1927; LODEWIJKS, 1943; ZWERFMANS, 1951). More is known about the last 25 years, though the information is still fragmentary (VAN BREE, 1960; VAN DE BUND, 1964; SIJBRANDS, 1965; BURNY, 1976; DE FONSECA, 1979, 1980) or broad (BERGMANS, 1981; BERGMANS & ZUIDERWIJK, 1986). The same applies to the eastern part of Zealand Flanders (add: BLOMMAART, 1953; BUISE & SPONSELEE, 1978).

DE FONSECA (1979) had mapped the presence of *Hyla arborea* in the neighbouring Belgian area around Knokke and Sint-Margriete. These data complete the knowledge of the distribution range of the Tree Frog in this part of the Netherlands and Belgium.

The map (FIGURE 1) shows all of the distribution data collected in the present survey, from the references above, the files of the Research Institute for Nature Management, the State Forestry Service, the Herpetogeographical Service of the Lacerta Society, P. J. VAN DER FEEN, PH. DE FONSECA, supplemented with unpublished new data from R. BEIJERSBERGEN, R. BROUWER, J. M. BURNY, MRS. L. BUTLER, L. D'HOORE, G. HANEKAMP, E. H. KRIJGER, and MRS. F. M. ZWIER-DE WANDEL. FIGURE 1 indicates that the Tree Frog is found in large parts of Zealand Flanders and that it must have been a common species in the first half of the century.

TABLE II. Sites where *Hyla arborea* was recorded between 1975 and 1977 for the last time. Records by J.M. BURNY (*=pool infilled between 1977 and 1983).

Site name	Pool no.	Amersfoort coordinate
Oudelandse Polder	8	15.360/376.460
Kievittepolder	12	15.200/378.130
Cadzand	15	16.765/377.825
Cadzand	24	17.985/377.565
Sint Anna ter Muiden	39	14.170/371.610
Nieuwe Passageule Polder	108	23.435/370.140
Aardenburg	173	18.375/366.420
Aardenburg	223*	19.635/367.375
Bewester-Eede-benoorden-Sint Pietersdijkpolder	222*	17.700/367.720

Numbers

Calling males were found in 52 pools in the study area, in which Tree Frogs were found at least once during the survey period. Countings of calling males give an impression of the densities in the separate waters (TABLE III). Remarkable are the numerical fluctuations in a pool over the years. The recaptures have shown that Tree Frogs can be sedentary or migrate over large distances. Migration was found among pools nos. 1, 13, and 19 (at distances of approx. 4 km from each other), where the annual numbers differ considerably and where mutual recaptures were made after one winter. Only rarely exchanges were determined between two neighbouring pools within the same season (e.g., nos. 174 and 203).

TABLE III. Maximum numbers of Tree Frogs, observed on one evening/night during the reproduction period. Figures represent males, with females in parentheses. (- = not surveyed, x = water infilled or transformed by excavation.)

Water no. or name	1981	1982	1983	1984	1985	1986
1	65 (4)	28 (3)	57 (24)	10 (1)	64 (12)	15 (3)
2	3	0	5 (2)	0	5	1
3	0	0	0	0	0	3
4	0	0	0	0	6	0
9	5 (2)	0	2 (2)	0	1	3
10	2	x	x	x	x	x
11	26 (1)	8 (1)	9 (1)	0	3	7
13	18 (14)	34 (1)	51 (9)	39 (2)	15	35
14	0	2	0	0	0	1
19	5 (1)	6 (1)	39 (1)	5	18	2
20	0	0	1	5	3	0
25	0	0	0	0	3	3
26	1	0	0	0	10	3
27	0	0	0	0	2	0
28	0	0	0	0	1	x
30	–	–	1	0	20	x
32	0	0	1	–	–	0
44	18	3	40	–	1	10
47	15 (2)	7 (1)	6	–	–	3
57	0	0	1	–	–	0
109	4	3	4	–	–	0
110	0	0	1	–	–	0
112	0	0	3	–	–	0
113	0	0	2	–	–	0
117	0	0	1	–	–	1
174	28 (1)	10 (2)	10	–	–	1
175	17 (3)	11	8 (1)	–	–	1
176	1	1	0	–	–	1
177	3 (1)	x	x	x	x	x
179	8 (1)	3	0	–	–	0
181	20	5	15	–	–	12
182	1	0	0	–	–	2
186	0	0	0	–	–	1
195	0	2	0	–	–	0
197	15	1	x	x	x	x
198	5 (1)	x	x	x	x	x
202	3	5	0	–	–	1
203	8	7 (1)	7	–	–	1
211	0	0 (1)	0	0	0	2
217	0	3	0	0	0	0
218	x	0	1	0	1	0
221	5	0	0	0	0	0
229	0	0	2 (1)	–	–	1
234	–	2	17 (6)	5 (1)	19 (6)	3
246	0	0	5	40	8	10
255	0	0	0	0	3	0
256	–	–	0	0	3	1
380	0	0	0	–	–	3
472	0	0	0	–	–	1
Veste	0	0	6	0	10	2
cellar	1	1	10 (7)	5 (2)	5 (9)	3 (3)
ditch	–	–	–	–	–	1

On a number of sites enough recaptures were made to allow an estimate of the total numbers per year (males only) with a derivation of the Petersen estimate (Lincoln index), by which the captures are accumulated over several days ("weighted mean", BEGON, 1979).

The numbers of Tree Frogs estimated for some of the spawning waters are represented in TABLE IV. They show that pool no.1 (at Retranchement) and pool no.13 (at Vlamingpolder/Cadzand- Bad) were the sites richest in *Hyla arborea* over the survey period. In 1985 the survey focused on Retranchement, where special attention was paid to the captures in the land habitats near pool no.1, leading to estimate (± 2 SD) the numbers for pool no.1 and its direct surroundings (the cellar hole included) for the whole season in 1985 at 266 ± 26 (242 individuals caught). For males, females, and second-calendar-year juveniles, the estimates were 147 ± 20 (135), 95 ± 13 (88), and 36 ± 36 (19), respectively. Second-year juveniles which could be sexed later in the season were included in the male and female sections. The adjoining villages of Retranchement and Terhofstede together have 14 spawning pools. For 1985 for the whole complex an estimate of the total numbers of males, females, and second-year juveniles resulted in 397 ± 36 (344), based on captures in pools nos. 1, 2, 4, 25, 26, 30, 234, 256, Veste, cellar, and the nearby land habitats.

TABLE IV. Estimate (± 2 SD) of the total number of males during the reproduction period per pool in four years, and the number of individuals caught (in parentheses). (- = not surveyed, or estimate not possible.)

Water no.	1981	1982	1983	1985
1	118 ± 31 (91)	53 ± 17 (46)	131 ± 46 (88)	118 ± 30 (94)
2	—	—	7 ± 4 (7)	—
11	36 ± 32 (28)	10 ± 4 (11)	—	—
13	18 ± 7 (18)	68 ± 18 (62)	117 ± 61 (64)	—
19	—	6 ± 5 (7)	52 ± 12 (52)	22 ± 8 (22)
44	27 ± 15 (23)	—	—	—
47	39 ± 24 (27)	—	—	—
174	38 ± 21 (34)	12 ± 9 (11)	—	—
175	26 ± 15 (24)	14 ± 9 (14)	—	—
181	—	4 ± 3 (5)	—	—
234	—	—	27 ± 10 (27)	24 ± 11 (24)

There appears to be a relationship between the maximum number of Tree Frog males recorded on a site on one evening/night in a season and the estimate ("weighted mean") of the total number present during the reproduction period. This relationship is best fitted by the curve $y = 0.749x^{1.237}$ (FIGURE 3) assuming that a population is absent when it has not been recorded present (line passes through origin). The relationship can be simplified to a linear one represented by the line $y = 1.73x$, but the curve is significantly better (P= 0.0007). With the curve the total numbers can be predicted for the pools where an estimate was not possible owing to the lack of recaptures. This was done by fitting to a generalized linear model: ln (y) = ln (a) + (b) ln (recorded number), with the assumption that the variance is directly proportional to the expectation for all observations. Based at the predictions, FIGURE 4 shows the fluctuations in numbers over the years for some of the pools in the Retranchement-Cadzand area and for the whole complex. With this method, the total predicted values (± 2 SD) for all pools of the study area arrive at 430 ± 42 (1981); 196 ± 25 (1982); 494 ± 44 (1983); 176 ± 17 (1984); 309 ± 29 (1985); 170 ± 23 (1986).

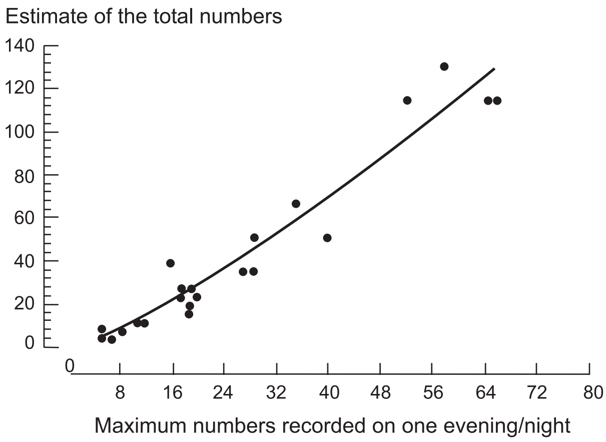

FIGURE 3. Relationship between maximum number of Tree Frog males, recorded on one evening/night during a season, and the estimate ('weighted mean') of the total numbers present during the reproduction season, for a number of pools and a number of years (cf., TABLE IV).

Methodological aspects

Hyla arborea manifested itself loudly by calling. Therefore, localization of calling males was the most productive method to spot them. But because of the large size of the study area, great effort was required to obtain a reliable picture of the actual presence of males. In several pools, mostly with bigger choruses, Tree Frogs were traced fast and easily, in others only after repeated visits, and in one not at all.

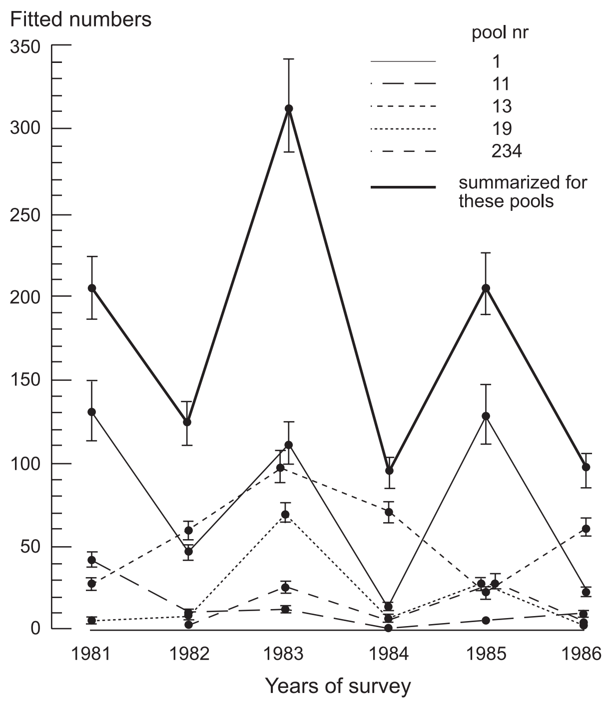

FIGURE 4. Fluctuations in numbers of males (fitted) in some pools in the Retranchement-Cadzand area over six years.

Males were calling spontaneously during the reproduction period, from mid-April until the end of June, sometimes on their daily way towards the spawning water and especially on that very site. These mating calls were heard from shortly before evening twilight until about five o'clock in the morning (varying with weather conditions). Single mating calls could also be heard in daytime from the terrestrial vegetation. Recording a calling male at some distance was strongly affected by wind and by racket from traffic and agricultural machines. Under favourable circumstances the sound could be heard at a distance of more than 1 km. In a pool calling activity was not heard every evening. It was not possible to predict whether any pool had chorus activity on the basis of the activity on another site. Besides, the number of calling males varied in the course of an evening/night, and often a chorus was interrupted by pauses of different lengths. During the chorus period it was also possible to evoke calling activity by playing a tape recorder with the species' mating calls at close distance (less than 25 m), or by making noises such as blowing one's nose and clapping one's hands (only at the height of the chorus period). According to J. M. BURNY the frogs can also respond to the jingling of a cycle bell (pers. comm.). Attempts to evoke calling activity were not always successful, e.g., when the Tree Frogs were absent or just remained silent. So, no reaction to tape-recorded mating calls did not give certainty about the absence of males in pools. Nevertheless, it proved to be a good technique to trace animals faster, if present.

Counting calling males in a chorus at a distance was difficult. Choruses up to ten males could be counted fairly easily. Bigger choruses required a careful survey along the edge of the water.

Females were hard to find during the chorus period. Only very few females and amplexuses were observed in the water in the dark. In the daytime they sometimes were discovered hidden under the grass at the edge of a pool.

In the summer, from early July, no Tree Frogs were found in the water nor were mating calls heard there.

After the reproduction period adult Tree Frogs, both males and females, were found in the terrestrial vegetation in dry weather, and often fully exposed to the sun. Specimens could also be found under the same conditions in the period between hibernation and reproduction season.

During the summer period the size and colour of the vocal sac strongly decreased in some males. As the vocal sac is the main feature for sex discrimination in the field, special attention had to be given to the sexing of adults later in the season.

Outside the reproduction period, single calls were heard from the terrestrial vegetation, especially in the afternoons and the early evenings. These calls differed from the mating calls by being somewhat weaker, different in tone, and uttered less frequently. The calls consisted of two to six pulse groups. They were heard between hibernation and mating (earliest date: 25 March), and from the beginning of August until the third week of November. Evoking these calls with tape-recorded mating calls was only occasionally successful. However, this method sometimes revealed Tree Frogs, which would have passed unnoticed otherwise in the complex structure of the vegetation.

Netting for tadpoles was not very successful. The results were very poor compared with the number of eggs deposited and/or the juveniles metamorphosed; in many cases the result was even nil. Under warm weather conditions, tadpoles could be found in groups, floating directly under the water surface and above the submerged water vegetation. They are very shy then and when approached they quickly disappear into the depths.

From the metamorphosis (in hot seasons starting in the second week of July) juveniles were found at the edge of a pool or in the nearby vegetation, often clustered.

During the winter period, some fortuitous observations were made of hibernating adults in or near summer habitats. A systematic survey of hibernating animals was not possible.

Discussion

This survey resulted in a number of new known sites with *Hyla arborea* all situated within the known range in Zealand Flanders. The atlas of the Netherlands herpetofauna (BERGMANS & ZUIDERWIJK, 1986), of course provided with most of the data (till 1986), gives an optimistic view of the Tree Frog situation in western Zealand Flanders because of the large quadrats (25 km^2), with Tree Frog presence in 50% of these quadrats. In FIGURE 2 the quadrats are 100 times smaller and it appears that the actual distribution is scattered over only 4% of the quadrats. Recaptures have shown that the populations are not completely isolated. But as the migrants formed only a slight proportion of all recaptures, the exchange rate among populations will be low. This underlines the vulnerable position of many sites and makes the Tree Frog an ever more threatened species. FIGURE 1 shows that *Hyla arborea* has lost a noticeable number of sites the last few decades. BURNY (TABLE II) indicates a strong numerical decrease in sites in the period 1977-1980. As the older records are not very exact, the decline cannot be expressed in a number, but it must be considerable. Worse even is the situation in eastern Zealand Flanders for which no recent records exist. Although in certain areas potential habitats still may have survived (e.g., the region of Spui-Magrette-Axel), one has to accept that *Hyla arborea* no longer inhabits that part of Zealand Flanders. The picture of the neighbouring Belgian West Flanders is not accurate, as it is only based on old data from DE FONSECA, supplemented with incidental data for 1986.

From the low proportion of waters populated it should not be concluded that the Tree Frogs lack a proper dispersion potential, as their presence depends on a suitable combination of aquatic and terrestrial habitats, and only few land habitats were found. But also a number of waters in the study area appeared to be brackish, polluted or over-shadowed (STUMPEL, 1987). These were never known to have accommodated Tree Frogs.

In 1953 the sea flooded large parts of the southwestern area of the Netherlands. The consequences for the study area were such that only two areas were inundated: "Tienhonderdpolder" and "Willem-Leopold Polder". In the latter, Tree Frog activity was recorded once (pool no. 4). To what extent the flood has affected the distribution of *Hyla arborea* there, however, cannot be assessed, but the impact seems negligible.

Differences in presence over the years for a number of pools (TABLE III) can be explained by dispersion and/or migration. According to BAUMGARTNER (1986) *Hyla arborea* can be a wandering species. The recaptures confirm this. This had led to the situation that some pools were populated by one male Tree Frog only once during the survey period. They must have been migrants passing, or pioneers trying to settle somewhere. Nevertheless, they might have attracted females.

Countings of Tree Frogs differed not only considerably among pools, but also per pool per year. Differences in numbers of calling males per pool per year can be explained by fluctuations in the reproduction success in the preceding years, by migration (STUMPEL & HANEKAMP, 1986), and also by varying success of the fieldwork. Nevertheless, it is presumed that all pools which were rich in Tree Frogs (>10 calling males) were found. Differences in numbers among pools are also related to the size and quality of the habitats, the quality being dependent on the habitat management by man.

Some remarks have to be made on the method of estimating the numbers per pool. This weighted mean method assumes that the population is closed and that there are neither births nor deaths. These assumptions do not hold: e.g., births have been registered, deaths are most likely, and migrations have been recorded (through recaptures in other pools during the same season, but only to an insignificant fraction). Migration will interfere with the model. However, on the basis of the values found for pool no.1 and its surroundings it is regarded realistic to assume that emigration and immigration balance each other, which keeps the model valid. Anyway, the results require a cautious interpretation. The value of the estimates lies in the mutual comparison of pools and years.

In this respect, it is one of the striking results that the numerical estimate of males in the richest pool (no.1) is the same for 1981 and 1985 (TABLE IV), in which years this pool was studied most intensively. It may indicate either a relationship between intensity of capturing and numbers, or the maximum density for this pool.

The recaptures also learnt that many males do not stay in the pool for the whole reproduction period. So it is impossible to count all the males in a population during a single visit. But the relationship between the maximum number of males on a site recorded on one evening/night during a season and the estimated total number present during the reproduction period demonstrates that the number of calling males can be used as a relative measure of the size of the male population.

It should be noted that the fitted values of the estimates in pools with low numbers of males are minimum values, because most likely the real maximum number was not always determined. Therefore, FIGURE 4 should only show that there can be great fluctuations.

Chorus activity is influenced by air temperature, the onset of twilight (light intensity), an annual endogenous rhythm in the Tree Frog, and probably also by atmospheric pressure and the amount of precipitation (reviewed by SCHNEIDER, 1977). When a chorus calls, the sound is not of equal vocal strength during an evening and/or night: there is an optimum in chorus activity, and also pauses occur (cf. also VAN GELDER & EIJSINK, 1978). As the survey visits took place at different hours of evening and night and under various weather conditions, the above will explain the differences found in chorus activity and in the responses to the tape recorder. Therefore, repeated visits at different times raise the chance of meeting calling males. But it remains remarkable that VAN BREE (1960) did not discover Retranchement as a Tree Frog site, particularly because, according to the land owner, Tree Frogs have always been present there in large numbers for at least the last 50 years.

The single calling of males from the terrestrial vegetation provided an extra opportunity to find Tree Frogs in the land habitats. So, evoking these calls can be recommended for distribution surveys. Several authors mention the calls, but the difference with the mating call is not paid attention to (e.g., LODEWIJKS, 1943; VAN BREE, 1976; RODING, 1977). SCHOUTEN (1985) described summer calls in *Hyla meridionalis*. His description shows resemblance with the sounds that have been heard in *Hyla arborea*. PAILLETTE (1970) also found occasional calling during the summer in *Hyla meridionalis*. As certain pools do not contain Tree Frogs every year, it is obvious that surveys have to cover more than one year in order to register all the waters suitable for Tree Frogs.

Remarkably, tadpoles were difficult to find. Probably they live in the deeper parts of a pool. Their floating behaviour may result from the need to collect thermal (solar) energy, oxygen, and/or food (algae) in the upper water layer when the weather is hot.

Conservation aspects

The Tree Frog populations can be classified according to the numbers of frogs and the densities of pools per site (destroyed sites not covered). This may also reflect the actual value of the sites for the survival of the whole population in Zealand Flanders:

1. The main population in the area of Retranchement/Terhofstede.
   The highest numbers of Tree Frogs were recorded in this complex. Until now, this is the biggest population in the Netherlands over the last 15 years (cf., EIJSINK & HENDRIKS, 1973; VAN GELDER *ET AL*., 1978; BROEN & VERGOOSSEN, 1983; STORTELDER & REYRINK, 1985; STUMPEL & HANEKAMP, 1986). However, before long it may be equalled by the increasing population of central Limburg, which consisted of approx. 130 calling males in 1985 (W. VERGOOSSEN, pers.

comm.). In the summer Tree Frogs have been found in the terrestrial vegetation, spread over the whole area. The number of waters, the different positions in which they are situated in the landscape and with regard to each other, and the abundance of suitable land habitats must have caused this rich population.

2. Big populations in the Vlamingpolder (Cadzand-Bad), Kruisdijk (Sluis), and Aardenburg.
   The Vlamingpolder has only two pools which contain high numbers of Tree Frogs. Kruisdijk is a small estate (approx. 2.5 ha) with a large U-shaped canal and surrounded by a circular dike (relevee). It is an enclave in extended arable fields. Only in 1981 permission was given to visit the canal and catch the Tree Frogs. In 1983 at some distance a minimum estimate was made of 40 calling males. The situation in Aardenburg is similar to that in Retranchement/Terhofstede with a number of pools scattered over the edges of the town. Tree Frogs were found there in 13 different waters and on land.
3. Small populations in the Kievittepolder, Knokkert, and Driewegen.
   In the Kievittepolder most Tree Frogs were found in 1981 (pool no. 11; cf., FIGURE 4). In 1975 BURNY (1976) found the biggest population of the whole study area in the Kievittepolder. So the quality of this habitat must have decreased strongly in the last ten years. This was probably a result of the increase in shrub vegetation and the loss of some pools and a part of the summer habitat.
   The Knokkert (pool no. 19) has shown a remarkable increase since 1983, which cannot be explained. The land habitat has degraded severely during the survey period by planted deciduous trees growing tall and shadowing the habitats. Restoration activities in pools nos. 20 and 218 appeared to result in colonization by Tree Frogs.
   Of Driewegen countings are only available for 1981, but it is known that the Tree Frogs were still present there in four pools in 1986.
4. Low numbers in Oudelandse Polder Northwest, Nieuwe Passageule Polder West, Margueritepolder, Sint Kruis, and Groedse Duintjes.
   In the Oudelandse Polder Northwest there is only one pool nicknamed the "Kikkerput" (= Frog pond) because of the clear presence of Tree Frogs in former times. It is close to the Kievittepolder and the two polders may form a complex (the distance between pools nos. 9 and 11 is 450 m).
   The Nieuwe Passageule Polder West contains 15 pools; Tree Frogs were found in four. The distance to the single pool in the Margueritepolder is 600 m.
   In Sint Kruis the pool area is long-drawn over 3 km and close to Aardenburg. Two important pools were lost (nos. 197 and 198). Now, only three pools are left, where Tree Frogs were recorded once during the survey.
   The Groedse Duintjes is the only marsh area. Great parts of this site were destroyed during the survey period.
5. Occasionally, single Tree Frogs in Marolleput, Kasteelpolder, Pyramide, Cadzand-Bad, Heille.
   Marolleput (no. 57), Kasteelpolder (no. 32), and Heille (no. 472) have the aspects of suitable Tree Frog pools, but the absence of land habitats is the probable reason for the absence of a population.
   In Cadzand-Bad (no. 14) it is the other way round with good land habitats being available, but the pool is completely shadowed by trees.
   The single observation at Pyramide possibly concerns a migrating specimen from Driewegen.

Such a classification may help to set priorities for a conservation plan. It can also be misused by declaring the lowest categories not important, leaving those to destruction in connection with town and country planning or changes in land use;

low-density pools may play an important role as stepping-stones for connecting and expanding populations.

Publishing exact distribution data of such a threatened and vulnerable species implies some risk (collecting for pet-keeping, trade). But as the results of the survey, apart from their value for zoogeography, can be applied in nature conservation and management, the author is convinced that publication must prevail over holding the records back. No conservation and management measures can be carried out if the responsible bodies do not know where the animals live.

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5 Characterizing the suitability of new ponds for amphibians

Abstract. Newly constructed ponds in the Netherlands were sampled for the presence of amphibians. Nine species were found. Relationships were established with pond characteristics and effects were found of factors such as pond age, topography of the surroundings, vegetation cover of water and bank, and electrical conductivity of the water. A total of 16 pond characteristics were screened for their explanatory power to discern ponds that are or are not inhabited by a certain amphibian species. Also interactions between pond characteristics were screened, and were often found to be significant. For example, electrical conductivity was strongly related (negatively) with *Rana temporaria* presence in the older but not in the younger ponds. The greatest number of effects were found for *Triturus vulgaris* and the least for *T. cristatus*. The effects give indications as to the specific requirements to be considered when constructing ponds.

Introduction

In a case study a new method is presented for the evaluation of the success of new pond creation, using discriminant analysis. We show that the effects of pond characteristics on the presence of amphibians can be defined and estimated in different ways by means of marginal and conditional tests, and that interactions between pond characteristics play a role as well.

Amphibians are declining in the Netherlands. Nine out of the 16 species of amphibians (56%) are on the Red List (CREEMERS, 1996). One of the causes of their decline is the loss of ponds (small, isolated, freshwater bodies) in the countryside. Since 1982, Pond Action Plans are being carried out in order to restore old ponds and to create new ones (BOSSENBROEK *ET AL.*, 1982). Their aim is to improve the aquatic habitat of amphibians in general and for some threatened species, which are the most dependent on ponds for their reproduction (e.g., *Hyla arborea*, *Triturus cristatus*) in particular. Those plans are based on the expectation that the range of amphibians is widened and that populations increase in size. These expectations are evaluated here and the methodology of the analyses is critically discussed.

Methods

An inventory was made of new ponds, whose exact position and year of construction was known. This resulted in a list of 1691 ponds that had been dug during the last 15 years with two exceptions that were 35 years old. From this list a random, stratified sample was taken. As the ponds had been created by various organizations and in different parts of the country, the stratification was firstly made per province, and secondly within the province per year of construction. We aimed at an equal number of ponds per province, with the exception of one province. As the province of Limburg had many more ponds, the sample there was larger. In practice, however, some ponds did not meet our requirements (e.g., they were not isolated, or stocked with waterfowl or fish) and therefore had to be deleted, with the result that the desired numbers of ponds could not be realized. Within each province a proportional sampling took place according to the years of construction, but with the restriction that each year was represented in the sample if possible. In the end the total sample consisted of 133 ponds.

A number of characteristics of ponds and their direct surroundings were selected, which were supposed to influence, whether or not in combination, the presence of amphibians. A form was designed to register those features in the field. For statistical analysis, only seven main and nine secondary pond characteristics were considered (TABLE 1, columns 1 and 2).

All ponds were visited twice (April-June and August-September 1994) to encounter both the early and late breeding species. The ponds were sampled by means of netting and visual observation of eggs, larvae, juveniles and adults. The frogs of the green frog complex (*Rana* synkl. *esculenta*) were regarded as one taxon as it was often not possible to recognize the three different forms (two species and one hybrid) in the field from eggs, tadpoles or leaping specimens. All characteristics were filled in on the form at the spot, except for the distance to the nearest pond. Those data were derived from digitalised topographical maps, by calculating the shortest distance between the pond and a potential reproduction site.

TABLE 1. Selected characteristics of ponds and their surroundings. Class = class grouping; *n* obs. = number of observations; Min. = Minimum value; Max. = Maximum value.

Characteristic	Code	Class	*n* obs.	Median	Mean	Min.	Max.
MAIN							
Distance to the nearest potential reproduction water (m)	DISW	<100	66	47.50	46.8	2.00	97.0
		≥100	67	246.00	314.5	103.00	1081.0
Distance to the nearest potential land biotope (vegetation > 1 m high) (m)	DISL	<5	65	2.00	1.57	0.000	4.0
		≥5	68	11.50	43.03	5.000	425.0
Age (years)	AGE	<4	72	2.00	1.819	0.000	3.00
		≥4	61	6.00	7.984	4.000	34.00
Depth (cm)	DEP	<100	55	80.00	69.3	10.00	95.0
		≥100	78	120.00	143.0	100.00	500.0
Shading (12.5% classes)	SHA	≤12.5%	106	1.00	1.000	1.000	1.000
		>12.5%	27	2.00	2.778	2.000	5.000
Acidity (pH)	PH	<6.8	41	6.10	5.780	3.200	6.700
		6.8-7.8	43	7.20	7.256	6.800	7.800
		≥7.9	43	8.40	8.579	7.900	10.800
Electrical conductivity of the water (mS/m)	EC	<133	43	83.00	83.1	34.0	132
		133-258	43	193.00	191.4	133.0	258
		≥259	44	472.50	540.3	270.0	2833
SECONDARY							
Topography within a 100 m radius	TOP	flat	60	1.00	1.000	1.000	1.000
		hilly	70	2.00	2.471	2.000	3.000
Transparency of the water	TRA	clear	59	1.00	1.000	1.000	1.000
		turbid	74	2.00	2.176	2.000	3.000
Presence of seepage water (y/n)	SEEP	no	112	0.00	0.0000	0.0000	0.0000
		yes	19	1.00	1.0000	1.0000	1.0000
Water table below ground level (cm)	LEV	≤50 cm	58	1.00	1.000	1.000	1.000
		>50 cm	73	2.00	2.521	2.000	4.000
Vegetation cover of the bank (%)	VEGB	≤50%	67	3.00	2.299	0.000	4.000
		>50%	66	7.00	6.288	5.000	7.000
Vegetation cover of the water (%)	VEGW	≤5%	74	0.00	0.338	0.000	1.000
		>5%	59	4.00	4.424	2.000	7.000
Unvegetated part of the bank (%)	UNVB	0%	55	0.00	0.00	0.000	0.00
		bare parts	78	40.00	48.08	10.000	100.00
Water surface area (m^2)	SURF	≤50 m^2	45	35.00	30.8	4.00	50.0
		50-140 m^2	44	75.00	82.2	54.00	140.0
		>140 m^2	44	307.00	321.8	149.00	866.0
Main land use within a 100 m radius	LAND	forest/park	61	3.00	2.607	1.000	3.000
		meadow	43	4.00	4.000	4.000	4.000
		field	28	5.00	5.000	5.000	5.000

Some amphibian species (*Triturus alpestris*, *T. helveticus*, *Alytes obstetricans*, *Bombina variegata*) have a restricted distribution in the Netherlands. For those species it was determined in which of the sample ponds they might be expected on the ground of their distribution pattern. For the last three species the numbers of potential ponds were too low for statistical analysis.

For the statistical analyses the records of the first visit were used, supplemented with data on amphibians from the second visit. The pond characteristics were recorded either as a continuous variable (sometimes severely rounded), as a class, or as an ordinal variable. For the analyses they were all coded as a qualitative factor with two or three classes. Three classes were made when a non-monotonous relationship with the presence of amphibians was expected. This was the case for SURF, LAND, PH and EC (for codes see TABLE 1). The class margins were chosen in such a way that the numbers of observations are divided over the classes as equally as possible (TABLE 1, columns 3 and 4).

The relationship between presence/absence of amphibians and pond characteristics was analyzed by linear discriminant analysis. This model assumes additivity of effects at a certain scale. This was not expected to be true for all pairs of explanatory variables. Therefore we included interactions between the pond characteristics of primary interest (DISW, DISL, AGE, DEP, PH, EC) in the model. No interactions with shading (SHA), also a variable of primary interest, were included, because there were insufficient data to estimate those interactions. Also the nine pond characteristics of secondary interest were only modelled as main effects. Our model thus consisted of 31 model terms (16 explanatory variables, 15 interactions), equivalent with 46 parameters (because some variables had 3 levels), to be estimated from a total of 123 ponds for which all data were available.

The analysis consisted of screening the 31 model terms for significant effects, followed by the calculation of tables with crudely estimated presence frequencies for each of the significant effects. The estimated presence frequency for level k of model term j should be thought of as being a prediction of the mean presence frequency in the complete data set if all ponds in the data set would have level k for model term j.

We performed a screening analysis similar to the approach described by BROWN (1976), but employing the discriminant analysis model rather than the log-linear model used there. In a screening analysis all model terms are subjected to two statistical tests:

1. In the marginal test the relation between the response (presence/absence of amphibians) and a model term on its own is tested for statistical significance. Other explanatory variables are only relevant in that the residual variation, against which a possible effect of the term under scrutiny is tested, is estimated from the full model.
2. In the conditional test the relation between the response (presence/absence of amphibians) and a model term is tested after correction for the effects of all other model terms. For example, we may investigate differences in presence/absence due to differences in pH, 'other things being equal'. In practice, the conditional test is performed by investigating the change in the residual sum of squares from deleting the model term from the full model.

The inclusion of interactions in the model complicates the use of marginal and conditional tests. A marginal test of an interaction must include the corresponding main effects in the model, and a conditional test of a main effect should not correct for effects of interactions involving that main effect. The Genstat procedure RSCREEN (VAN DERVOET, 1996) has been written to perform such screening tests in an appropriate way.

Linear discriminant analysis is formally equal to a linear regression analysis of the presence variable (here coded 0 for absent and 1 for present) on the model terms. Conditional presence frequencies for the levels of a model term under scrutiny were estimated crudely by averaging the fitted values from this formal regression over the levels of the other factors in the model, employing the proportions observed in the data as weights in the averaging step ('test-factor standardization', see e.g., LANE & NELDER, 1982).

More sophisticated estimates of the weighted averages of the presence probabilities per pond are possible by explicitly calculating posterior probabilities for each pond followed by weighted averaging of these probabilities. The crude method was preferred here because standard Genstat regression routines for weighted averaging could be used for forming the predictions.

Results

Amphibians were found in 107 (80%) out of the 133 ponds. Reproduction was observed in 90 ponds (68%). A total of nine species was recorded (TABLE 2). Common frogs were the most widespread. Four other anurans were not found, although some ponds were situated within their distribution range (*Hyla arborea*, *Bufo calamita*, *Rana arvalis*, *Pelobates fuscus*).

Using the seven main and nine secondary pond characteristics, statistical analyses were carried out on the presence of six species of amphibians and of amphibians in general (all species together). A distinction was made between ponds with only presence of amphibians and ponds with evidence of their reproduction (eggs, larvae, or juveniles found; TABLES 3 and 4). Tables with conditional presence frequencies were calculated for all significant effects (TABLES 5-11). We refrain from presenting also all marginal presence frequencies, but they are available upon request from the authors. It can be seen in TABLES 3 and 4 if marginal effects are positive or negative. For the significant marginal interactions (and some three-level main effects) the direction of the effects is specified in the text below.

TABLE 2. Presence of amphibians in ponds. The column 'Number of ponds' gives the number of ponds surveyed within the distribution range of the species.

Species/taxon	Number of ponds	Presence	Evidence of reproduction
all species	133	107 (80%)	90 (68%)
Rana temporaria	133	75 (56%)	60 (46%)
Triturus vulgaris	133	48 (36%)	33 (25%)
Rana synkl. *esculenta*	133	45 (34%)	16 (12%)
Triturus alpestris	80	19 (24%)	12 (15%)
Bufo bufo	133	14 (11%)	11 (8%)
Alytes obstetricans	24	7 (29%)	7 (29%)
Triturus cristatus	133	4 (3%)	3 (2%)
Bombina variegata	24	2 (8%)	1 (4%)
Triturus helveticus	54	3 (6%)	1 (2%)

In the analysis of amphibians in general, a significant conditional effect was found for the topography. Amphibians are expected in 85% of the sites with differences in height (relief) against 65% of the sites without relief. In the marginal test also a higher presence in older ponds was found, provided that there was some cover of water vegetation and that the bank vegetation was closed. However, in all these cases the effect was less clear (though not absent) if other pond features were taken into account.

Reproduction stages of amphibians are expected more often in ponds without shading than in ponds with shading. For the characteristic 'shading' no significant conditional effects were found if the species were considered separately.

The common frog (*Rana temporaria*) can especially be expected in shallow ponds, in ponds with a completely vegetated bank, and in larger ponds. In ponds younger than 4 years old no relationship with the electrical conductivity of the water (EC) was found. In contrast to this, in older ponds the expected presence appears to be strongly dependent on the EC; remember that estimates are crude ones, which allows values < 0% and > 100%. This pattern was also observed in the marginal frequencies. The significant marginal interaction DISW.DEP, in both TABLES 3 and 4, was caused by the presence of more frogs in shallow ponds if the distance to the nearest water was less than l00 m, but more frogs are found in deeper ponds if this distance was more than 100 m.

For the reproduction stages, similar effects were found. Moreover, it was found that for ponds with a short distance to land habitats (< 4 m) it is favourable if the distance to other reproduction waters is short. For ponds with a greater distance to land habitats no effect was found of the distance to other ponds. This pattern was also observed in the marginal frequencies.

TABLE 3. Significance of relations between pond characteristics and presence of amphibians. m = marginal test; c = conditional test; + = significant positive relation; - = significant negative relation; * = significant effect (see text); blank cells = no significant relations or effects ($P > 0.05$). The number of symbols indicates the degree of significance: one symbol: $0.01 < P \leq 0.05$; two symbols: $0.001 < P \leq 0.01$; three symbols: $P \leq 0.001$. Model term codes: see TABLE 1. Species codes: All = all species together, Rt = *Rana temporaria*, Rse = *Rana* synkl. *esculenta*, Tv = *Triturus vulgaris*, Ta = *T. alpestris*, Tc = *T. cristatus*, Bb = *Bufo bufo*.

Model term	All		Rt		Rse		Tv		Ta		Tc		Bb	
	m	c	m	c	m	c	m	c	m	c	m	c	m	c
DISW														
DISL														
PH									+					
EC			−				+							
DEP				−−			−−							
AGE	+				−−−	−−	+++	+			+		+	++
SHA														
TOP	++	+			+	+			++					
TRA							−−−							
SEEP													+	
LEV					−−−		+++	++						
VEGB														
VEGW	+						+++	+++			+	+		
UNVB	−−		−−−	−	−−								−	
SURF				+	++		*							
LAND							*							
DISW.DISL										*				
DISW.PH										*	*			
DISL.PH										*				*
DISW.EC														
DISL.EC														
PH.EC														
DISW.DEP			**											*
DISL.DEP											*			
PH.DEP														
EC.DEP														*
DISW.AGE														*
DISL.AGE					*		***							
PH.AGE							***	*						
EC.AGE			*	**			*	*				*		
DEP.AGE													**	*

TABLE 4. Significance of relations between pond characteristics and presence of reproduction stages of amphibians. For symbols and codes, see TABLE 3.

Model term	All		Rt		Rse		Tv		Ta		Tc		Bb	
	m	c	m	c	m	c	m	c	m	c	m	c	m	c
DISW														
DISL														
PH														
EC														
DEP				−										
AGE							+				+			
SHA		−												
TOP									+		+			
TRA							−−−	−						
SEEP													+	
LEV							+++	+	+					
VEGB														
VEGW						+	++	++						
UNVB	−		−−	−−						−				
SURF				+										
LAND							*							
DISW.DISL			*	*						**				
DISW.PH									*					
DISL.PH														*
DISW.EC														
DISL.EC														
PH.EC														
DISW.DEP			*			*								
DISL.DEP											*	*		
PH.DEP						*								
EC.DEP							**							
DISW.AGE										*				
DISL.AGE							**							
PH.AGE								**						
EC.AGE			*	*				**		*		*		
DEP.AGE							**							

The green frogs (*Rana* synkl. *esculenta*) were expected more often in younger than in older ponds. The presence of topography is important. The cover of the water vegetation plays a positive role for the reproduction. In shallow ponds an almost neutral pH value seems to be essential for reproduction. In the marginal test there was a significant interaction between the distance to the nearest land habitat and age: for young ponds a relatively large distance to the nearest habitat was favourable, whereas for older ponds the reverse was true. However, this pattern was no longer significant after correction for other model terms.

Also most reproduction was found in shallow ponds if other ponds were nearby, but in deep ponds if other ponds were at a distance of over 100 m.

For the smooth newt (*Triturus vulgaris*) the greatest numbers of effects are found. This species is expected more in older than in younger ponds, particularly in older ponds which are not too acidic and which are relatively clean. Furthermore it is beneficial if the water table is at least 0.5 m below the ground level, and if the cover of the water vegetation is > 5%. In the marginal tests more animals were found in the medium-sized waters than in the small and large ponds. Surrounding meadows were negatively correlated with newt presence, which was also the case in the analysis of reproduction stages. The marginal interactions PH.AGE and EC.AGE showed similar patterns as the conditional tables. There was also a significant DlSL.AGE marginal interaction, with a nearby land habitat having a positive effect for younger, but a negative effect for older ponds. This was also found in the analysis of reproduction stages.

TABLE 5. Significant conditional effects: all amphibians. Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)		Predicted presence (%) (with standard error)
All	TOP	flat	65 (7)
		hilly	85 (7)
All (r)	SHA	⩽12.5%	66 (7)
		>12.5%	33 (15)

For the reproduction stages similar results were obtained, whereas also clear transparent water had a positive effect. Marginally, a low EC was favourable for reproduction in the shallow ponds, whereas EC was less important in the deeper ponds. Another effect that was only significant in the marginal test, was that there were relatively few reproduction stages in the young deep ponds.

For the alpine newt (*Triturus alpestris*) the model explains relatively little of the variation in presence, as indicated by the large standard deviation of the means. Significant effects were the mutual interactions between pH, distance to land habitat, and distance to water habitat. This species seems to prefer a pH of 8-11, if the distance to the nearest reproduction water is relatively short. Also for ponds with a nearby land habitat (< 5 m) the pH is of interest. If nearby land habitats are present, the neighbourhood of other ponds is strongly beneficial for the presence of this species.

Reproduction stages are particularly to be expected in ponds with a completely vegetated bank, whereas also here the combination of closeby land and closeby water habitats is favourable. The proximity of other ponds had a positive effect for the younger ponds. Reproduction stages are especially expected in older ponds with a high or low EC. The marginally significant interaction DISW.PH for reproduction stages was caused by a relatively large frequency of reproduction stages in alkaline ponds with a distance of less than 100 m to other ponds.

TABLE 6. Significant conditional effects: *Rana temporaria* (Rt). Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)				Predicted presence (%) (with standard error)
Rt	DEP	<1 m			72 (8)
		⩾1 m			35 (7)
	UNVB	no bare parts			73 (9)
		bare parts			34 (9)
	SURF	⩽50 m^2			32 (9)
		50-140 m^2			49 (9)
		>140 m^2			74 (11)
	EC	<133 mS/m	AGE	<4 yrs	47 (11)
				⩾4 yrs	101 (17)
		133-258 mS/m		<4 yrs	51 (12)
				⩾4 yrs	38 (14)
		⩾259 mS/m		<4 yrs	54 (16)
				⩾4 yrs	7 (15)
Rt (r)	DEP	<1 m			56 (9)
		⩾1 m			27 (7)
	UNVB	no bare parts			58 (9)
		bare parts			20 (9)
	SURF	⩽50 m^2			13 (10)
		50-140 m^2			41 (9)
		>140 m^2			57 (11)
	DISW	<100 m	DISL	<5 m	56 (12)
				⩾5 m	24 (12)
		⩾100 m		<5 m	23 (11)
				⩾5 m	40 (12)
	EC	<133 mS/m	AGE	<4 yrs	34 (12)
				⩾4 yrs	77 (17)
		133-258 mS/m		<4 yrs	40 (12)
				⩾4 yrs	13 (14)
		⩾259 mS/m		<4 yrs	33 (17)
				⩾4 yrs	15 (15)

Of the analysed species the great crested newt (*Triturus cristatus*) occurred least often, only in 4 ponds. A high cover of the water vegetation was favourable, and also a low EC in the older ponds. This newt was only found in neutral ponds with and in alkaline ponds without a nearby reproduction water (significant marginal DISW.PH interaction). In another classification, they occurred only in relatively deep ponds with, and in shallow ponds without a nearby land habitat (significant marginal DISL.DEP interaction, also found in the analysis for the reproduction stages).

TABLE 7. Significant conditional effects: *Rana* synkl. *esculenta* (Rse). Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)				Predicted presence (%) (with standard error)
Rse	AGE	<4 yrs			51 (7)
		⩾4 yrs			17 (8)
	TOP	flat			19 (8)
		hilly			43 (8)
Rse (r)	VEGW	⩽5%			3 (5)
		>5%			19 (6)
	DEP	<1 m	DISW	<100 m	15 (9)
				⩾100 m	−4 (9)
		⩾1 m		<100 m	4 (8)
				⩾100 m	22 (8)
	DEP	<1 m	PH	<6.8	1 (14)
				6.8-7.8	26 (9)
				⩾7.9	−11 (11)
		⩾1 m		<6.8	18 (9)
				6.8-7.8	7 (9)
				⩾7.9	13 (10)

The reproduction stages are especially found in older ponds (like in the alpine newt), with either a high or a low EC. If a land habitat is nearby, a deep pond seems to be better than a shallow one.

The common toad (*Bufo bufo*) is particularly expected in ponds of at least 4 years old. This is especially clear if there are no other ponds in the vicinity, or if the pond is deeper than 1 m. The positive effect of age for deeper, but not for shallow ponds, was also found significant in the marginal test. For shallow ponds holds that they must have a low EC, or that other ponds must be nearby. Finally, a pH of 8-11 seems to be favourable, particularly if a land habitat is closeby.

Only this last effect (interaction pH with distance to land habitat) was also found for the reproduction stages.

TABLE 8. Significant conditional effects: *Triturus vulgaris* (Tv). Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)				Predicted presence (%) (with standard error)
Tv	AGE	<4 yrs			24 (6)
		⩾4 yrs			46 (8)
	LEV	⩽50 cm			27 (7)
		>50 cm			50 (6)
	VEGW	⩽5%			27 (6)
		>5%			58 (7)
	PH	<6.8	AGE	<4 yrs	34 (12)
				⩾4 yrs	23 (12)
		6.8-7.8		<4 yrs	16 (10)
				⩾4 yrs	72 (13)
		⩾7.9		<4 yrs	26 (9)
				⩾4 yrs	73 (14)
	EC	<133 mS/m	AGE	<4 yrs	20 (9)
				⩾4 yrs	77 (14)
		133-258 mS/m		<4 yrs	40 (9)
				⩾4 yrs	37 (11)
		⩾259 mS/m		<4 yrs	15 (13)
				⩾4 yrs	55 (12)
Tv (r)	TRA	clear			42 (7)
		turbid			24 (6)
	LEV	⩽50 cm			22 (7)
		>50 cm			39 (6)
	VEGW	⩽5%			22 (6)
		>5%			44 (7)
	PH	<6.8	AGE	<4 yrs	30 (12)
				⩾4 yrs	22 (12)
		6.8-7.8		<4 yrs	17 (10)
				⩾4 yrs	78 (12)
		⩾7.9		<4 yrs	21 (9)
				⩾4 yrs	25 (14)
	EC	<133 mS/m	AGE	<4 yrs	20 (9)
				⩾4 yrs	77 (14)
		133-258 mS/m		<4 yrs	31 (9)
				⩾4 yrs	25 (11)
		⩾259 mS/m		<4 yrs	16 (13)
				⩾4 yrs	21 (12)

TABLE 12 gives a more detailed account of the factor 'age'. Amphibians were found in ponds of all ages. The number of reproducing species in one pond varied from one to five. The number of five was already reached in a pond of only 3 years old. The data demonstrate that ponds can be colonized quickly by reproducing amphibians, in view of the high occupation of young ponds (over 50% presence in ponds of 1 to 7 years old). Tadpoles of common frogs were once found in the same season that the pond had been built.

TABLE 9. Significant conditional effects: *Triturus alpestris* (Ta). Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)				Predicted presence (%) (with standard error)
Ta	DISW	<100 m	DISL	<5 m	51 (17)
				≥5 m	6 (19)
		≥100 m		<5 m	−10 (17)
				≥5 m	31 (17)
	DISW	<100 m	PH	<6.8	−5 (20)
				6.8-7.8	16 (21)
				≥7.9	96 (24)
		≥100 m		<6.8	−9 (20)
				6.8-7.8	25 (18)
				≥7.9	16 (23)
	DISL	<5 m	PH	<6.8	−32 (23)
				6.8-7.8	18 (16)
				≥7.9	86 (27)
		≥5 m		<6.8	19 (18)
				6.8-7.8	24 (23)
				≥7.9	16 (22)
Ta (r)	UNVB	no bare parts			27 (10)
		bare parts			−1 (12)
	DISW	<100 m	DISL	<5 m	36 (14)
				≥5 m	−3 (16)
		≥100 m		<5 m	−10 (14)
				≥5 m	27 (14)
	DISW	<100 m	AGE	<4 yrs	27 (12)
				≥4 yrs	4 (18)
		≥100 m		<4 yrs	−10 (13)
				≥4 yrs	31 (19)
	EC	<133 mS/m	AGE	<4 yrs	4 (17)
				≥4 yrs	42 (23)
		133-258 mS/m		<4 yrs	19 (14)
				≥4 yrs	−24 (17)
		≥259 mS/m		<4 yrs	−8 (23)
				≥4 yrs	50 (38)

To test whether the age of a pond plays a role in the presence of common frogs, the pond age was plotted against the percentage of ponds with reproducing common frogs as compared to the total number of ponds per year of construction (FIGURE 1). A non-linear relation has been fitted (smoothing spline function with 5 degrees of freedom; GENSTAT 5 COMMITTEE, 1993). This line suggests that already after 3 years an optimum situation is reached, when more than half of the ponds have reproducing common frogs.

The survey did not consider other organisms than amphibians in ponds, but occasional remarkable observations were made, such as the presence of the very rare stonewort *Nitella translucens* in a pond of 3 years old.

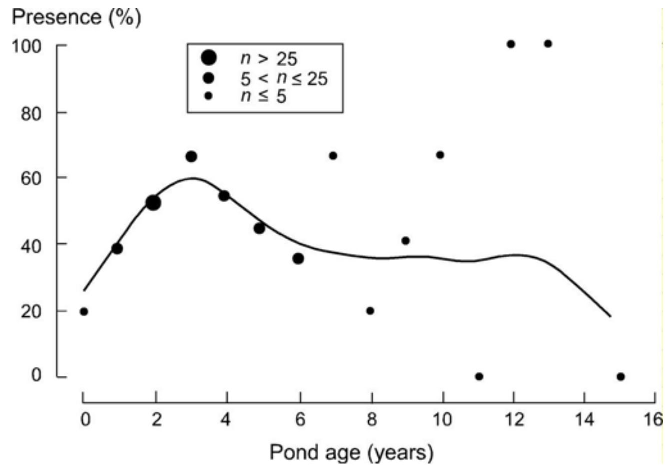

FIGURE 1. Relationship between pond age and the percentage of ponds with reproducing common frogs.

TABLE 10. Significant conditional effects: *Triturus cristatus* (Tc). Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)				Predicted presence (%) (with standard error)
Tc	VEGW	⩽5%			0 (2)
		>5%			7 (3)
	EC	<133 mS/m	AGE	<4 yrs	−7 (4)
				⩾4 yrs	14 (6)
		133-258 mS/m		<4 yrs	3 (4)
				⩾4 yrs	−1 (5)
		⩾259 mS/m		<4 yrs	1 (5)
				⩾4 yrs	8 (5)
Tc (r)	DISL	<5 m	DEP	<1 m	−6 (5)
				⩾1 m	9 (4)
		⩾5 m		<1 m	7 (4)
				⩾1 m	1 (4)
	EC	<133 mS/m	AGE	<4 yrs	−6 (4)
				⩾4 yrs	10 (6)
		133-258 mS/m		<4 yrs	4 (4)
				⩾4 yrs	−3 (5)
		⩾259 mS/m		<4 yrs	1 (6)
				⩾4 yrs	16 (6)

TABLE 11. Significant conditional effects: *Bufo bufo* (Bb). Predicted presence frequencies are means in the data set expected if all ponds in data set would have had the indicated level. Pond characteristic codes: see TABLE 1. (r) = ponds with evidence of reproduction.

Species	Pond characteristic(s)				Predicted presence (%) (with standard error)
Bb	AGE	<4 yrs			1 (4)
		≥4 yrs			23 (5)
	DISL	<5 m	PH	<6.8	8 (10)
				6.8-7.8	6 (7)
				≥7.9	42 (11)
		≥5 m		<6.8	−2 (9)
				6.8-7.8	18 (9)
				≥7.9	12 (7)
	DISW	<100 m	DEP	<1 m	20 (8)
				≥1 m	9 (6)
		≥100 m		<1 m	1 (8)
				≥1 m	23 (7)
	EC	<133 mS/m	DEP	<1 m	34 (11)
				≥1 m	9 (7)
		133-258 mS/m		<1 m	−2 (9)
				≥1 m	18 (8)
		≥259 mS/m		<1 m	−2 (12)
				≥1 m	22 (8)
	DISW	<100 m	AGE	<4 yrs	9 (6)
				≥4 yrs	18 (8)
		≥100 m		<4 yrs	−4 (7)
				≥4 yrs	35 (8)
	DEP	<1 m	AGE	<4 yrs	8 (9)
				≥4 yrs	14 (7)
		≥1 m		<4 yrs	−1 (6)
				≥4 yrs	36 (8)
Bb (r)	DISL	<5 m	PH	<6.8	5 (9)
				6.8-7.8	3 (7)
				≥7.9	32 (10)
		≥5 m		<6.8	−7 (8)
				6.8-7.8	16 (9)
				≥7.9	5 (6)

TABLE 12. Pond age and presence of amphibians. Ao = *Alytes obstetricans*, Bb = *Bufo bufo*, Bv = *Bombina variegata*, Rse = *Rana* synkl. *esculenta*, Rt = *R. temporaria*, Ta = *Triturus alpestris*, Tc = *T. cristatus*, Th = *T. helveticus*, Tv = *T. vulgaris*; % = percentage of the number of ponds of the same age.

Age (years) in 1994	Number of ponds with reproduction (%)	Species number in all ponds	Maximum species number per pond	Reproducing species	Maximum number of reproducing species per pond
0	1 (20)	1	1	Rt	1
1	9 (50)	4	2	Bb Rse Rt Tv	2
2	28 (82)	6	4	Bb Rse Rt Ta Th Tv	4
3	12 (80)	6	6	Bb Bv Rse Rt Ta Tv	5
4	8 (73)	5	3	Bb Rse Rt Ta Tv	3
5	5 (56)	4	3	Bb Rse Rt Tv	3
6	10 (71)	6	5	Ao Bb Rt Tv	3
7	3 (100)	4	4	Ao Bb Rt Tv	4
8	2 (40)	4	3	Rse Rt Ta Tv	3
9	3 (60)	6	5	Ao Bb Rt Tc Tv	4
10	2 (67)	4	4	Rt Ta	2
11	3 (60)	6	5	Ao Ta Tc Tv	3
12	1 (100)	2	2	Rt	1
13	1 (100)	2	2	Rse Rt	2
15	1 (50)	2	1	Tv	1
34	2 (100)	2	2	Bb Tv	1

Discussion

Ecology and conservation

Generally, the creation of new ponds has been a success for amphibians. This is shown by the percentage of colonized ponds (68% with reproduction), and the number of species involved (nine). The greatest share had the common frog (*Rana temporaria*), the green frogs (*R.* synkl. esculenta), and the smooth newt (*Triturus vulgaris*), which are the more common taxa in the Netherlands.

Although the data set allows for a variety of analyses, we particularly paid attention to confirmative analyses of selected, simple hypotheses. From the conclusions, as summarized in the TABLES 3 and 4, the presence of species of amphibians can be related to a number of pond characteristics. In many cases effects were found of the age of a pond, the topography of the surroundings, the cover of the water and bank vegetation, and the electrical conductivity of the water.

The importance of the pond characteristics appeared to vary among species. Evidently the factors which determine the presence of amphibian species in ponds are part of a complex network of relationships and are strongly influenced by the local situation. Only a few characteristics seemed to be important for amphibians in general. This can be attributed to the great variation in specific demands of the species. In a number of species we found relations with certain pond characteristics. They give indications on which specific requirements should be considered when constructing ponds. The general knowledge of the biology of amphibian species should be further integrated when designing pond plans.

With respect to the ecology of the species it is difficult to find explanations for the relations between the presence of a species and pond characteristics. They rather give rise to formulate hypotheses for further research. However, some of them may be explained in a more general way.

As to the age of a pond, in general there may be an optimum situation at a certain age, as is suggested for *Rana temporaria*. Ponds are subject to succession of the vegetation: they start with a bare floor and can develop into a forest. By means of management measures, such as removal of plants and mud, and grazing, this succession can be suppressed by man. Most likely, amphibian species meet the different requirements to their habitat in different stages of the succession. The exact conditions, under which certain species meet their optimum habitat should however be further investigated.

Ponds are only part of the habitat of amphibians. Therefore it is no surprise that effects were found of the topography of the surroundings. With more relief there is an increasing chance for land habitats to be present, as height differences lead to more variation in the structure of the vegetation. The characteristic DISL (distance to the nearest potential land habitat), with plant growth of over 1 m in height regarded as a potential land habitat, showed effects in four species.

With respect to the cover of the water vegetation we found conditional effects in the green frogs, the smooth newt and the great crested newt. A dense aquatic vegetation will offer more food for the larvae (algae, invertebrates) and protection against predators (e.g., fish) than open water will do. Moreover, more places for attaching eggs will be available. The electrical conductivity is a measure of the number of ions dissolved in the water. Ponds differ naturally in conductivity across the oligotrophic-eutrophic spectrum according to their geological structure, but in many agricultural areas those values have increased significantly by dunging and using fertilizers. Amphibians only tolerate a certain degree of water enrichment and pollution for the development of their eggs.

Amphibians have been observed in ponds of all ages and three years after their construction five species could already be found. Not all species reacted to the availability of new ponds with the same speed. Numerous factors could be responsible for that. The potential of species to colonize new ponds is generally great. However, how fast a pond is actually accepted appeared in practice to be strongly dependent on the location and the construction method used. It will also be influenced by the size of and the distance to the nearest population. The common toad and the smooth newt have particularly been found in older ponds, whereas the green frogs were observed in younger ones.

The selection of pond characteristics was made arbitrarily, based on the experiences of field herpetologists, and we must be cautious of other factors playing a role too. Not all characteristics have constant values during the season (e.g. PH, SURF, VEGW). By using only the data obtained during the reproduction period of the amphibians we suppose to have calculated with the most relevant figures.

By constructing ponds, environments for other organisms are being created at the same time, as was shown by the presence of rare plants. Although relations with other organisms have to be investigated further, it is clear that ponds for amphibians can contribute significantly to the biodiversity of the countryside.

Methodology

Linear discriminant analysis has been used before for finding habitat determinants by BEEBEE (1985), whose approach was followed by others (PAVIGNANO, 1988; LAAN & VERBOOM, 1990; PAVIGNANO *ET AL.*, 1990; ILDOS & ANCONA, 1994; ANCONA & CAPIETTI, 1995). BARANDUN & REYER (1997) applied discriminant analysis after a principal component analysis on pond characteristics, interpreting the principal components as ecological factors. Discriminant analysis was introduced as a more comprehensive method of data analysis than methods used previously (BEEBEE, 1985). For example, chi-square tests have been calculated from 2 by 2 tables, in which ponds are classified by presence/absence of an amphibian species and some dichotomized pond characteristic (e.g. $pH \leq 6/pH > 6$; example from COOKE & FRAZER, 1976).

Unfortunately, there has been no discussion in these papers about the different interpretations (marginal or conditional) that should be given to significant effects found by different methods of analysis. Moreover, in the above papers there was no discussion of possible non-additivity of effects in the linear model. Finally, some of the studies (ILDOS & ANCONA, 1994; ANCONA & CAPIETTI, 1995) are statistically unacceptable, because the number of parameters in the model was much too high in comparison to the number of statistical units (ponds), leaving not enough degrees of freedom for a sensible estimation of the residual variances and covariances necessary for the calculation of the discriminant function. For example, ILDOS & ANCONA (1994) have data on only 41 water bodies, but consider 33 variables for inclusion in a discriminant function. They obtain a perfect discrimination between used and unused sites which they consider as evidence that "even seemingly generalist species [...] are indeed selective in the breeding site choice". Rather, this perfect discrimination should be seen as the near-equivalent of the perfectly fitting straight line through two points.

In principle, there are two competing models for the analysis of presence/absence data: logistic regression (related to chi-square tests) and discriminant analysis. In this study, discriminant analysis was preferred, mainly for computational reasons: for linear discriminant analysis no iterative calculations are necessary, and therefore also no problems with convergence of the algorithm can occur. With logistic regression, regularization techniques are necessary, which we hope to study in future work.

Both marginal and conditional effects may be of interest to the biological researcher. Marginal effects signal the presence of correlations, without specifying if such correlations are due to direct or indirect causal pathways. Conditional effects cannot be due to indirect effects of other variables in the model, and therefore come closer to the 'pure' relation between explanatory variable and response. The comparison of marginal and conditional effects may be a good starting point for investigating the importance of explanatory variables.

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6 Intraspecific variation in two life history traits in frog larvae (*Rana temporaria*) from five populations along a north-south gradient

Abstract. When selecting frogs for introduction into new or former habitats, it is important that the donor specimens are adapted to the environmental conditions of the introduction site. European Common frogs, *Rana temporaria*, from Netherlands populations occurring 200 km apart, showed substantial variation in the longitudinal growth and developmental time of their tadpoles. Going southwards, populations along a 650 km gradient from northern Germany to northern France had larger tadpoles and a shorter developmental time. A Netherlands population from a colder microhabitat deviated from this trend, behaving like the northernmost population in Germany. The possibility of a trade-off between growth and developmental time is discussed. Stress factors, such as crowding, may increase the negative effects of unfavourable environmental conditions. A decrease of phenotypic variation, normally found at the edge of a species' distribution area, may also occur in the centre of its range.

Introduction

Once a habitat has been restored, or a new one created, nature management often includes reintroduction or introduction of a species. When this habitat suffices to host the species, the most suitable animals for re-introduction need to be found. In many cases, there is no donor population nearby, which raises the problem of where to find one. The question is relevant whether the individuals from the donor population are adapted to the conditions of the new or restored habitat. Before making a choice, it is important to know the extent of intraspecific variation in that particular species, especially concerning life history traits. Several recent reintroduction attempts may have failed because of the wrong donor choice, due to lack of this sort of information (TESTER, 1990; SIEPEL, 1997).

Generally, the exposure to specific ecological conditions leads to local adaptation of animal populations and therefore to phenotypic and genetic differences (STEARNS, 1992). Favourable conditions leading to a larger population may result in a relative increase in genetic variation. Marginal conditions may act as a selective force on a population, reducing the genetic variation (e.g., SUOMALAINEN, 1962). Substantial variation in life history traits may be expected in populations living under different ecological conditions (HYPOTHESIS 1: DIFFERENT ECOLOGICAL CONDITIONS LEAD TO DIFFERENCES IN LIFE HISTORY TRAITS). This phenomenon can be expected in common species, especially when the individuals are not very mobile, as this reduces the chance of gene exchange. To test this hypothesis, we used the European Common frog (*Rana temporaria*) as it is a common species with a low mobility.

In northwest Europe, *Rana temporaria* L., 1758 is a common amphibian. Its world range stretches from northern and central Europe to beyond the Urals in Russia. The species shows such little morphological variation that only a few subspecies have been described (GROSSENBACHER, 1997). *Rana temporaria temporaria* is widespread, the other subspecies are found in small, isolated areas. Our research involves the nominate subspecies. As there is still little knowledge about the variation in the species' ecological requirements, we have paid special attention in the present study to the relationship between life history traits, geographic origin, and environmental conditions; a new research goal.

The aim of this study is to explore whether *Rana temporaria temporaria* is really as uniform as generally believed. For this purpose, we studied the phenotypic variation in populations originating from isolated water bodies (ponds) along a 650 km north-south gradient. Moreover, we looked at the physiological responses of the different populations to pH, temperature and crowding. For practical purposes, we confined our study to growth and developmental time (length of a period) of the tadpoles. We expected a difference in developmental time in tadpoles from populations at different latitudes: the more northerly a population, the colder the climate, the shorter the favourable season and thus the shorter the developmental time (HYPOTHESIS 2: A SHORTER AND COLDER SEASON LEADS TO A SHORTER DEVELOPMENTAL TIME). We furthermore studied the relationship between the developmental time and the body length. The growth of a large body takes time and energy. In accordance with the Dynamic Energy Budget theory (KOOIJMAN, 1993), it may be expected that under unfavourable conditions (such as a shorter and colder season and possibly a colder microhabitat, or a contaminated habitat) the developmental time works at the cost of the growth and vice versa. So, under unfavourable conditions there may be a trade-off between developmental time and growth (HYPOTHESIS 3: UNDER UNFAVOURABLE CONDITIONS THE DEVELOPMENTAL TIME TRADES OFF AGAINST BODY LENGTH).

Material and methods

In order to obtain tadpoles for the experiment, we collected eggs of *Rana temporaria* in the field, sampling from a number of females at five sites in three countries (TABLE 1). These sites were located along a north-south gradient, and were at similar altitudes of less than 100 m above sea level. All sites were subject to an oceanic climate.

TABLE 1. Location of sites where eggs were collected.

code	*Site*	*Bundesland/Province/Département*	*country*	*co-ordinates*
SH	Bothkamp	Schleswig-Holstein	Germany	54°10'N, 10°07'E
DR	Dwingeloo	Drenthe	Netherlands	52°49'N, 6°25'E
LN	Milsbeek	Limburg (North)	Netherlands	51°44'N, 5°57'E
LS	Bemelen	Limburg (South)	Netherlands	50°50'N, 5°48'E
AR	Lametz	Ardennes	France	49°33'N, 4°40'E

In the laboratory, the eggs were hatched out in reservoirs, one for each site, and the tadpoles raised until Witschi's stage 24 (WITSCHI, 1956), that is, the stage immediately after the gills become invisible from the outside. The experiments started by selecting such tadpoles randomly from the five reservoirs. The variation in the initial length of the tadpoles was 8.2 %. For each experiment, a group of fifteen tadpoles from each site was put in a 6 litre aquarium filled with tap water, which was placed in a large reservoir with a constant water temperature. The water in the aquaria was refreshed weekly. In order to imitate a day and night cycle, all tadpoles were exposed to artificial light between 08.00 and 20.00 h; during the remaining period, it was completely dark. So that food was not a limiting factor, they were fed chopped nettle leaves (*Urtica urens*) *ad libitum*. All experiments were done in triplicate, in order to test sufficient individuals from a population. However, when working out our data, all larvae were taken together, as we were looking at population characteristics in this experiment.

When the tadpoles reached Witschi-stage 29, with the feet stretched out from the lower tail-fin, we determined the total length (body + tail) and the developmental time. This stage was chosen as it can be determined with an accuracy of one day. Furthermore, in later stages, a reduction of the tail length may be observed.

Three experiments were carried out. In the first one, the pH was set at at 3.0, 4.0, 5.0, 6.5, 8.0, and 9.5 and regulated with the help of standard combinations of citric acid, HCl, NaOH, Na_2HPO_4 and $NaHCO_3$. The water temperature in the reservoirs was kept at 10, 15, 20, 24 and 28 °C.

Experiment 1. The populations DR and LS (TABLE 1) were exposed to various pHs and temperatures (TABLE 2) in order to see if there were differences in growth and development, and thus in ecological response, between populations from the north and south of the Netherlands.

TABLE 2. Set-up of Experiment 1. Comparison of the two Netherlands populations DR and LS at varying pH and temperature

Temp. in °C	***pH***	***pH***	***pH***	***pH***	***pH***	***pH***
10	3.0	-	-	6.5	8.0	-
15	-	-	-	6.5	-	-
20	3.0	4.0	5.0	6.5	8.0	9.5
24	-	-	-	6.5	-	-
28	3.0	-	-	6.5	8.0	-

Experiment 2. We carried out the second series of experiments with populations from different latitudes, namely SH, LN and AR (TABLE 1), which we exposed to pH 7 and a temperature of 20 °C, as these were the values for tap water and the ambient temperature (TABLE 3). By comparing growth and development times in tadpoles from sites spaced farther apart than those in Experiment 1, we hoped to see if there was a trend between northern and southern sites spaced at larger distances.

TABLE 3. Set-up of experiment 2. Comparison of three populations from different latitudes. For codes, see TABLE 1.

Latitude (°N)	***Population***	***pH***	***temp. (°C)***
54°10'	SH	7	20
51°44'	LN	7	20
49°33'	AR	7	20

Experiment 3. In the last experiment, we looked at the effect of crowding on the tadpoles of one particular site, Milsbeek in North Limburg. We compared the growth and developmental time of fourteen tadpoles that were kept together in 7 litres of water, with the same number kept separately, each tadpole in 0.5 l. The water had a neutral pH and temperature of 20 °C in all cases. Crowding may have a greater effect on growth and development under unfavourable conditions. The LN population was supposed to live under colder microclimatic conditions than the northern populations SH and DR.

We used Student's t-test for statistical analyses.

Results

In the first experiment, the different pHs affected the growth and developmental time in different ways in the two populations (TABLE 4). At pH 5, the larvae differed in their body length when they reached stage 29, the LS larvae being larger than those of DR. A lower pH inhibited growth more in the DR population than in the LS. However, in both populations, the tadpoles reached their greatest length at pH 5. Regarding developmental time, that of both populations differed between pHs 5 and 6.5 At pH 5, the DR larvae tended to develop faster than the LS larvae. The optimum pH conditions for a short developmental time, meaning fast growth, seem to be at pH 5 for DR and at pH 6.5 for LS.

Exposure to different temperatures also had an effect (TABLE 5). At 24^{o}C, the LS larvae grew larger than the DR larvae. The DR larvae reached their greatest length at 15^{o}C, whereas those from LS did so at 20^{o}C. At 10^{o} and 24^{o}C, the DR larvae needed fewer days to develop to stage 29 than the LS larvae, but more days at 20^{o}C. The LS population showed the fastest development at 20^{o}C, whereas the DR larvae tended to develop faster with increasing temperatures, showing an optimum at 24^{o}C.

The DR population was found in an area with acidic soils about 200 km north of the LS population, which occurred on alkaline soils. The area of the northern population also had a colder climate. Our results indicate differences, adaptations, between the two populations. Apparently, adaptations may exist within quite short distances.

TABLE 4. Effect of various pHs on growth and development of tadpoles at 20 ^{o}C. Mean length and mean developmental time (columns *b-c, f-g*), trends (*d, h*) and t-test results (*e, i*). P=probability, s=significant (yes/no), n=number of individuals, *=all tadpoles died before reaching stage 29

a	*b*	*c*	*d*	*e*		*f*	*g*	*h*	*i*	
	mean body length (mm)					***mean developmental time (days)***				
pH	DR	LS	trend	t-test DR vs LS		DR	LS	trend	t-test DR vs LS	
				P	s				P	s
3	*	*	-	-	-	*	*	-	-	-
4	38.3 ± 2.0 (n=4)	43.8 (n=1)	5.5	-	-	48.8 ± 6.9 (n=4)	49.0 (n=1)	0.2	-	-
5	41.8 ± 2.4 (n=26)	44.9 ± 2.6 (n=17)	3.1	<0.01	y	22.8 ± 3.9 (n=26)	34.4 ± 9.5 (n=17)	11.6	<0.01	y
6.5	39.9 ± 1.7 (n=23)	40.6 ± 2.6 (n=24)	0.7	0.28	n	27.0 ± 0 (n=23)	26.7 ± 0.8 (n=24)	0.3	0.04	y
8	35.4 ± 2.0 (n=22)	35.8 ± 2.4 (n=52)	0.4	0.49	n	54.4 ± 26.4 (n=22)	48.3 ± 7.4 (n=52)	-6.1	0.13	n
9.5	*	*	-	-	-	*	*	-	-	-

TABLE 5. Effects of various temperatures on growth and development of tadpoles at pH 6.5 Mean length and mean developmental time (columns *b-c, f-g*), trends (*d, h*) and t-test results (*e, i*). P=probability, s=significant (yes/no), n=number of individuals, *=all tadpoles died before reaching stage 29.

a	*b*	*c*	*d*	*e*		*f*	*g*	*h*	*i*	
	mean body length (mm)					***mean developmental time (days)***				
temp. (^{o}C)	DR	LS	trend	t-test DR vs LS		DR	LS	trend	t-test DR vs LS	
				P	s				P	s
10	42.1 ± 1.9 (n=64)	42.3 ± 3.4 (n=57)	0.2	0.76	n	51.5 ± 5.6 (n=64)	60.9 ± 10.9 (n=57)	9.4	<0.01	y
15	42.5 ± 3.4 (n=10)	43.5 ± 2.3 (n=17)	1.0	0.41	n	46.0 ± 0 (n=10)	46.0 ± 0 (n=17)	0	-	-
20	39.9 ± 1.7 (n=23)	40.6 ± 2.6 (n=24)	0.7	0.28	n	27.0 ± 0 (n=23)	26.7 ± 0.8 (n=24)	-0.3	0.04	y
24	37.6 ± 1.5 (n=17)	40.0 ± 2.5 (n=18)	2.4	<0.01	y	24.0 ± 0 (n=17)	30.7 ± 9.5 (n=18)	6.7	<0.01	y
28	*	*	-	-	-	*	*	-	-	-

To see if our supposition of a north-south gradient was grounded, we raised larvae from the SH, LN and AR populations at 20^{o}C and pH 7 (TABLE 3). Thus, we extended the line connecting the DR and LS population northwards and southwards, and added a sampling point in between. We have combined these results with those from Experiment 1 (TABLES 6 and 7).

TABLE 6. Effect of latitude on growth and development of tadpoles. Temperature 20^{o}C in all cases. pH 6.5 in DR and LS; pH 7 in SH, LN and AR. n=number of individuals, s=significant.

population	***latitude (^{o}N)***	***length (mm)***	***time (days)***	***n***	***s length***	***s time***
SH	54^{o}10’	37.8 ± 2.8	31.8 ± 9.2	107	a	b
DR	52^{o}49’	39.9 ± 1.7	27.0 ± 0	23	b	a
LN	51^{o}44’	37.7 ± 2.1	29.9 ± 5.4	72	a	b
LS	50^{o}50’	40.6 ± 2.6	26.7 ± 0.8	24	b	a b
AR	49^{o}33’	40.7 ± 2.2	25.8 ± 5.7	68	b	a

TABLE 7. P values of the t-tests, screening for differences in length and in developmental time of the tadpoles between the five populations. Bold: significant.

length	*DR*	*LN*	*LS*	*AR*
SH	**P < 0.01**	P = 0.85	**P < 0.01**	**P < 0.01**
DR	-	**P < 0.01**	P = 0.28	P = 0.10
LN	-	-	**P < 0.01**	**P < 0.01**
LS	-	-	-	P = 0.79
developmental time	*DR*	*LN*	*LS*	*AR*
SH	**P = 0.01**	P = 0.12	**P < 0.01**	**P < 0.01**
DR	-	**P = 0.01**	**P = 0.04**	P = 0.31
LN	-	-	**P < 0.01**	**P < 0.01**
LS	-	-	-	P = 0.46

We found a geographical gradient showing an increase in the mean length of the tadpoles, from north to south, and a decrease in the mean developmental time in the same direction (TABLE 6); the LN population was an exception in this series. There were significant differences both in length and developmental time to stage 29 between the different populations, with the exception of the comparison between LS and AR (TABLE 7).

FIGURE 1 shows the relationship between length and developmental time for the five populations.

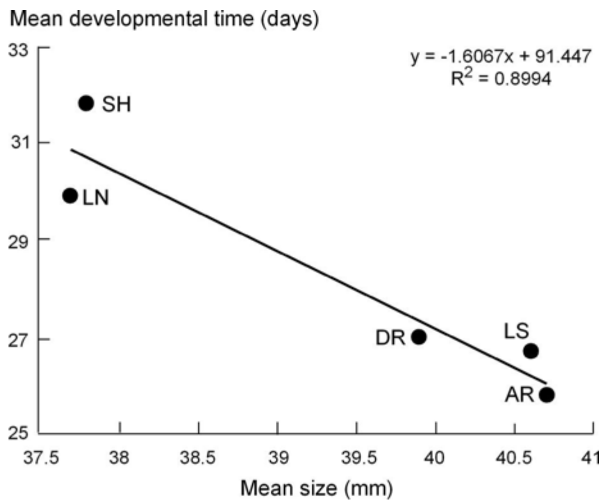

FIGURE 1. Relationship between length and developmental time.

The results of the experiment with the LN population show that crowding affects growth and development (TABLE 8).

TABLE 8. Effect of crowding on growth and development of tadpoles from the LN population. Cohorts consisted of 14 tadpoles. P=probability, n=number of individuals.

mean body length		t-test	mean developmental time		t-test
in cohort	alone		in cohort	alone	
38.4 ± 2.3 (n=221)	40.9 ± 2.8 (n=56)	P < 0.01	28.4 ± 4.9 (n=221)	22.2 ± 3.3 (n=56)	P < 0.01

Discussion

In the present study, we have shown the effect of pH and temperature on larval growth and rate of development for frog populations occurring only 100 km apart (between LN and LS), even though the frogs in these populations showed no morphological differences (TABLES 6 and 7). These results seem to support Hypothesis 1, which proposed substantial variation in life history traits under different ecological conditions. This implies that frog populations may not be the same, even when occurring at a short distance from each other. As our experiments deal with various localities, the differences must result from local selection pressure. This relationship becomes more apparent with the greater distances between populations along the north-south gradient of 650 km (TABLES 4 and 5). The greater length and the faster development in the south (TABLE 6) indicate a more favourable situation there. We can expect that the SH population at the northernmost latitude of the series will be adapted to the lowest average temperatures. As a decrease in temperature reduces growth (cf., VAN GELDER, 1987), the small SH tadpoles may be an expression of the adaptation to the environmental conditions at their site. Although the lesser growth of the tadpoles of the LN population does not at first sight fit in with our hypothesis, it can be explained by the nature of their habitat. In contrast to the other populations which came from ponds in the open field, these LN frogs were found in forest pools supplied with seepage water and cold water from a little stream.

Differences in life history traits within a species have been shown to be the result of local selection in relation to temperature, food availability, water level, etc. (BEATTIE, 1987; RIIS, 1991; LAURILA, 1997). Yet, little is known about the relative influence of these factors. AUGERT & JOLY (1993) found differences in *Rana temporaria* tadpole length at a distance of only nine kilometres in France, but the adults of these populations also differed in size.

Theoretically, it should be favourable for larvae to become large in as short a period as possible. According to this, it seems that of the five populations, the AR population is living in the best conditions: the tadpoles reach the greatest length in the shortest time. FIGURE 1 shows a possible trade-off between length and developmental time (cf., STEARNS, 1992). Would the larvae trade fast development in order to reach a minimum length before metamorphosis? We could expect the LN population to score in between the DR and LS populations, but apparently this population is stressed to such an extent by its cold environment, that not only do larvae attain a smaller length, but they need also more time for their development. This may indicate that Hypothesis 3 is true, where unfavourable conditions lead to a smaller length and/or a longer developmental time. Hypothesis 2, in which it was proposed that the colder the climate, the shorter the developmental time, has to be rejected on the grounds of the findings with the LN population. This leads to the possibility of an interaction between developmental time and growth. Apparently it takes more time to reach a certain length, which may explain that in the developmental time series the effect was the opposite to that expected.

When the effects of pH and temperature on growth and developmental time are compared, there appears to be less variance (2.9 times) in the length at stage 29, than in the developmental time to this stage (variance ratio of 0.0612 compared to 0.1762). Thus, there is little variance in the length of the larvae at this stage. This suggests that the larvae of *Rana temporaria* achieve a minimum length before metamorphosis. In general, the tadpoles tend to minimize their developmental time and to maximize their length, that is, they grow as quickly as possible and as large as possible before undergoing metamorphosis. However, under less favourable conditions, they have to reach a minimum length, no matter how long it takes.

The experiments with different pHs and temperatures show that stress can play an important role (TABLES 4 and 5). CUMMINS (1986), LINNENBACH & GEBHARDT (1987) and ANDRÉN & NILSON (1988) have shown that acidic water may have an effect on *Rana temporaria* tadpoles. Moreover, our experiments showed similar effects for alkaline water. Amphibians commonly have an optimum pH for the development of their eggs and larvae (PIERCE, 1985; HAIDACHER & FACHBACH, 1991; BEATTIE & TYLER-JONES, 1992). Thus, deviations from a certain optimum pH seem to negatively affect the growth and development. There is a similar relationship with the water temperature. Intraspecific differences in heat tolerance and preferred temperatures are well known in amphibian larvae and may lead to speciation (see summary in DUELLMAN & TRUEB, 1986).

Crowding may inhibit or even completely stop the growth and development of larvae (PORTER, 1972; PIKULIK, 1977; STEINWASHER, 1978). Furthermore, if a population is significantly stressed by crowding purely due to physical interference in its environment, we could expect effects to be enlarged if the larvae are in unfavourable conditions. As all larvae were kept together in aquaria during the experiments, the effect of crowding will have played a role in their development.

The results of the experiment with the LN population indicate the order of magnitude of its effect (TABLE 8).

We expected a geographical gradient in a north-south line. The geographical aspects of genetic variation have been studied in various organisms. According to HEDGECOCK (1978), genetic variation increases as a function of the geographical distance in the newt *Taricha rivularis*, and SCRIBNER *ET AL*. (1986) found the same applies to the terrapin *Trachemys scripta*. ARANO & ARNTZEN (1987) found most genetic variation in the newt *Triturus alpestris* in southeast Europe, declining towards central and northern Europe. A similar phenomenon was found by VEITH (1994) in the salamander *Salamandra salamandra*. We also found an effect from north to south, presumably as a result of the decrease in the average water temperature to the north. The LN population lives in cold water in the centre of its distribution range, and our experiments show that the limiting conditions may also be reached there. The above data leads to the hypothesis that, due to selection forces, species may show less genetic variation per population at the edge of their distribution area, but that under unusual conditions, populations with less variation may also be found in the centre of their range.
With regard to these examples, it can further be hypothesized that if a population is living at the margins of its ecological possibilities, additional stress factors (e.g., xenobiotic substances) will have a greater effect.

Our experiments show that when planning to introduce a species into a new or former habitat, it is important to first gain a clear understanding of which local conditions are ecologically limiting for that particular species. By choosing a donor population adapted to such conditions, there will be a good chance of success.

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7 Habitat management in practice

In the main sections of this chapter, 7.1.5 and 7.2.5, the needs of reptiles and amphibians are described from an ecological point of view, allowing their habitat characteristics to be deduced and understood. The consequences for the management of their habitats are discussed, and also whether present-day practices in nature management help meet their needs. Where appropriate, necessary changes are indicated. My long experience in the field enables me to judge the efficacy of many of the measures. Often, it is the order of magnitude that matters, and a skilled manager should be able to adapt measures to the local situation. Although the management of nature reserves is often directed at ecosystems or habitat types, in many cases, especially in small reserves and in an agricultural landscape, species specific measures may be needed.

But first, in order to set the scene for the group in question, there is a brief summary of the taxonomy, followed by a short natural history, sections on population densities and habitats in general. The management of the main habitat types is then discussed in detail. At the end of the amphibian habitat section, a number of species is highlighted. The chapter closes with an extensive literature list. I refer to various details of my work in numerous publications, including those that form Chapters 2 to 5 of this thesis. There are also references to the research of other conservation ecologists, mainly from northwestern Europe, that support my findings.

In Chapter 1, I argued that if we are to stop the decline of reptiles and amphibians, and set them onto the road to recovery, appropriate measures must be taken. This statement may cause surprise, as conservation measures have officially already been taken in the Netherlands. Legal protection, conservation policy and even, at local level, conservation action are all a fact. In practice, however, this is obviously not enough. Continuous monitoring of the state of nature in the Netherlands shows that the decline of the herpetofauna is continuing (e.g., WITMER *ET AL*., 2002). Those who follow developments in the field can confirm that population densities are dropping and that former habitats are no longer occupied. Although responsibility is carried on paper, who is responsible for carrying out the measures in the field, according to the accepted conservation priorities? A small number of Species Action Plans have been carried out indeed, but there is no idea about the long-term measures. Furthermore, in cases where a habitat is under threat, the precaution principle embedded in the Habitat Directive should be the point of departure. Instead, the conservationist is usually called upon to prove beyond doubt that the habitat will be damaged.

At present, the Netherlands has 16 250 000 inhabitants. Due to its small size (33 874 km^2 of land) and the extremely high density of the human population (on average 480/km^2), hardly any nature has been left undisturbed. There is a discrepancy between the amount of land allotted to nature and that for use by man. Consequently, any new claim on the countryside inevitably causes problems for nature. All present habitats of herpetofauna are in man-made landscapes. This implies that practically all habitats are dependent on a certain amount of human interference for their preservation, sometimes even on a very small scale.

Although we are legally obliged to take herpetofauna and their habitats into account in town and country planning, these obligations still seem to carry little weight. Sanctions for malpractices are not enforced, and at best, compromises are made, with marginal conditions for reptiles and amphibians. When deliberating whether the interests of economics or society should prevail over those of conservation, it is impossible to set priorities as long as there is no national survey of their best habitats and the largest populations. Therefore, important matters may be trivialised by planners on the one hand, whereas on the other hand conservationists may oppose activities that in fact have only a slight effect on regional populations. The question is whether the favourable conservation status of a habitat or species can be maintained or improved (e.g., Habitat Directive; ANONYMOUS, 1992). How long will it be before planners realise that habitat requirements of reptiles and amphibians are a reality and cannot be negotiated out of existence?

This study aims at highlighting the particular conservation measures that are needed for reptiles and amphibians; these are deduced from their ecology. The resulting list will certainly clash with common and generally accepted practices in the use and development of nature and the countryside (e.g., GIBBONS, 1988). However, as long as current practices continue, the herpetofauna will be in difficulties. These animals had a golden age in the traditional landscape untill into the first half of the 20th century, with its small-scale land use and management. As we cannot turn the clock back, substitute measures need to be developed that have a similar effect to those of that time. Compared with present practice, some measures may be much more expensive to carry out, others easier and thus cheaper. In all cases, the fauna should be taken into account, as happened inadvertently in the past. Special attention has to be given in the management of nature reserves, woodland, parks, recreation areas and other green spaces, as also in water management. Managers must gain this insight. A lot can still be achieved; there is enough good will.

However, at present in the Netherlands, most of the training for nature management is insufficiently orientated towards wildlife. There is too little animal ecology in the courses to enable the students to understand which measures are the appropriate for certain species. As a result, later in their jobs as conservation manager, they often do not focus on the right aspects, especially concerning the fauna. Practical management is carried out using customary or fashionable measures, without taking a critical look at the effects on the fauna in the habitat concerned. Monitoring situations beforehand and evaluating the effect of the measures after carrying them out, are still not common practice. Moreover, those higher in the hierarchy often do not keep sufficient check on the impact on the fauna. Thus, information is not generally available concerning the effects of conservation measures on reptiles and amphibians. Most has been published in the grey literature: journals, leaflets and reports with a limited distribution and selected readership. This means that people have little opportunity to learn from each other's experiences. Furthermore, expertise often gets lost through managers frequently changing their job or place of employment, a phenomenon of the last twenty years.

The management of herpetofauna in the Netherlands varies according to the aims of the owner of the land where their habitats occur; each owner has his own policy. Much of the land is owned by large bodies, such as the Ministry of Defence, the Ministry of Transport, Public Works and Water Management, District Water Boards, or local authorities. But land may also belong to private organisations, estate owners or farmers. Most relevant to our discussion are organisations whose aim is nature conservation, namely *Staatsbosbeheer* (State Forestry Service), *Natuurmonumenten* (Nature Monuments), and the twelve *Provinciale Landschappen*, the nature organisations of each province; together they own almost all of the nature reserves in the country. In order to estimate the possibilities for future management of reptiles and amphibians, we will examine the framework of each approach.

The aim of Staatsbosbeheer is to maintain, restore and develop forest, and at the same time preserving the natural heritage with the landscape and cultural-historical values. Although its main purpose is to create large self-regulating ecosystems, restoration and conservation of the habitats of threatened wildlife are included in its mission (STAATSBOSBEHEER, 2003). Under government authority, Staatsbosbeheer manages approximately 235 000 ha.

The goals of Natuurmonumenten are the sustainable maintenance, restoration and development of the maximum diversity of plants and animals within a particular ecosystem, and the preservation of geological structures in the landscape (NATUURMONUMENTEN, 1993). Natuurmonumenten aims at achieving this by the creation of a great variety of landscapes in which natural processes mainly determine the dynamics. The organisation exercises restraint concerning the management of habitats for species, although they have recognised the possibility that herpetofauna need particular measures (NATUURMONUMENTEN, 1997). Natuurmonumenten is an independent organisation, managing approximately 87 000 ha.

As the name suggests, the Provinciale Landschappen are organised at provincial level, the Landschap of each province having its own organisation. The Geldersch Landschap, for example, dedicates itself to the maintenance and management of the natural and man-made cultural-historical heritage of Gelderland. In the interests of biodiversity, they focus their management on man-made landscapes (GELDERSCH LANDSCHAP, 2002). In total, the Provinciale Landschappen manage approximately 93 500 ha (GELDERSCH LANDSCHAP, 2004).

7.1 Reptiles

Seven species of reptiles are indigenous to the Netherlands (see TABLE 1); they are all terrestrial. Marine turtles sometimes occur off the coast in the North Sea. The Leatherback turtle (*Dermochelys coriacea*) is a relatively frequent visitor, while the Loggerhead (*Caretta caretta*), the Hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempii*) and Green turtle (*Chelonia mydas*) are rare vagrants (cf., GENT, 1998); none of the turtles nest on our beaches. Although *D. coriacea* and *C. caretta* are considered native to the neighbouring waters of the United Kingdom (LANGTON *ET AL*., 1996), records from our territorial waters are so scarce that they are not considered indigenous species (M.S. HOOGMOED, pers. comm.).

The Squamata is the only order of the class Reptilia in the Netherlands. Both sub-orders are found here, the Sauria (lizards) and Serpentes (snakes). The four indigenous lizards are spread over two families, the Sand lizard (*Lacerta agilis*), Wall lizard (*Podarcis muralis*) and Common lizard (*Zootoca vivipara*) in the Lacertidae and the Slow-worm (*Anguis fragilis*) in the Anguidae. There are also two families of snakes, the Colubridae with the Grass snake (*Natrix natrix*) and Smooth snake (*Coronella austriaca*), and the Viperidae, with our only poisonous snake, the Adder (*Vipera berus*).

In present-day Netherlands, the most important habitats of reptiles are found in heathlands, coastal sand dunes, bogs, scrubs and forests (TABLE 1). Five of the seven species cannot survive outside them (STUMPEL, 1985B); the Grass snake (*N. natrix*) also uses other habitat types. The Wall lizard (*P. muralis*) is confined to a completely different habitat type in the city of Maastricht: old stone walls and ruderal places with an exceptional warm microclimate.

Reptiles in the Netherlands often share the same habitat type, as these places meet their joint requirements for thermoregulation, food and shelter; within the habitat type they have their own niche. Furthermore, in the terrestrial phase of their life cycle, some amphibians occupy these habitat types as well. Thus, habitat management for a certain habitat type may benefit more than one species.

TABLE 1. Main habitat types of reptiles in the Netherlands. The more squares, the more important the type is for a particular species. Species ordered synoptically.

Habitat type / Species	Forest	Scrub	Heath land	Bog and wet heath	Coastal sand dune	Old sea wall	Marsh and ditch	Old stone wall
Anguis fragilis	■ ■ ■	■ ■ ■	■ ■	■				
Vipera berus	■ ■	■ ■	■ ■ ■	■ ■ ■				
Coronella austriaca	■	■ ■	■ ■ ■	■ ■				
Zootoca vivipara	■	■ ■	■ ■ ■	■ ■ ■	■	■		
Lacerta agilis	■	■ ■	■ ■ ■		■ ■ ■			
Natrix natrix	■	■	■ ■	■ ■		■ ■	■ ■ ■	
Podarcis muralis								■ ■ ■

7.1.1 A short natural history

Reptiles are ectothermic, which means that they need external energy for carrying out their daily activities and for completing their life-cycle. Needing warmth to move, they are only active during the day in the Netherlands. They show thermoregulatory behaviour, basking in the sun to increase their body temperature, or sheltering in the vegetation or hiding underground to cool down. Warming up and cooling down may take some time, depending on the time of day or year and the weather, but it can also alternate with increasing frequency as it gets warmer.

In the relatively cool, oceanic climate of the Netherlands, a place to hibernate is essential. All seven species go into hibernation, some as early as September, although they sometimes emerge on warm days in winter. The active season starts in the early spring. The males come out of hibernation first, needing the sun’s warmth to complete gametogenesis (HERLANT, 1933; SAINT GIRONS, 1963). In the mating season, which usually starts in April, males may defend their territory, displaying to impress their competitors or fighting with them. They can be easily seen at this time. Sexual maturity is reached in two or three years in both sexes. After mating has taken place, the gravid females also need extra warmth to develop the embryos. Therefore, in summer, they are more often seen basking than the males. It takes some months before either eggs are laid by oviparous species, or females of ovoviviparous species give birth to young. The juveniles are usually seen from late summer onwards. A new generation is produced every one or two years; reptiles have a population turnover of less than ten years.

The structure of the vegetation is important for thermoregulatory behaviour. Patches devoid of vegetation can provide basking places, and tall structures, such as bushes, can offer places for both basking and shelter. They may bask on top of such structures or seek shelter in the shade underneath or inside them. Thus, vertical as well as horizontal variation in structure is needed for a good quality habitat. In spring and late summer, animals may be basking in the sun all day, but in the heat of mid-summer, they limit this behaviour to the early morning and the last hours of the afternoon. This prevents the animals from desiccating, as well as from overheating. For this reason, in warm and dry summers, they may remain hidden for some days or weeks (PHELPS, 2003). The exact places where reptiles hibernate and aestivate are largely unknown.

To obtain water, they may drink from leaves after rain, or from puddles, pools or other open water, or from dew.

During the active season, they eat large amounts of food, building up reserves for the next reproductive season, and also to see themselves through the winter months in hibernation. All reptiles, their young included, are carnivores, hunting moving prey only. A reptile may actively pursue its prey, or wait for it in ambush. Several times a year, as it grows bigger, a reptile sheds its skin, rubbing against plants or rough objects to start the process of sloughing.

The area in which all these different activities take place is called the home range of the population. It will be obvious that the animals are spread unevenly over this area, depending both on the time of year, and the quality of the habitat from the reptile's point of view. There will always be more individuals in parts where their needs are well met, and within these high quality areas an uneven distribution throughout the year.

7.1.2 Population density

My observations of reptile populations in the field, have led me to conclude that densities may vary greatly in space and time. However, there are insufficient data to quantify this (cf., TONKES, 1991). From the few studies of reptile population dynamics that have been carried out in the Netherlands, only qualitative data on populations are available for most habitats. However, important exceptions are the reptile populations of the nature reserves De Hamert and the Hatertse en Overasseltse Vennen, where the University of Nijmegen has carried out long-term surveys (e.g., VAN NULAND & STRIJBOSCH, 1981; STRIJBOSCH & CREEMERS, 1988). Besides this, an estimate of the relative abundance of the Sand lizard (*Lacerta agilis*) was made for all known sites in the coastal sand dunes (OVERLEG DUINHAGEDIS, 1999). These results are included in TABLE 2 that brings together all quantitative data on populations in the Netherlands. I have included data that I judged to be reliable, from both published and unpublished work. Data from outside the Netherlands are not included as, coming from different habitats, under different climatic conditions, they are of limited relevance to our discussion.

Although there is certainly much variation in the population densities in TABLE 2, the numbers are hardly comparable. Due to differences in the size and quality of the habitats, the year of investigation, the methods used for sampling and the accuracy with which the field work was carried out, we may only conclude that population densities do seem to differ between populations, and in the same population between years.

It will be clear from TABLE 2 that the information that we have on population density in reptiles is of little use for the purpose of nature conservation. If we are to estimate the effects of subsequent habitat management on the size and density of reptile populations, their value at the starting point should always be established before carrying out management measures. This implies a difficult as well as time-consuming study of a population in advance. For example, some species, such as the Slow-worm and the Smooth snake, are so secretive that it is extremely difficult to obtain accurate estimates of the population densities (FRIGGE *ET AL*., 1978A; KLOMPEN & SMEETS, 1979A; STUMPEL, 1985A; VAN HECKE, 1989; VAN DER SLUIJS, 2003). Also such studies are not feasible for highly mobile species like the Grass snake, with individuals moving over great distances (ZUIDERWIJK & WOLTERMAN, 1995; ZUIDERWIJK *ET AL*., 1999). Nevertheless, such population studies are needed. Therefore, time and money should be allocated for this sort of work.

TABLE 2. Population densities of reptiles in the Netherlands. To allow comparison, the present author converted the values in the literature to the number of adults per hectare (rounded off); standard error ignored.

Vernacular and scientific names	**Location**	**Habitat type or landscape element**	**Population density (adults/ha)**	**Home range (m^2) according to sex**	**Year**	**References**
Slow-worm *Anguis fragilis*	Onderlangs, Wageningen	edge of deciduous forest	714	♂ 43-816 ♀ 2-1115	2003	van der Sluijs (2003)
Sand lizard *Lacerta agilis*	Hamert, Bergen (L)	heathland	95	♂ 550 ♀ 250	1976-1982	Strijbosch (1986)
		(N-facing slopes) (S-facing slopes)	69 119		1976-1982	Strijbosch & Creemers (1988)
			29-46		1976-1982	Strijbosch 1988b
		grassy heathland		♂ 1350 ♀ 400	1976-1982	Strijbosch (1987)
	Amsterdamse Waterleiding-duinen	coastal sand dune	7.4		1995	Brandjes & Groenveld (1995)
			11		1998	Hootsmans (2002)
	Voornes Duin, Oostvoorne	coastal sand dune	16-24		1975	van Leeuwen & van de Hoef (1976); Overleg Duinhagedis (1999)
		in *Calamagrostis epigejos*		♂ 20 ♀ 21		
		in *Hippophae rhamnoides*		♂ 37 ♀ 32		
		in *Salix repens*		♂ 72 ♀ 47		
	Vlieland	coastal sand dune	10		2000	G. de Roos (pers. comm.)
Wall lizard *Podarcis muralis*	Hoge Fronten, Maastricht	stone walls of fortifications	6.5	♂ 5-63 ♀ 2-55	1978	Strijbosch *et al.* (1980)
			20.8		2002	Moors (2003); Moors & Frissen (2004)

Vernacular and scientific names	Location	Habitat type or landscape element	Population density (adults/ha)	Home range (m^2) according to sex	Year	References
Common lizard *Zootoca vivipara*	Hamert, Bergen (L)	heathland (N-facing slopes) (S-facing slopes)	130		1976-1982	Strijbosch (1986)
			156 41		1976-1982	Strijbosch & Creemers (1988)
			33-62		1976-1982	Strijbosch (1988b)
Smooth snake *Coronella austriaca*	Meinweg, Herkenbosch	railway embankment		(one ♂) 3400 (two ♀) 200-1800	1978	Klompen & Smeets (1979a)
	Hamert, Bergen (L)	heathland		80 000 – 100 000 (gravid ♀) 5 000	1982	Tonkes (1991)
Grass snake *Natrix natrix*	Broekhuizen, Leersum	estate	4		1975	Daan (1975)
		estate	8		1976	Boeken (1977)
	Noorderhout, Gouda	park	2		1988	Willigenburg (1988)
Adder *Vipera berus*	Wolfhezer Heide	heathland	3-4		1955	van Wijngaarden (1959)
	Speulder- en Sprielderbos	mixed forest	0.1		1958	van Wijngaarden (1959)
	Meinweg, Herkenbosch	heathland	1-6	♂ 0-496 ♀ 8-171	1977	Frigge *et al.* (1978b)
		heathland	10-16	♂ 9-27628 ♀ 0-28541	1978-1980	Klompen & Smeets (1979b); Lenders (2004)
		heathland	10		1978	Strijbosch (1987)
		forest glades	16		1978	Strijbosch (1987)
	Boswachterij Smilde	pine forest	0.4		1904	Dreesman (1904)

7.1.3 Conservation priorities

All species, except the Common lizard (*Zootoca vivipara*) are on the national Red List (HOM *ET AL*., 1996). Although the Common lizard is the commonest reptile in the Netherlands, it can hardly be called common any longer; this species has lost so much habitat that conservation measures are needed (STRIJBOSCH, 2004; see TABLE 3). The Wall lizard (*Podarcis muralis*) is particularly vulnerable, as it reaches the northernmost point of its distribution area in the Netherlands. Being restricted to only one site, it greatly needs special attention. The present status of the Adder (*Vipera berus*) is considered so serious, that a Species Action Plan is being carried out (LENDERS *ET AL*., 2002), the only one for reptiles until now. The Smooth snake (*Coronella austriaca*), that is even more threatened, has still to wait its turn.

TABLE 3. Reptiles in need of conservation in the Netherlands. Status according to national Red List, Common lizard excepted.

Vernacular name	Scientific name	Status
Wall lizard	*Podarcis muralis*	endangered
Smooth snake	*Coronella austriaca*	threatened
Slow-worm	*Anguis fragilis*	vulnerable
Sand lizard	*Lacerta agilis*	vulnerable
Grass snake	*Natrix natrix*	vulnerable
Adder	*Vipera berus*	vulnerable
Common lizard	*Zootoca vivipara*	conservation dependent

7.1.4 Habitat

Reptiles do not occupy all parts of their habitat at all times of the year; and within the habitat, they are spread unevenly, with the highest densities at sites with optimum conditions, often recognisable by their mature vegetation structure. These so-called foci (MOULTON & CORBETT, 1999) are important for the survival of the population per se, and also form the source for dispersal. However, also other places may be extremely important for the population. Some species show high site-tenacity as to their basking places and hibernacula, which emphasises their vulnerability once more. It means that once these places are destroyed, the animals have no alternative and are lost. Sometimes, females select special places for egg laying or giving birth to young outside their usual home range.

Thus, the places where reptiles hibernate, mate, deposit eggs, give birth, and spend the summer may be situated in different places within the habitat; these places may be at some distance from each other. Their habitat is the total of all these places together. The minimum size of a habitat depends on the home range of a viable population, and also on any temporarily occupied area outside it. Its extent can only be established after a detailed population study, determining the size of the home range and also the position of any hibernacula and sites of egg deposition outside it. The dynamics of the population, including the movements of individuals, must be understood before we can take measures to protect them.

To summarise, to cater for the particular demands on their habitat, a population of reptiles needs a minimum area to be viable (e.g., SHAFFER, 1981; LENDERS, 1984A; SMIT & ZUIDERWIJK, 1991; VAN DIJK, 1996). The vegetation structure and microclimate in different parts of the habitat should be suitable for thermoregulation, i.e., preferably south-facing slopes and edges of tall vegetation well exposed to the sun. In addition, the vegetation should offer shelter, from the sun in hot weather, and for hiding from predators. The vegetation should harbour suitable fauna in abundance, in order to provide enough food throughout the active season. Lastly, there should be suitable habitat for hibernation, and, as extra must for egg-laying species, a place for egg incubation.

Heathlands and heather vegetations are the most important habitat for reptiles in the Netherlands; here all indigenous species except the Wall lizard may occur (e.g., STUMPEL, 1985B; STRIJBOSCH, 2002). Compared to other habitats, they harbour the greatest numbers of reptile populations, in the highest densities, and with the greatest species diversity, all six species sometimes occurring in the same area. Sand dunes, bogs, scrub, woodland edges and glades are also important habitats. The Grass snake also uses other habitats, such as marshes, damp meadows, and all kinds of other aquatic habitats. The Wall lizard occurs exclusively in an urban environment. However, it should be stressed that it is the size and quality of these various landscape elements that determine whether they can function as habitats or not.

Nature managers in England have shown that measures in heathland management directed towards the Sand lizard's requirements are favourable for all other species of reptiles (MOULTON & CORBETT, 1999). The Sand lizard can therefore function as a good target species for herpetofaunal heathland management (STUMPEL, 1981).

The reptile habitats in the Netherlands are predominantly characterised by low and open vegetation on poor sandy soils. In such places there are extreme differences in temperature between day and night. Optimal habitats are found in areas with much topography, with a mature vegetation of heather, which may be at least thirty years old. Such habitats meet the high demands reptiles have concerning spatial variation in the vegetation structure. Key features are the combination of tall and low, as well as open and dense vegetation. The strong spatial heterogeneity reptiles require (e.g., STRIJBOSCH, 1988A), is on a very small scale; they need a mosaic of habitats within a habitat (CORBETT & TAMARIND, 1979). Such demands fit in well with those of other species typical of the heathland fauna, namely thermophilous invertebrates and certain birds, other targets of faunal heathland conservation.

The first step in the conservation of reptiles is the safeguarding of their habitats. In the Netherlands, this means that areas where these habitats occur, need to become part of a nature reserve. Next, the main aim of the owner should be to carry out nature management that ensures that requirements of reptiles are met in the long term; or to put it more precisely, ensures the population's survival for the next hundred years with a certainty of 95% (cf., SHAFFER, 1981; SOULÉ, 1987). As most of the species find what they need in heathland, the survival of reptile populations will be strongly affected by any form of intervention in this ecosystem. It is therefore of utmost importance that all conservation management measures on heathlands are screened for their effect on reptiles.

The main reptile habitats will now be dealt with in turn, in order to specify the appropriate measures and to give practical tools for their enforcement. The list is not complete, but the most suitable management can be deduced by looking at the situation with the closest resemblance. Each habitat type is first described, together with the species that occur there. It is made clear how these characteristics meet the needs of the reptiles. The present-day practices in the habitat, in connection with conservation or other activities, and their effect on the animals, form the subject of the part that follows, and finally, conclusions are drawn from this information by providing a list of the appropriate conservation measures.

7.1.5 Main habitat types

7.1.5.1 Forests

Forests are an important habitat for the Slow-worm, and all other indigenous species may be found, except the Wall lizard. However, reptile populations in forests have declined dramatically during the last decades (cf., VAN DELFT & KUENEN, 1998).

Forests on sandy soils are clearly preferred: oak (*Quercus*), birch (*Betula*), beech (*Fagus*), pine (*Pinus*), spruce (*Picea*), and larch (*Larix*) are typical trees of reptile habitats. In a recent study (DE JONG *ET AL.*, 2002), the needs of reptiles in forests have been specified regarding the size and botanical composition of the lot, the succession stage, the canopy cover, the presence of a scrub layer and of glades, and the length of edges; they have been categorised according to their preferences.

In the Netherlands, dense forests are not reptile habitats, as the tree canopy prevents sunlight from reaching the forest floor. However, as soon as there is an opening in the canopy, such as in glades, along tracks and roads, and also at the woodland edge, reptiles seize their chance, although large populations will generally not develop. Open places may also be caused when trees are struck by lightning or blown over by strong winds. Erosion and activities of animals, such as beavers and horses, play an insignificant part in the Netherlands.

Slow-worm
Anguis fragilis
Linnaeus, 1758

Distribution worldwide: Western Palaearctic. Almost the whole continent of Europe and eastwards up to western Siberia and northwestern Iran. Absent from Ireland and the larger Mediterranean islands.
Distribution in NL: The Pleistocene part of the country (east and south of the Netherlands). Origin of the coastal sand dune populations open to question.
Subspecies: 3. In NL: *Anguis fragilis fragilis* Linnaeus, 1758.
Habitat in NL: Half-open vegetations in warm places with moist soil, notably in forest edges, forest glades, mature heather vegetation, chalk grassland, sometimes in gardens, parks, road verges and railway embankments.
Status in NL: Vulnerable.
Threats: Closing of forest canopy; isolation; mechanical mowing.
Conservation: Appropriate habitat management; careful management of path and road verges.

No exact data are available as to the degree of openness that is needed for reptiles. My experience in the field leads to the conclusion that the Slow-worm is the first to be found when the canopy opens. According to C.F. VAN DE BUND (pers. comm.), the Slow-worm is only found if parts of the forest floor are sunlit some hours per day. Such glades can be quite small for this species, but more open space is needed for other forest dwellers, such as the Adder, the Grass snake and the Common lizard. When the forest opens up further, there is a stage, yet undefined, at which the Sand lizard and Smooth snake may appear, although these two species are more typical for heathland. To put it round another way, the vegetation succession in forests forms a threat to reptiles as the closing of the canopy reduces the number of sunlit places (e.g., STRIJBOSCH & VAN GELDER, 1997). Moreover, young forests have well-developed ground vegetation, whereas in older forests this ground cover disappears.

Reptiles have been persecuted in forests for a long time. In the past, forest workers on the *Veluwe* (central Netherlands) systematically exterminated Adders or forest eels as they were called, often killing Slow-worms and Smooth snakes in the process. Although snakes are killed much less nowadays, it still happens, even though illegal under national and international law.

Most forest workers do not recognise the importance of heather vegetation, often storing cut trees on local, small patches of heather to await collection by trucks. The heather and the soil are damaged unnecessarily in this way and it may take a long time before they regain their original state.

So sunlit places are essential for the presence of reptiles in forests. Their significance as a reptile habitat can be greatly enhanced by making slight adaptations in the common forestry management practices. However, in general, far-reaching changes may be required if forestry management is to be directed towards the conservation of threatened animals (DEGRAAFF & MILLER, 1996). The nature of such adaptations can be deduced by studying the ecology of the species concerned, and be published as practical measures in a manual for forest and nature managers (e.g., SPELLERBERG, 1988; REYNOLDS *ET AL.*, 1992; VAN DEN BOS, 2002).

As is shown in the Chapters 2 and 3 (STUMPEL, 1985A, 1988), open edges are important for the survival of reptile populations (cf., DENT & SPELLERBERG, 1987, 1988). If they are managed appropriately, there is a huge number of hectares available for reptile habitats. The vegetation of glades and forest edges is often similar to that of open heathland. South-facing edges with no shade from the forest opposite have a high potential for developing into habitat within a short time; if Heather, Bilberry or Cowberry are already present, sunny edges can be suitable for reptiles almost immediately. If zones are made free of trees for a width of 15-20 metres along paths, using as a rule of thumb the future height of the trees, a vegetation of grasses and dwarf shrubs of *Calluna* and *Vaccinium* species will soon develop. Thus, the north side of paths is particularly suited for making such zones, as they face south and will quickly develop into a reptile habitat. If trees are also removed from a zone along the south side of the path, more sunlight can reach the open space on the north side. As such habitats are line-shaped, they are ideal for connecting populations in forest areas. However, with a width of twenty metres, zones are assumed to be big enough to function as a habitat and not just as a stepping stone for reaching other habitats. Changing coniferous forest into deciduous woodland may also be favourable to reptiles, as the soil and microclimate will become moister, deciduous trees evaporating less water than conifers do.

Present management

Traditionally, the aim of forestry management has been to produce timber; conservation of wildlife was not part of that aim. Silvicultural practices will have had quite a radical impact on reptiles in the past, although there are no references on their effect. Open places were absent, except where old elevations were cut down and replaced by new plantations as a result of the management cycle. Although they were created only by chance, they have been very important for the survival of reptile populations in forests. In recent years, this rotation time has been prolonged, by which the frequency of making open places is reduced. The new trend in forestry distinguishes between natural forest, production forest, and so-called multifunctional forest. Multifunctional forest is managed as production forest and for recreation, as well as for nature (VAN DEN BOS, 2002). Although the management of the multifunctional forests offers the best opportunities for dealing with the needs of reptiles, natural and production forest can be important as well, especially when they harbour reptile foci or are adjacent to them. Providing guidelines for the management of multifunctional forest, VAN DEN BOS (2002) recommends wide forest edges. However, as the recommended vegetation height is greater than a metre, they will not be able to function as a reptile habitat. VAN DEN BOS gives attention to birds, butterflies and ants especially, but although reptiles are mentioned, the target types of the multifunctional forest do still not include them. Furthermore, studies on the management of forest edges still lack specific measures for reptiles (e.g., STORTELDER *ET AL.*, 1999), even though there is a legal obligation to maintain the favourable conservation status of protected animal species, such as reptiles.

Recommended management

1. Survey the presence of reptiles: it is especially important to establish where foci are situated.
2. Set priorities concerning the place for management activities. Give a high priority to applying appropriate management to remaining core areas for reptiles.
3. Develop potential habitat by creating open edges and clearings, focusing on sites where neighbouring foci and remnants of populations of reptiles are still present.

4. Manage the vegetation of glades and forest edges in the same way as open heathland (7.1.4.3).
5. Connect isolated sites, especially by developing open edges along parcels.
6. Consider reintroducing species into sites that have lost their occupants during the last years in order to build up a stronger regional population.
7. Make provisions for fire prevention, such as fire lanes.
8. In all cases, monitoring of the development of reptile populations is of utmost importance.

7.1.5.2 Scrub

Scrub is a vegetation of woody plants, such as shrubs, bramble bushes, young trees and even uncultivated hedges, of less than four metres high. The tangled growth of twigs and leaves gives it a complex structure. Often scrub is seen as wasteland, or as an unattractive stage of the vegetation succession. The combination of grassland and scrub is rare in the Netherlands nowadays, which is partly due to current practices in grassland management. All bushes are removed by cutting and mowing; the vegetation is then kept short by establishing a grazing regime.

Especially the edges of scrubs are important for reptiles. If they are south-facing, scrub with its complex structure can provide reptiles with ideal circumstances for basking and cooling down. Reptiles need a mosaic of bushes and open places, the scale of which is not yet possible to express in a figure.

Scrub in combination with low vegetation of grasses or dwarf bushes can have the necessary structure to make the site functional for reptiles. Brambles (*Rubus fruticosus*) have upgraded the structure of low quality heather and made the site suitable for Sand lizards in the *Groevenbeekse Heide* near Ermelo. Equally, piles of dead pine branches in an area of open sand attracted many Sand lizards in *Heidestein* near Driebergen (STUMPEL, 1990A).

7.1.5.3 Heathlands

Heathlands are the most important habitat for reptiles in the Netherlands, harbouring the most species and the largest populations. Therefore more information is given on this vegetation type and various aspects of its management, in order that the impact of those measures on reptiles is better understood.

Heathlands are the result of the agricultural use of forests on sandy soils in the past, especially after the Middle Ages. They in turn were preserved by the role they played in traditional agriculture; their succession development into forest was stopped by sheep grazing, mowing and removal of the turfs. However, since the invention of artificial fertilisers, heathlands have lost their agricultural function;

they have either been changed into fields and pastures or planted with conifers. Those that remain are heavily threatened by eutrophication by polluted air from intensive stock-rearing agriculture or industry (cf. WEEDA, *ET AL*., 2002).

In present-day Netherlands, there is little heathland left (VAN DUUREN *ET AL*., 2003). By 1990, only 36 000 ha (6%) was left of the 600 000 ha that there had been in 1833. The statistics do not provide details on the composition and the quality of the heath. Today, large parts of Netherlands' heathlands are poor in plant species, and have become overgrown by grasses. Even worse, my estimate is that less than 20% of the present area is potential reptile habitat. Old stands of heather, which provide optimum conditions are rare, and the last known two sites with heather of over a metre tall at *Bergvennen* (Lattrop) and *Meinweg* (Herkenbosch) were destroyed by mismanagement fifteen years ago; the reptiles disappeared. Today, I know of no heathland that has not been influenced by management measures during the last thirty years. As old mature dry heathlands no longer exist in the Netherlands, most managers have no idea what such heathland looks like.

Sand Lizard
Lacerta agilis
Linnaeus, 1758

Distribution worldwide: Palaearctic. From southern England eastwards to Lake Baikal and northwest China. In Europe from southern Sweden to the Pyrenees and northern Greece; absent from Italy.
Distribution in NL: Sandy soils in the Pleistocene part of the country and the coastal dunes, including some of the West Frisian islands.
Subspecies: 9. In NL: *Lacerta agilis agilis* Linnaeus, 1758.
Habitat in NL: Open vegetation on dry sandy soil. Heathlands, coastal dunes, verges of roads and railway embankments.
Status in NL: Vulnerable.
Threats: Habitat loss; inappropriate management of heathlands.
Conservation: Unconditional protection of key sites; improvement of heathland management; enlargement of heathland area.

Heathland is a general term for an extensive area with low shrub vegetation on poor, sandy soils. Botanically, heathlands are divided into three vegetation Classes: *Nardus* grasslands, the dry heaths, and the bogs and wet heaths (SCHAMINÉE *ET AL.*, 1995, 1996). Within the dry heaths, the Association of Common heather (*Calluna vulgaris*) and Needlefurze (*Genista anglica*) is the most widespread type of heathland in the Netherlands (WEEDA *ET AL.*, 2002). This section only deals with dry heaths; wet heaths are discussed in 7.1.5.5, the section on bogs and wet heaths.

Heathland is a vegetation complex dominated by the dwarf shrub Common heather, also named Scotch heather or just Heather. Grasses, mainly Purple moor-grass (*Molinia caerulea*) and Wavy hair-grass (*Deschampsia flexuosa*), and other dwarf shrubs, such as Cross-leaved heather (*Erica tetralix*), and sometimes Crowberry (*Empetrum nigrum*), also occur. The dwarf shrubs can reach heights of over one metre, but they rarely grow taller than 1.5 metre (BEIJERINCK, 1940); 1.60 m was measured in England (STUMPEL, 1981). *Empetrum nigrum* is restricted to the northern half of the country; it is typically found at the edges of shifting sands, but further in the heathland, it grows among the *Calluna vulgaris*, although it may be locally dominant.

The main heathland plants are often mixed with other grasses and other shrubs, such as *Vaccinium* species and Juniper (*Juniperus communis*). Gorse (*Ulex europaeus*) and Broom (*Cytisus scoparius*) may grow nearby. Dry heathland can support a great diversity of mosses and lichens.

Heathland is a succession stage in the vegetation series from open sand to oak (*Quercus*) and beech (*Fagus*) forest on poor soils. Due to the poverty of minerals in the soil, the succession proceeds very slowly and can be further suppressed by extreme environmental conditions, such as salty sea winds, and by management. Sometimes the succession is so slow that it looks as if heathland is the final stage. Often, there may be spontaneous rejuvenation, with young shoots developing from seemingly dead wood. In time, such processes can result in a great variety of vegetation structures. In areas where shifting sands have been fixed by heathland vegetation, the vegetation has a similar structure, as the heather grows very slowly there. Heather can grow to be very old and thus this varied vegetation structure may exist for a long time, sometimes as long as forty years (WEBB, 2002). Mature heathland is rarely invaded by trees: only Pine (*Pinus sylvestris*) is able to germinate in deep heather. On the other hand, young heather is very susceptible to invasion by trees, notably birch (*Betula*).

In the past, during the time that heathlands were used for agriculture, management measures will often have been harmful to reptiles. Yet, as so many heathlands remained undisturbed, enough key populations survived: after a number of years, they recolonised the damaged sites. This process may still occur, although on a smaller scale, in some of the military training-grounds (VAN DER ZEE, 2002).

Now that their agricultural use is over, heathlands have been managed exclusively with regard to their flora and landscape, and for recreational purposes, and the typical fauna, especially reptiles, have been neglected. The management of heathlands for reptiles is not a big item in present nature management. Owners of extensive areas of heathland, such as *Staatsbosbeheer* and *Natuurmonumenten* have a policy for managing ecosystems rather than species, even though there are legal obligations for looking after fauna species. According to Annex I of the European Union's Habitat Directive, heathlands deserve special protection. However, no sub-types have been defined for herpetofauna or any other faunal group.

Traditionally, the nature management of heathland is carried out on a botanical basis and the measures taken in the field only concern the plants. In addition, heathlands are recognised as remnants of an old agricultural landscape, in which flocks of sheep played an important role; there is a wish to preserve such landscapes. The general public wants no more than an expanse of purple-flowering heather, known in Dutch as a tourist's heath. This botanical management is so entrenched that up till now, it has proved impossible for herpetologists to change managers' attitudes. In spite of numerous talks, excursions and publications (e.g., STUMPEL, 1983A, 1985B, 1992A; VERSTEGEN *ET AL.*, 1992; BINK *ET AL.*, 1998) bringing the reptile problem to people's notice, there has been no effect in the field. There must be a structural change if we are to stop the decline in reptiles. This can be realised, as has been shown in England, where due to careful and specific management during the last twenty-five years, there has been a significant improvement in reptile habitats and populations. Yet papers are still being published in the Netherlands proposing heathland management which is harmful to reptiles, and thus illegal (e.g., PIEK, 1998; ELBERSEN *ET AL.*, 2003).

Heathland management is clearly subject to trends. In the nineteen eighties, the mechanical removal of turfs was a popular measure, whereas at present, grazing is the main activity. From the point of view of reptile conservation, turfs have been removed on too large a scale, often in the wrong places (cf., STUMPEL, 1987A, 1992A). Neither is grazing an appropriate management measure in the Netherlands for heathlands where reptiles occur. In principle it is all right (cf., STRIJBOSCH, 2002), but grazing should only be carried out in a very large area with a healthy reptile population. Moreover, the density of grazers should be such that parts of the area remain ungrazed, the management taking into account the animals' seasonal grazing behaviour (OFFER *ET AL.*, 2003; LENDERS, 2004). None of these conditions can be met in the Netherlands.

Since the Netherlands have to contend with a high deposition of nitrogen from the air, almost all heathlands are faced with the problem that grasses and brambles encroach so quickly that heathlands may become overgrown within a period of ten years. There are people who fear, although it has yet to be proved, that it is impossible to preserve heathland as a vegetation type under the current environmental conditions; they advise spending the energy on other habitats. The future will show whether they are right or not; for the time being, there is no reason to abandon this invaluable habitat. It is invaluable, not only for reptiles, but also as the main source of oligotrophic environments for nature in general (WESTHOFF *ET AL.*, 1970-1973). Safeguarding and properly managing heathlands must be made a priority conservation item. Moreover, international agreements, such as the Habitat Directive, oblige us to do this.

Smooth snake
Coronella austriaca
Laurenti, 1768

Distribution worldwide: Western Palaearctic. Large parts of Europe; regionally widespread or scattered; eastwards to the Urals and the Caspian Sea. Absent from Ireland, northern Scandinavia and southern Iberia.
Distribution in NL: Sandy and peaty soils in the Pleistocene part of the country.
Subspecies: 3. In NL: *Coronella austriaca austriaca* Laurenti, 1768.
Habitat in NL: Open vegetation on dry sandy soils. Heathlands, edges of bogs, verges of roads and railway embankments.
Status in NL: Threatened.
Threats: Habitat loss; inappropriate management of heathlands.
Conservation: Protection of key sites; improvement of heathland management; extension of heathland area.

Wildlife management for dry heathlands has only rarely been recognised as an apart conservation need; it has certainly not been common practice in nature conservation (e.g., HOOGERWERF *ET AL.*, 1998; VAN TURNHOUT *ET AL.*, 2001), let alone that management policy was developed (VAN GELDER, 1988). In this respect, British biologists have been far ahead of conservationists in the Netherlands in realising the importance of this habitat (GIMINGHAM, 1972). Even so, it is clear that dry heathlands are at the least of special conservation interest for birds, reptiles and invertebrates (e.g., VAN DE BUND, 1986; VERSTEGEN *ET AL.*, 1992; JONKERS, 1995; SIEPEL, 1988; OFFER *ET AL.*, 2003).

However, not all heathlands are good reptile habitats. It is the structure of the heather and presence of a litter layer that is so important, rather than the botanical composition (e.g., CORBETT, 1983; GODDARD, 1983; GENT & GIBSON, 1998). Reptiles use various stages in the succession of the heath; the early developmental stages do not provide enough structural complexity for reptiles. STRIJBOSCH (2001) gave details of the succession stages used by Common lizards in a heathland area in the Netherlands, and showed that they preferred the middle part of the series with well-developed heather, although still with only very few scrub and trees. Furthermore, the time taken for a particular species to colonise varies. Generally, most species need many years for a successful colonisation. After heather had been removed, it took ten to fifteen years before the litter layer was suitable for soil invertebrates (CHAPMAN & WEBB, 1978); certain ant species needed fifteen years to establish themselves (MABELIS, 1976). It is likely that reptiles need at least as long.

Botanists, on the contrary, state that heather has had its best time after fifteen years, as the plants get an untidy appearance (WEEDA *ET AL.*, 1988). Moreover, from an agricultural point of view, as old heather is no longer eaten by sheep, the vegetation needs to be rejuvenated. Both these are good examples of the controversies that arise because the views on nature management proceeding from botany and zoology are not being combined. Surveys in southern England have shown that the best reptile habitats are found in dry heathlands that have been left undisturbed for at least thirty years (CORBETT & TAMARIND, 1979; STUMPEL, 1981; MOULTON & CORBETT, 1999). That such heathlands can no longer be found in the Netherlands is arguably a conservation blunder.

As heathland matures, the diversity in structure increases in all three dimensions. Characteristic is the variation: bare and vegetated patches, sun and shade, tall and low vegetation, bushy and straggly plants. This variation in structure can only be achieved if the heather is allowed to grow old. The heather plants of young heathlands are all of the same age, and therefore such heathlands are far less physically varied in structure. When above-ground parts of *Calluna vulgaris* plants die off as a result of old age, drought, or frost, young shoots may emerge from the heart of the plant. If this is left to happen over a long period of time, a heathland will develop with plants of many different ages with their differences in structure, thus providing the classic mosaic habitat of a reptile population with a high density of animals. When more than ten years old, heather plants, which are then woody, are very sensitive to damage. If thick branches break near the base of the trunk, the plant dies (e.g., WEEDA *ET AL.*, 1988), and other plants, less favourable for reptiles, take over. Therefore, the damage done by trampling on heather, whether by people during their work or recreation, or by large grazing animals, is a significant albeit indirect threat to reptiles.

The structure of heath is very hard to describe in detail as so many variables are involved (e.g., BEIJERINCK, 1940). I have studied the vegetation structure in Sand lizard habitats by measuring the height and species composition along two transects of four metres long, placed crosswise, comparing sighting places with those that were uninhabited, but without any useful outcome (A.H.P. STUMPEL, unpublished). Little effort seems to have been made to describe and quantify the structure of the vegetation with regard to its importance in the habitat choice for small animals in general (e.g., BARKMAN & STOUTJESDIJK, 1987) and for reptiles in particular (ANONYMOUS, 1983; HOUSE, 1980; HOUSE & SPELLERBERG, 1983; MOULTON & CORBETT, 1999). Structure analyses have been successful for birds, and several vegetation layers could be distinguished that they use, namely trees, high shrubs, low shrubs, herbs and grasses (OPDAM & SCHOTMAN, 1986). However, the methods were unsatisfactory for reptiles, probably due to the fact that they occur almost exclusively in the low shrub and herb layers. These show an almost infinite possible variation in the size, thickness and direction of twigs, stalks and leaves that is almost impossible to describe systematically. Although such detailed information has little relevance to field workers who have to carry out the measures, it is useful for managers to have when deciding on them.

Boundaries between vegetation types, interfaces, are often an important constituent of a reptile habitat. In a study in the *Hamert*, near Bergen in Limburg, local densities in Common and Sand lizards were two to three times as high near forest edges than in the open heath (STRIJBOSCH & CREEMERS, 1988). Similar results were obtained in southern England with Sand lizards (HOUSE & SPELLERBERG, 1983).

It is essential for the conservation and management of reptiles that we are able to recognise the appropriate habitat structure, and also understand why it is appropriate. The following list is based on observations made during thirty years of field visits in northwestern Europe, notably in the Netherlands, Belgium, England, Germany and Denmark. Although qualitative, it gives a good idea of what a good reptile habitat should look like. Some variation is possible, depending on the local situation with regard to the topography and the quality of the heather. These guidelines should provide managers with a useful insight into the needs of reptiles.

Common Lizard
Zootoca vivipara
(Jacquin, 1787)

Distribution worldwide: Palaearctic. Europe and northern parts of Asia up to Sakhalin and Hokkaido, but absent from Iceland, Greece, and central and southern parts of Spain and Italy.
Distribution in NL: Sandy soils and bogs of the Pleistocene part, except for some sea walls and coastal sand dunes in the province of Zealand and the West Frisian islands of Terschelling and Schiermonnikoog.
Subspecies: 3. In NL: *Zootoca vivipara vivipara* (Jacquin, 1787).
Habitat in NL: Moist places with rather dense vegetation. Forest edges, scrub, heathlands, bogs, verges of roads, railways and ditches, and some coastal dunes and sea walls.
Status in NL: None (although probably *vulnerable* before long).
Threats: Lowering of the water-table; vegetation succession (too rapid, due to extreme nitrogen deposition); large-scale land use; inappropriate management of forests and heathlands.
Conservation: Keeping habitats wet; preventing open places closing over.

Characteristics of the ideal heathland habitat:

a. **Size:**
   - No less than 2 ha for good quality habitat when there are other habitats in the vicinity.
   - No less than 10 ha for isolated habitats and snake habitats (cf., TABLE 2).

b. **Openness:**
   - 1 m wide sandy tracks or patches or strips form interruptions at least every 30 m in dense stands of heather (horizontal structure).
   - Isolated trees, shrubs or bushes 30 m apart are highly favourable (vertical structure).

c. **Height:**
   - Whole series from bare sand to the tallest heather bushes within a short distance.
   - Heather at least 0.5 m on average, with great variety in height.
   - Additional structural variation from trees and shrubs; the shorter the heather, the more functional these are.

d. **Exposure:**
   - Areas with varied topography.
   - South-facing slopes for basking, especially if edged with heather.
   - Sandy paths with east-west direction provide these favourite basking places.

Guidance and education can also contribute to the conservation of reptiles. Most people are not aware of reptiles or how their own behaviour often forms a risk to reptile habitats. If better informed, they may be more careful with fire, control their pets, and not trample through the heather. Damage to incubating eggs and the structure of the heather may thus be avoided.

To manage heathland for reptiles, depending on the local situation, the following measures are appropriate:

Doing nothing. If the heath is left alone, it will maintain or gradually develop the structure required for reptiles, as mentioned above. In undisturbed areas, this situation can persist for several decades. The ideal option for managers: it costs neither money nor time. If the area has been disturbed (which is mostly the case in the Netherlands), or if succession has proceeded too far, problems may arise which have to be dealt with by one or more of the following interventions in the field. Special measures must be applied to manage foci.

Selective cutting. To prevent the vegetation closing, bushes and young trees must be removed. Care should be taken not to damage heather plants while carrying out the work.

Removal of turfs. Once the trees and bushes have been removed, the removal of the turf layer is the only effective way to put back the succession; it creates the best abiotic environment for the development of new heath. Applies a) when succession has proceeded so far that forest is developing; heather plants and reptiles have consequently disappeared, and b) when the heath becomes overgrown by grasses or brambles; although reptiles can be present, there is a moment when new heath is judged to offer more for the future.

Creation of sandy places. Open sandy places, preferably in the form of east to west strips, or small patches, may be needed as a special measure for Sand lizards when little or no open sand is available (STUMPEL & VAN DE BUND, 1991). They function as a place for egg deposition, and are equally valuable to heathland invertebrates.

Minimum dimensions of 10 x 1.5 m have proven to be useful for practical management in southern England (K.F. CORBETT, pers. comm.).
Fire prevention. Heath fires can be counteracted by a system of firebreaks; these have proven to be effective in England (LANGTON & BURTON, 1998; THE HERPETOLOGICAL CONSERVATION TRUST, unpublished). Fires frequently occur in northwestern Europe and are very damaging for reptile habitats.

Present management

The following summary is of practices in current heathland management among most of the land owners in the Netherlands (cf., DE MOLENAAR, 1995):
Removal of turfs. In Dutch: *plaggen*. In order to create a good abiotic point of departure for the development of heather vegetations, the herb and bush layers are removed completely, together with the upper soil layer where the plants are rooted and minerals concentrated. Such interventions were carried out by machine over extensive areas (e.g., DIEMONT *ET AL*., 1982; STUMPEL, 1987A; VAN GELDER & HANEKAMP, 1987). Very occasionally, the turfs are removed by hand.
The treated surface can no longer support reptiles, and it takes many years before a vegetation has developed that might attract them. As long as no turfs are removed in reptile core areas and from places where heather grows, it is a correct measure. HANEKAMP & BEIJE (1986) have advised not removing turfs unless the grasses have encroached 80% of the area.
Mechanical mowing. The heather is cut with a machine and the clippings removed. Two types of arguments may be used concerning the environment or the Heather plants: a. removal of nutrients for the impoverishment of the abiotic environment; b. the assumptions that the heather needs to be rejuvenated, or the heather is dead, or the heather needs to be protected against damage by the Heather beetle (*Lochmaea suturalis*).
The removal of nutrients is a good measure for maintaining the oligotrophic environment for plants, but it is unclear why at present heather should be rejuvenated. Such an intervention only makes sense for agricultural purposes: young shoots will develop for grazers, and the clippings can be harvested; of interest to poor farmers in the past. It does make sense for recreation as the young shoots flower, but this is not an item for nature conservation. The supposition that heather is dead as a result of frost or drought is often not true: new shoots will develop from the heart of the plants after some time. Plagues of Heather beetles only happen in young heathlands, where many plants have the same age.

The disadvantage of mowing is that it sets back the development of a heathland with a complex structure. Furthermore, plants such as grasses may be favoured and encroach upon the heather. However, if the natural development of the heather is allowed to take its course, there will be more variation in the structure of the heathland, and that is what the reptiles need.

Burning. Sometimes, heathlands are burned for rejuvenation, although this happened more in the past than at present. It was done in the winter, preferably in February when the subsoil is moist; there was no damage to the litter layer.

Nowadays, fires mostly happen in the summer with disastrous consequences: not only are the heather plants and the litter layer lost, but many reptiles get killed. Fires are often started by holiday-makers, either accidentally through barbecueing or carelessness with cigarettes, or deliberately; and also by military exercises.

Grazing. Grazers, namely sheep, cattle and horses are used as cheap labourer for creating variation in the structure of the vegetation: they do the cutting of the vegetation and create open places. This measure is so popular, that almost all of the heathlands in the Netherlands are grazed nowadays.

The aim of grazing is good (e.g., STRIJBOSCH, 1999): forest growth is suppressed, open spots are created, and nutrients are removed, although not significantly (only via the meat of young animals). But the outcome is mostly wrong for reptiles: grazers do not allow the heather plants to grow taller than 50 cm and to develop a complex structure. In practice, the grazing intensity is too high: either the size of the grazed area is too small or the density of the herd is too high; the result is overgrazing. Another disadvantage of grazing is that the interest has changed from heathland management into cattle management: animal welfare is often more important than the effect of the cattle on the vegetation. Moreover, the large grazers have become a tourist attraction, resulting in the same attitude among managers.

Taking all these negative effects into account, it must be concluded that grazers, including flocks of sheep, no longer belong on heathlands where reptiles occur or could occur.

Lack of management. Neglect is causing many heathlands to develop into forest; they can no longer function as a reptile habitat.

Heathland managers are mostly satisfied with structural variation solely in the horizontal dimension; this means that the more complex needs of reptiles are not met. They claim that reptiles take advantage automatically, an opinion which is completely unjustified. Due to this there has been much habitat loss for reptiles in nature reserves in the last years. The recent recognition of the lack of impact studies for reptiles in modern heathland management (NUIS, 2003) is a hopeful sign of a change in attitude.

Recommended conservation

Reptiles are rare, threatened and legally protected; the guidelines below should be seriously considered. Reptiles can only be taken into account when people know where the animals occur. Although their distribution is quite well known (BERGMANS & ZUIDERWIJK, 1986; databank of RAVON), quantitative data are scarce; the whereabouts of the best habitats for all six species are simply not known. Before we can set priorities for conservation, it is urgent that this backlog be cleared. Once we know where the populations live, their habitats must be excluded from measures if botanical, landscape or cultural historical measures are going to be carried out. Most habitats are small and isolated; they need to be enlarged, preferably by appropriate management of adjacent areas. Once the habitat has been obtained for nature conservation and a good management deployed, other conditions have to be taken care of. Fire prevention and information for holiday-makers must be part of the conservation package. Finally, as obliged by the Habitat Directive, the situation has to be monitored, in order to follow and also understand developments in the field.

A detailed Management and/or Recovery Programme should be set up (STUMPEL, 1983A; GENT & GIBSON, 1998), specifically for the characteristics and circumstances of the local situation. It should include a management calendar (CORBETT, 1994; BULLOCK *ET AL.*, 1998), worked out in great detail. This approach has had much success in England (CORBETT, 1990, 1994; CORBETT & MOULTON, 1996).

Summary. Recognise the need for taking account of reptiles in heathland management: adapt measures when and where necessary in places they still occur, or could, if given the chance.

Following these actions stepwise forms the best scenario for reptile conservation:

1. Survey and map the reptile habitats, determining where reptiles occur. It is important to establish the position and extent of their foci.
2. Take measures to protect the habitat against any human interference, except herpetofaunal nature management. Ensure legal protection is enforced.
3. Put a management regime into operation, aiming at highest possible quality of the habitat. Where needed, improve the present management.
4. Restore habitat deterioration: Shading by shrubs and trees > 20%: remove most of them, taking care not to damage surrounding heather plants. Leave a few well spaced. Encroachment by grasses, bramble, rushes, etc.: remove the turfs where no heather plants are growing and no reptiles have survived (e.g., DONKER, 1999). Applies a) when encroachment is 50% and reptiles have already disappeared, and b) when there are still reptiles present, but

encroachment is over 80%. Create sandy tracks for egg-laying sites and also for fire prevention.
5. Extend the site: improve potential habitat or create new habitat. One large area is preferable to several, smaller ones. Connect isolated or remote habitats.
6. Monitor the development of the vegetation structure and of the reptile population. Adjust the management measures where needed.

7.1.5.4 Coastal sand dunes

Due to their isolation from the Pleistocene sands, the coastal sand dunes are poor in reptile species: only three lizards occur. Although the Sand lizard is found along the whole North Sea coast, the Common lizard is only present in Zealand and on some of the West Frisian Islands. The Slow-worm has either been overlooked for a long period (ZUIDERWIJK, 2002/2003) or has possibly been introduced (LUNTZ, 2000).

The coastal sand dunes differ from the inland sand dunes in their origin, the features of their soil and vegetation, and in being directly influenced by the sea. Large parts of the dunes have a calcareous soil originally, their succession series running from bare shifting sands via grassy vegetations and Sea Buckthorn bushes (*Hippophae rhamnoides*) to oak forests (STORTELDER *ET AL*., 1999). Parts with non-calcareous soils have vegetation quite similar to those of the inland sandy soils, being characterised by heather vegetations. Large parts of the coastal sand dune areas are being used for recreation and for the production of drinking water.

In the calcareous sand dunes, reptiles are found in areas with a small-scale topography and in various small-scale transition zones between vegetation types. Two main types of habitat can be recognised: grassy vegetation and the transition of grassy vegetation into scrub. The grassy vegetation is self-maintaining, as it is the pioneer vegetation of the ever-shifting sands on the sea side of the dunes. It is dominated by Marram (*Ammophila arenaria*) and Lyme grass (*Leymus arenarius*); deep tangled Marram has the optimal structure for Sand lizards. The transition zone has a more complex character. Somewhere in the succession of grassland into scrub, certain vegetation structures develop that may be indicated as edge vegetation. They are composed of a rich variety in grasses, sometimes dense Bush grass (*Calamagrostis epigejos*), sedges, notably *Carex arenaria*, herbs and low shrubs, such as Creeping willow (*Salix repens*), *Rosa* and *Rubus* species, Hawthorn (*Crataegus monogyna*), and *Hippophae rhamnoides*. Habitats in these transition zones usually have a mosaic of patches of bare sand and vegetation that varies in height up to approximately 60 cm; they are south-facing.

The reptile habitats in non-calcareous areas are characterised by heather vegetation.

The situation of the Sand lizard in the coastal sand dunes varies between the different areas. The largest populations of the Sand lizard occur in the *Amsterdamse Waterleidingduinen*, the *Kennemerduinen* and *Meyendel*; they are common there and genetically healthy (NIJMAN, 1996). In other regions, the populations are much less studied, but recent observations suggest that Sand lizards on Vlieland are declining locally, and have become extinct on Schiermonnikoog and Goeree.

Vegetation succession can be suppressed through the grazing of wild rabbits and domestic cattle, horses and goats. Threats to transition vegetation structures are neglect of management, by which the succession proceeds into scrub or forest, and recreational use of the land, resulting in sharp boundaries between open sand and dense scrub without edge vegetation. Barriers for reptiles are formed by extensive open sand areas, dense forests and canals. Rabbits have a strong impact on the habitat, creating open places by their grazing and digging, but there are significantly less rabbits than some decades ago; a problem for the reptile habitats. More details of the vegetation in Sand lizard habitats are provided by VAN LEEUWEN & VAN DE HOEF (1976) and OVERLEG DUINHAGEDIS (1999). The needs of the other two reptiles in this habitat type have to be studied in further detail.

Present management

Only the management measures of Sand lizards in the calcareous areas of the dunes will be discussed; the conservation measures in the non-calcareous areas are the same as for heathlands (7.1.4.3).

Although the nature management of the coastal sand dunes is aimed at the system, rather than at the species (OVERLEG DUINHAGEDIS, 1999; HOOTSMANS, 2002), current measures have had a positive effect on the Sand lizard as various succession stages have developed with vegetation in a mosaic pattern. However, such effects are coincidental; when the results of management activities are evaluated, effects on reptiles are not considered.

Current nature management measures include:

- allowing sand to drift (previously prevented), which results in the development of depressions in the outside dunes;
- raising the water table in order to lessen desiccation;
- mowing and grazing to combat encroachment by grasses and shrubs;
- mechanical removal of turfs for impoverishing the soil and suppressing the vegetation succession.

Specific management measures for reptiles usually have no priority over botanical and landscape measures; they are also rare. Nevertheless, the edges of open sand areas have been created with their borders not in a straight line (PRAAGMAN, 1998), which is a good thing, and the bushes mown in the period of

August-September, when the Sand lizards have the possibility of running away. This is before they go into hibernation. Grazing has a positive effect on the Sand lizard's habitat by opening up the cover of *H. rhamnoides* bushes, creating sandy tracks in grassy vegetation (GROENVELD, 2003). It is practised at low stocking rates (0.2 cows/ha), but we still need to know what the limit of the grazing pressure should be.

Recommended management

At the moment, the Sand lizard populations seem to be doing well in large parts of the coastal sand dunes. Nevertheless, their situation could be improved by building up larger populations and enlarging their distribution. The situation should be monitored permanently, adapting the nature and the intensity of the measures if necessary. Detailed management measures for Sand lizards have been described by a consultative body (OVERLEG DUINHAGEDIS, 1999). Accepting that the management for reptiles has a lower priority than botanical management, this group has presented guidelines for avoiding the negative effects of turf removal, grazing, and sand drifts. Furthermore, they give suggestions for cancelling out, or easing, the effects of barriers; recreation activities can be tolerated, but they have to be controlled. The group's main aims are to improve the habitat quality within the Sand lizard's present habitats and to prevent its progressive isolation within and between habitats. It is clear that the management for reptiles ought not to depend on which measures are necessary for the flora. An integration of botanical and faunal management is possible in many places. Still, core areas of Sand lizards must receive special attention if there is any risk of damage by the intended measures. Concentrations of egg-laying sites must be saved unconditionally.

Maintenance of mosaic vegetations is the main management issue. The management must therefore be fine-tuned. If this is not done by old-fashioned land-use practices, such as local grazing by single horses or goats, or by natural processes such as wind erosion, other measures must be taken to produce the same effects. Furthermore, the timing of measures, such as the removal of turfs and mowing, is important. In this dry environment, special attention must be given to fire prevention.

7.1.5.5 Bogs and wet heaths

So-called 'living' bog is very rare nowadays. In the past, there were extended areas of bog in the Netherlands, but nowadays only small and eroded remnants are left. If they are to survive, measures must be taken to counteract the effects of drainage and eutrophication in the surrounding agricultural landscape. Moreover, many bogs, disturbed by drainage and excavation, have developed into birch carr. As long as sunlight reaches the woodland floor, reptiles may survive there for some time.

Adder
Vipera berus
(Linnaeus, 1758)

Distribution worldwide: Palaearctic. From Britain and France all over northern and central Europe and northern Asia up to Sakhalin. Absent from Ireland, the southern half of Iberia, Italy and Greece, and Turkey.
Distribution in NL: Sandy and peaty soils in the Pleistocene part of the country, except those in the province of North Brabant.
Subspecies: 3 (under revision). In NL: *Vipera berus berus* (Linnaeus, 1758).
Habitat in NL: Moist places with rather dense vegetation. Forest edges, scrubs, heathlands, bogs, verges of roads and railways.
Status in NL: Vulnerable.
Threats: Lowering of the water-table; rapid vegetation succession (due to extreme nitrogen deposition); large-scale land use; inappropriate management of forests and heathlands; persecution.
Conservation: Keeping habitats wet; preventing closing over of open places; preserving hibernacula and resident summer places.

This habitat type is a complex of bogs and wet heaths which merge into one another. In bogs, the plant communities grow above the level of the water table on bulges of living *Sphagnum* moss that are isolated from the mineral soil by a peat layer. As the mosses form a mosaic of elevations and depressions, the vegetation structure is very varied; rushes and sedges alternate with Bog Rosemary (*Andromeda polifolia*) and Cranberry (*Oxycoccus palustris*). Wet heaths are found on peaty sand soils and on degenerated bogs (e.g., SCHAMINÉE *ET AL*., 1995). They generally have little topography and less structure than bogs. The vegetation is dominated by Cross-leaved heather (*Erica tetralix*) and where the heath has been disturbed, by Wavy hair-grass (*Molinia caerulea*); bushes of Bog myrtle (*Myrica gale*) may occur locally.

The reptiles typical for this wet or moist type of habitat are the Common lizard and the Adder, which are present all year long. Other reptiles such as the Smooth snake may also be found during their summer feeding period; this, mostly at the edges of bogs and wet heaths, in contact with dryer heathland habitats. The bogs *Fochteloërveen*, *Bargerveen* and *Aamsveen* harbour the richest reptile populations at present, comparing the numbers in locations with this type of habitat.

Neither bogs nor wet heaths need any internal management. Instead, management measures must be directed at the preservation of the abiotic system. Maintaining or creating a large buffer zone to prevent the disruption of the delicate hydrological system can ensure that the core area remains undisturbed. Once this has been done, the management for reptiles in bogs and wet heaths is simple: do nothing, leave the habitat alone.

Current practice in the restoration of bogs is the construction of dams to retain the rain water in the system. Just as with the heathlands, reptiles are not taken into account; dams are planned where reptile populations occur. The alternative, of constructing the dam in the neighbouring agricultural area is either not considered, or found too expensive, and thus ignored. Furthermore, young trees are cut down with machines without first checking for the presence of reptiles. Such activities may have significant effects on the local populations of the Adder in particular, and most likely, on those of the Smooth snake as well; contravening the Flora and Fauna Act, they are illegal.

It will be clear from this that before carrying out any activity, a survey of reptiles and their habitats has to be made. A bog restoration plan ought to take account of the habitat requirements of reptiles. Hibernacula and other places where they occur must be protected from these operations. If such activities are inevitable, they should be carried out at a time of year suitable for the reptiles, and also with enough adaptability to allow any reptiles that are encountered to move away safely. As there is as yet no experience with such projects, managers should be very careful and alert. As work proceeds, the situation should be monitored continually, and the selected measures adjusted when needed.

7.1.5.6 Old stone walls

Old stone walls are far from solid. The stones do not fit perfectly, having holes and crevices in between and at the back of the wall. There are usually herbs and bushes growing at the bottom of the wall, and they also partly cover it. If they are south-facing with a warm microclimate, old walls can be a good reptile habitat in the Netherlands.

A site of particular interest is the *Bossche Fronten* in Maastricht, the only habitat of the Wall lizard in this country. It is divided into two parts: the *Hoge Fronten* and the *Lage Fronten*, that are isolated from each other by a road with heavy traffic. The *Hoge Fronten* has been a protected Nature Monument since 1992, and consists of a system of wide earthen ridges, fortified with thick walls of red stone with dry moats in between. The *Lage Fronten* has no protected status, and is situated lower down at about a 100 m from the *Hoge Fronten*; the moats between the walls contain water. The climate of South Limburg differs from that of the rest of the country by having relatively warm summers and relatively moderate winters. At present, both parts of the *Bossche Fronten* have a strong Wall lizard population, and also harbour populations of the Slow-worm and Common lizard.

Wall Lizard
Podarcis muralis
(Laurenti, 1768)

Distribution worldwide: Only in Europe, south of the line Maastricht-Bratislava. Absent from southern Iberia and the large islands of the Mediterranean.
Distribution in NL: Only Maastricht.
Subspecies: 9. In NL: *Podarcis muralis brogniardi* (Daudin, 1802).
Habitat in NL: Stone walls.
Status in NL: Endangered.
Threats: Isolation; restoration of stone walls; vegetation succession; collectors.
Conservation: Connection of isolated sites; extension of the habitat; appropriate management of stone walls and the surrounding vegetation.

Wall lizards reach the northernmost part of their range in Maastricht. The conditions are so marginal that they do not reproduce each year (STRIJBOSCH *ET AL.*, 1980); it is not yet known where the lizards deposit their eggs. The marginal conditions and isolation of the habitat mean that the population is always at risk; a series of cold summers can decimate the numbers. This may also result from inbreeding and disease, and other dangers, such as predation by cats and collection. The lizards are living on and in south-facing walls, primarily built of dark-coloured stones with holes and deep-lying joints. The walls are partly covered with herbs in a mosaic pattern and have a system of holes and passages within. Recently, some sub-populations of the Wall lizard were discovered in ruderal places at distances of one kilometre from the *Hoge Fronten*, and migrating juveniles were seen even further away, following the embankment of a railway line (KLOOR, 2003; TILMANS *ET AL.*, 2003). The habitat at the *Bossche Fronten* apparently fulfils the requirements of the Slow-worm and Common lizard as well, but those details have not yet been studied.

After the disastrous clearing of all vegetation in the dry moats in 1974 and restoration of parts of the walls, which made disappear the holes, the Wall lizard population reached rock bottom. Because of several measures that have been taken since, the situation has strongly improved. Holes were bored in the walls (KRUYNTJENS, 1994A), and, as a result of a breeding programme, young were released back into the habitat (KRUYNTJENS & BIARD, 1991; KRUYNTJENS, 1994B). Moreover, a management plan for the *Hoge Fronten* has been enforced; it includes monitoring of the situation with respect to the Wall lizard (MOORS, 2003). The growth of the vegetation is at present controlled by a combination of grazing by sheep and cutting by hand. The present situation at the *Bossche Fronten* is clearly all right for the Wall lizard; the thriving population has reached his maximum density. Future studies would be useful to reveal information about the places where the lizards deposit their eggs, so that these demands can be taken into account. However, it remains unacceptable that the *Lage Fronten* and the other sub-habitats are not protected in view of the legal obligations of the Flora and Fauna Act.

Management should be directed at clearing bushes, if shading proceeds too far (HANEKAMP & STUMPEL, 1983), at maintaining the right structures in the walls, and at keeping away collectors and domestic predators. As the walls have a cultural historical value, there will be the wish to keep them in a good condition and do restoration work. Such activities must be carefully supervised by skilled managers, taking into account the timing and scale for the Wall lizard (e.g., STUMPEL, 1994; ZITZMANN, 2003). Furthermore, the effects of sheep grazing should be monitored, and management adjusted if needed. It is assumed that the other reptile species will benefit from the measures taken for the Wall lizard.

7.1.5.7 Other reptile habitats

Other reptile habitats are found in various places in the countryside and occasionally in urban areas, although this is rare. Mostly used are:

A. Road verges and railway embankments. The vegetation is usually heather or grass on poor sandy soils. They may function as a habitat per se, or form a connection between other habitats because they are line-shaped. They can be important for the survival of local or regional populations (ZUIDERWIJK, 1989; STUMPEL, 1990C; VAN DE BUND *ET AL*., 1995; SMIT *ET AL*., 1996; TILMANS *ET AL*., 2003). Management: as for heathlands (7.1.4.3).
B. Abandoned quarries and pits, mostly of sand, gravel, loam or marl. As they are often located in or near forests and heathlands, they may be especially valuable to the Sand lizard, the Common lizard and the Smooth snake, as they provide the right mosaic of low vegetation and open patches on warm places. Management: as for forests (7.1.4.1) and heathlands (7.1.4.3).
C. Old fortifications. Some abandoned fortifications surrounded by moats provide a habitat for the Grass snake. Being partly covered with bushes and other plants, they offer shelter to the snakes. Management: leave undisturbed as far as possible. Restoration plans should take the needs of the Grass snake into account; complete tidying up of the walls may be harmful.
D. Old sea walls sometimes harbour populations of the Grass snake or Common lizard (LUIJTEN *ET AL*., 1998; ZUIDERWIJK *ET AL*., 1999). Some walls are built entirely of earth, others are strengthened by stones. The vegetation is a mosaic of grasses, tall herbs and bushes. There is no shade from trees; holes and crevices between the stones, if present, provide shelter for the reptiles. Management: conservation of the mosaic structure of the vegetation by mowing with a very low frequency: once every two years and not always at the same place.
E. Marshes and ditches. These can function as part of the aquatic habitat of the Grass snake. Management: in the section on amphibians (7.2.5.1 and 7.2.5.3).

Note: The construction of the new town IJburg and the destruction of the so-called *PEN* island (ZUIDERWIJK *ET AL*., 1999; JANSSEN, 2004) is causing a serious threat to a large population of the Grass snake living in the southwestern corner of the lake *IJsselmeer*. The snakes inhabit an extensive area with open water, sea walls and elements of small-scale agriculture and may travel over distances of up to five kilometres. Such a population is unique in the Netherlands. Their habitats are being destroyed and migration routes disturbed. It is for the future to show whether the population will survive.

Grass snake
Natrix natrix
(Linnaeus, 1758)

Distribution worldwide: Palaearctic. All over Europe, but absent from Ireland, Scotland, and northern Scandinavia. In Asia eastwards as far as Lake Baikal.
Distribution in NL: Central and eastern Netherlands, westwards including the transition between Holocene and Pleistocene soils and the borders of the IJsselmeer. Introduced populations surviving in the provinces of South Holland and Limburg.
Subspecies: 13 (under discussion). In NL: *Natrix natrix helvetica* (Lacépède, 1789).
Habitat in NL: Diverse. Water edges with lush vegetation, fens, marshes, meadows, heathlands, forest edges.
Status in NL: Vulnerable.
Threats: Too few egg-laying places; habitat fragmentation; traffic; vegetation succession.
Conservation: Creation of heating heaps; connection of habitats; appropriate management of edge vegetations.

7.1.5.8 New habitats and facilities

As well as managing existing habitats, habitats can also be created and further developed for reptiles. By offering an abiotic environment and subsequently establishing an appropriate management programme, the area may develop into a reptile habitat, although this usually takes many years. Planning the new habitat close to occupied habitats increases the chance of reptiles colonising it. Success can never be guaranteed, which once more emphasises the importance of maintaining existing habitats.

There are also ways of improving the quality of the countryside for reptiles. One is to properly manage small landscape features, such as rough vegetation, wooded banks, wooded copses, gardens, hedgerows, railway embankments, road-side verges, sand dunes, quarries, old buildings and ruins; there is a chance they get colonised by reptiles. Another one is to provide the means for migration and dispersion of the animals when there are man-made obstructions, at the same time diminishing the risk of accidents (SMIT & ZUIDERWIJK, 1991; STUMPEL, 1997A). Making dung or compost heaps for the Grass snake to lay their eggs in can help to improve their breeding success (ZUIDERWIJK *ET AL*., 1993). Such warm heaps may also attract female Slow-worms as a place to give birth to their young.

The efficiency of providing technical constructions to help the migration and dispersion of animals, by enabling animals to avoid such obstructions as roads and canals, has yet to be proved for reptiles (cf., FORMAN *ET AL*., 2003). Furthermore, they are probably only useful for individuals, not to populations. Large tunnels under roads, and so-called ecoducts forming a land bridge over them, could potentially be very effective (BERGERS & KALKHOVEN, 1996; STUMPEL, 1997A), but it should be kept in mind that most of the indigenous reptiles are very poor colonisers. Small tunnels, drift fences, culverts, gutters and so-called vertebrate exits will be of no use for reptiles. Only the Grass snake may take advantage of tunnels under roads and of connections between ditches and canals.

7.2 Amphibians

The Class Amphibia is represented by two orders in the Netherlands, the tailed amphibians Urodela, the salamanders and newts, and the tailless amphibians Anura, the frogs and toads. While the urodeles are represented by only one family, the *Salamandridae*, common salamanders, the anurans are divided into five: the *Bufonidae* (true toads), *Discoglossidae* (disc-tongued frogs), *Hylidae* (tree frogs), *Pelobatidae* (spadefoots) and *Ranidae* (true frogs). The Amphibia include fifteen species and one hybrid in the Netherlands (see TABLE 4). The Green frog group (*Rana* synkl. *esculenta*) consists of two species, Pool frog (*Rana lessonae*) and Marsh frog (*Rana ridibunda*), and this hybrid, the Edible frog (*Rana* kl. *esculenta*). The abbreviations ‘synkl.’ and ‘kl.’ in the scientific names are used to indicate that the hybrid steals gametes from its parents (kl. stands for *klepton*, derived from a Greek word for stealing) (GÜNTHER, 1990).

Anurans and urodeles differ in their ecology and habitat selection, but as they often select the same aquatic habitat for reproduction, many management measures are relevant to species of both orders.

TABLE 4. Main aquatic habitat types of amphibians in the Netherlands. The more squares, the more important the habitat type. Species ordered synoptically.

Habitat type **Species**	**Marsh**	**Moorland pool**	**Permanent pond**	**Temporary pond**	**Ephemeral pool and puddle**	**Ditch**	**Canal**	**Lake**	**Stream**
Rana temporaria	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■	■ ■ ■	■		
Triturus vulgaris	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■		■ ■ ■	■		
Rana kl. *esculenta*	■ ■ ■	■ ■	■ ■ ■	■ ■ ■		■ ■ ■	■ ■		
Rana lessonae	■ ■ ■	■ ■ ■	■ ■ ■	■ ■		■ ■ ■			
Hyla arborea	■ ■ ■	■	■ ■ ■	■ ■ ■		■ ■			
Triturus cristatus	■ ■	■ ■	■ ■ ■	■ ■ ■		■ ■ ■			
Rana ridibunda	■ ■ ■		■ ■	■		■	■ ■	■ ■ ■	
Pelobates fuscus		■ ■ ■	■ ■ ■	■ ■ ■					
Rana arvalis		■ ■ ■	■ ■	■ ■		■ ■			
Triturus helveticus		■ ■ ■	■ ■ ■	■ ■ ■		■ ■			
Bufo bufo		■ ■ ■	■ ■ ■			■ ■	■		
Bufo calamita		■ ■ ■	■ ■	■ ■ ■	■ ■ ■				
Triturus alpestris		■ ■	■ ■ ■	■ ■ ■	■ ■	■ ■ ■			
Alytes obstetricans			■ ■ ■	■ ■ ■	■ ■ ■				
Bombina variegata			■	■ ■ ■	■ ■ ■				
Salamandra salamandra									■ ■ ■

All Netherlands' amphibians are dependent on water for their reproduction, almost all of them preferring stagnant water (TABLE 4). Apart from more or less natural waters, such as marshes and heathland pools, man-made ponds and water-retaining ditches in the agricultural landscape form an indispensable habitat for amphibians nowadays. The restoration, creation and management of ponds are important tools when conserving amphibians, and ponds are given special attention in this study. Terrestrial habitats of amphibians show a variety of characteristics; their relevance is still insufficiently understood.

7.2.1 A short natural history

Like reptiles, amphibians are ectothermic animals that rely on environmental sources for gaining heat. They are generally active at lower temperatures than reptiles, and more often nocturnal. As they have a permeable skin, they loose water, especially at high temperature, low humidity and in wind. This means that their activity may be limited to periods of rainfall or high humidity (ZUG *ET AL*., 2001). Although their behaviour is generally guided by avoidance of desiccation, basking occurs in some species (*Hyla arborea, Rana* synkl. *esculenta*).

Although amphibians spend the winter in hibernation, they may show activity during this time if the temperature permits. They emerge in early spring; the timing depends on the species. When moving to their reproduction sites, they may cover large distances of sometimes over a kilometre. This migration may happen en masse, over a short period of time, sometimes of only a few days.

The timing of the breeding period depends on the species and its length on the weather conditions. Females deposit their eggs once a year. The Moor frog (*Rana arvalis*) and the Common frog (*R. temporaria*) are the earliest breeders, starting in mid-March, whereas the Green frogs (*Rana* synkl. *esculenta*) and the European tree frog (*Hyla arborea*) only start breeding in the second half of April, sometimes continuing until the beginning of July. All newts also usually start spawning from mid-April. The latest breeders are the Yellow-bellied toad (*Bombina variegata*), which deposits eggs until the end of July, and males of the Midwife toad (*Alytes obstetricans*) can even be found carrying eggs as late as August. There is also variation in the way the eggs are deposited, either in clumps (*Rana* species, Yellow-bellied toad, European tree frog), or in strings (*Bufo* species, Common spadefoot *Pelobates fuscus*) or, as in the case of the Midwife toad, as single eggs connected by a jelly string. The newts lay their eggs separately, while the Fire salamander (*Salamandra salamandra*) is ovoviviparous, the eggs developing within the female's body, and the larvae deposited in the water.

Alpine newt
Triturus alpestris
(Laurenti, 1768)

Distribution worldwide: Europe. From southern Denmark to Greece and from western France to Romania and Bulgaria. Isolated populations in the Cantabrian Mountains and central Spain. Absent from northeast Europe, the United Kingdom and Ireland.
Distribution in NL: Southern half of the country.
Subspecies: 3. In NL: *Triturus alpestris alpestris* (Laurenti, 1768).
Habitat in NL: Marshes, ponds and puddles.
Status in NL: Not threatened.
Threats: Loss of reproduction waters; drainage.
Conservation: Safeguarding of reproduction sites.

The eggs develop into larvae, also called tadpoles in anurans; the larvae grow in the water until they metamorphose. The gills of anuran larvae become externally invisible in an early stage, while those of urodeles remain visible all the time until metamorphosis. The juveniles of the Green frogs and Yellow-bellied toad may remain aquatic for the whole of the active season, but all other indigenous species leave the water, staying on land until ready to take part in reproduction. Most species reach sexual maturity in one to three years, but the Fire salamander may be six years old before it can reproduce (THIESMEIER & GROSSENBACHER, 2004).

So amphibians have a larval life stage. All Netherlands' species have free-swimming larvae which leave the water during metamorphosis. Newt larvae may show neoteny, a developmental process in which reproductive maturity is attained while the larvae retain their external morphology.

The turnover of the adult population is generally less than ten years, although the Fire salamander may be the exception again. However, population densities in amphibians may fluctuate so much that the determination of a turnover rate has little significance (cf., VAN GELDER & OOMEN, 1970).

The courtship of anurans happens both on land and in the water. Males congregate at the reproduction sites where they form choruses, and attract the females by vocal communication, producing species-specific calls (cf., WELLS, 1977). All ranid and bufonid species and the Yellow-bellied toad call from the water surface, while the European tree frog may also call from the vegetation on the shore or even on its way to the reproduction water. The only species calling under water in the Netherlands is the Common spadefoot. The Midwife toad calls on land, mostly in the vicinity of water. The largest choruses are formed by *Rana* species, the European tree frog and *Bufo* species; in the first two groups a chorus starts with the older males, the younger and newly-matured males joining in later during the reproduction period.

The anurans mate by forming an amplexus, the male on top of the female, either in axillary amplexus, holding on to her by her armpits, or with the grasp in the lumbar region forming an inguinal amplexus. The fertilization of anuran eggs happens externally. Most of the eggs are deposited at the places where the choruses are. The females leave the water after depositing the eggs, but being polygynous, the males may stay longer, mating several times in a season.

Courtship and mating is quite different in the urodeles. It all takes place underwater, quite silently. The partner choice is made by sight, *Triturus* species showing a high degree of sexual dimorphism, and also by smell, the males spreading pheromones (JEHLE & FABER, 2003); physical contact between males and females is minimal. Newts show courtship behaviour at the bottom of the reproduction water (HALLIDAY, 1977). This courtship conforms to a five-stage pattern (SALTHE, 1967): the male makes the initial overtures, he displays to her, the male moves away followed by the female, the male deposits a spermatophore and moves away, the female moves over the spermatophore and picks it up with her cloaca. Newts lay their eggs under water, the female wrapping each one individually in a leaf of a water plant. The details of displaying behaviour differ among the four *Triturus* species. Fire salamanders display on land with a semi-axillary amplexus, the female being on top. Mating also takes place on land by the deposition of a spermatophore, which is picked up by the female (ARNOLD, 1987).

After the reproduction period, the adult amphibians leave the water and spend the summer on land; some species, such as the Yellow-bellied toad and green frogs, tend to stay in the vicinity of the water, whereas other species disperse some distance away. Newts loose their crests and their bright colours. All amphibian species in the Netherlands will be hibernating by the second half of October; there is some variation, depending on the weather (cf., Section 7.2.4.4).

All amphibians, whether larvae, juveniles or adults, are carnivores hunting at moving prey, with the exception of the anuran larvae: they feed on algae and carrion. Once metamorphosis has taken place, as amphibians grow, they shed their skin regularly, often eating up the old skin.

7.2.2 Population density

Population density is hard to establish in amphibians. Although quite complicated for reptiles, it is often impossible to estimate which area is occupied by a population of amphibians. It remains the question whether connecting areas between spatially separated habitats belong to the total habitat surface area. Moreover, during the course of the season, amphibians either concentrate or spread themselves over their habitats. The reproduction strategy of amphibians is adapted to periodically unfavourable conditions. By producing great numbers of eggs (STUMPEL & SIEPEL, 1993; TABLE 5), they spread risks; the result is that high fluctuations in numbers are common. In addition, egg numbers vary between

Common toad
Bufo bufo
(Linnaeus, 1758)

Distribution worldwide: Palearctic. From Europe to Sakhalin and Japan and in northwest Africa. Widespread throughout the whole of Europe up to Lapland in the north; absent from Ireland, Balearic Islands, Corsica, Sardinia, Malta and Crete.
Distribution in NL: All over the country.
Subspecies: 3. In NL: *Bufo bufo bufo* (Linnaeus, 1758).
Habitat in NL: Very varied with rough vegetation near their reproduction waters.
Status in NL: Not threatened.
Threats: Loss of reproduction water; land reclamation.
Conservation: Safeguarding of reproduction waters and their appropriate management.

TABLE 5. Spawning of amphibians in the Netherlands. Data taken from the literature, and adapted to the situation in the Netherlands on the basis of the author's own observations. Due to great variation in the field, numbers are approximate.

Scientific name	Vernacular name	Main spawning period	Spawn type	Number of eggs per female	Reference
Salamandra salamandra	Fire salamander	Spring and sometimes autumn	No spawning; produces larvae	None (20-40 larvae)	THORN (1968); GUBBELS 1992; THIESMEIER & GÜNTHER (1996); THIESMEIER & GROSSENBACHER (2004)
Triturus alpestris	Alpine newt	May	loose eggs	100-200	MIAUD (1995); BERGER & GÜNTHER (1996); THOMAS *ET AL.* (2002); ROČEK *ET AL.* (2003)
Triturus cristatus	Great crested newt	May-June (-July)	loose eggs	200-400	THORN (1968); HAGSTRÖM (1980); MIAUD (1995); GROSSE & GÜNTHER (1996A); THIESMEIER & KUPFER (2000); LANGTON *ET AL.* (2001); ARNTZEN (2003)
Triturus helveticus	Palmate newt	May-June	loose eggs	100-500	MIAUD (1995); SCHLÜPMANN *ET AL.* (1996); SCHLÜPMANN & VAN GELDER (2004)
Triturus vulgaris	Smooth newt	May-June	loose eggs	100-350	MARQUENIE (1950); THORN (1968); COOKE & FRAZER (1976); HAGSTRÖM (1980); BAKER (1992); BUSCHENDORF & GÜNTHER (1996); COGALNICEANU (1999); THOMAS *ET AL.* (2002); SCHMIDTLER & FRANZEN (2004)
Alytes obstetricans	Midwife toad	May-August	egg strings	30-60	HEINZMANN (1970); DESFOSSÉS (1984); IN DEN BOSCH (1991)
Bombina variegata	Yellow-bellied toad	May-July	egg clumps	40-150	BUSCHMANN (1998, 2002); NIEKISCH (1996); NÖLLERT & GÜNTHER (1996); GOLLMANN & GOLLMANN (2002)
Pelobates fuscus	Common spadefoot	April	egg strings	700-3000	DANKERS & STUMPEL (1971); VAN GELDER & KALKHOVEN (1971); NÖLLERT (1984); ENGELMANN *ET AL.* (1986)
Bufo bufo	Common toad	April	egg strings	800-3000	DANKERS & STUMPEL (1971); COOKE (1975A); KADEL (1977); BEEBEE (1983); DESFOSSÉS (1984); READING (1986)
Bufo calamita	Natterjack toad	May-June	egg strings	2000-4000	DANKERS & STUMPEL (1971); HEMMER & KADEL (1971); BEEBEE (1979, 1983); NÖLLERT & NÖLLERT (1992); TEJEDO (1992)
Hyla arborea	European tree frog	May-June	egg clumps	150-300	MORAVEC (1989); GROSSE (1994); GROSSE & GÜNTHER (1996B)
Rana arvalis	Moor frog	March-April	egg clumps	800-1200	VAN GELDER & OOMEN (1970); DANKERS & STUMPEL (1971)
Rana kl. *esculenta*	Edible frog	May-June	egg clumps	2000-10000	DANKERS & STUMPEL (1971); GÜNTHER (1990)
Rana lessonae	Pool frog	May-June	egg clumps	600-3000	GÜNTHER (1990)
Rana ridibunda	Marsh frog	May-June	egg clumps	5000-10000	GÜNTHER (1990)
Rana temporaria	Common frog	March-April	egg clumps	800-2500	BOULENGER (1898); HÖNIG (1966); DANKERS & STUMPEL (1971); COOKE (1975A, 1975B); RYSER (1988); GROSSENBACHER (1990); BOSBACH *ET AL.* (2004)

TABLE 6. Population sizes of amphibians (adults only) in the Netherlands; usually expressed as the number of calling males in Anurans. Densities have been rounded off, and standard errors ignored.

Scientific name	**Vernacular name**	**Location**	**Habitat type**	**Population size**	**Year**	**References**
Salamandra salamandra	Fire salamander	Bunderbos, Elsloo	forest with wells and brooklets	400 adults in 0.5 ha	1990	GUBBELS (1992)
Triturus alpestris	Alpine newt	Meinweg, Herkenbosch	heathland and forest with pools	> 4860 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)
Triturus cristatus	Great crested newt	Meinweg, Herkenbosch	heathland and forest with pools	135 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)
Triturus helveticus	Palmate newt	Heerenven, Bergen (L)	heathland pool	> 2300 ♂♂+♀♀	1969	RIENKS & DANKERS (1971); VAN GELDER (1973A)
		Meinweg, Herkenbosch	heathland and forest with pools	> 920 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)
Triturus vulgaris	Smooth newt	Ketelven, Overasselt	heathland pool	> 800 ♂♂+♀♀	1975	HELMING (1976)
Alytes obstetricans	Midwife toad	Roothergroeve, Bemelen	marl pit	180 ♂♂	2002	CROMBAGHS & BOSMAN (2003)
		Meertensgroeve, Vilt	sand and gravel pit	1400 ♂♂	1984	BERGERS & FOPPEN (1985)
Bombina variegata	Yellow-bellied toad	Roothergroeve, Bemelen	marl pit	230 ♂♂+♀♀	2002	BOSMAN & CROMBAGHS (2003)
Pelobates fuscus	Common spadefoot	Hondsven, Gastel	pond	> 10 ♂♂	1981	STUMPEL *ET AL.* (1982)
				75 ♂♂	2001	BOSMAN (2004)
		Ewijk	pool	30 ♂♂	2002	DORENBOSCH (2004)
		Bentincksbosch, Ommen	mixture of foreland and forest	> 15 ♂♂	2000	VAN DER LUGT *ET AL.* (2000)
		Voorstonden, Brummen	estate with moats	21 ♂♂	1988	CREEMERS & CROMBAGHS (1995)
Bufo bufo	Common toad	Overasseltse en Hatertse vennen, Heumen	3 heathland pools	280 F	1971	VAN GELDER (1973B)
			pool (Roelofsven)	4000 ♂♂+♀♀	1977	LUERMANS & VAN DEIJNEN (1979)
		Drie Meertjes, Milsbeek	forest ponds	1500 ♂♂+F	1975	LUERMANS & VAN DEIJNEN (1979)
		Heerenven, Bergen (L)	heathland pool	580 ♂♂	1978	HULSWIT & MULDER (1984)
		Meinweg, Herkenbosch	heathland and forest with pools	> 600 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)

Scientific name	Vernacular name	Location	Habitat type	Population size	Year	References
Bufo calamita	Natterjack toad	Jezuïtenwaay, Duiven	dike burst pool	1000 ♂♂	1974	VAN DEN BERGH & STUMPEL (1975); STUMPEL (this thesis)
		Heerenven, Bergen (L)	heathland pool	1000 ♂♂+♀♀	1978	HULSWIT & MULDER (1984)
Hyla arborea	European tree frog	Retranchement	village with ponds and gardens	130 ♂♂	1983	STUMPEL (1987B)
		Aardenburg	town with ponds and gardens	100 ♂♂	1994	STUMPEL & CROMBAGHS (1995)
		Brand, Udenhout	cattle ponds	125 ♂♂	1994	STUMPEL & CROMBAGHS (1995)
		Vildersveen, Halle	peat moor pool	100 ♂♂	1993	STRONKS (1999)
		Tilligte	ice-skating rink	100 ♂♂	1994	STUMPEL & CROMBAGHS (1995)
		Zuid-Eschmarke, Enschede	meadows with ponds	280 ♂♂	1998	BRAAD (2000)
Rana arvalis	Moor frog	Heerenven, Bergen (L)	heathland pool	600 ♂♂+♀♀	1968	VAN GELDER & OOMEN (1970); RIENKS & DANKERS (1971); VAN GELDER & WIJNANDS (1987)
		Hoekenbrink, Smilde	heathland pool	1000 ♂♂	2003	R. BIJLSMA (pers. comm.)
		Bokkenleegte, Diever	heathland pool	275 ♂♂	1999	R. BIJLSMA (pers. comm.)
		Meinweg, Herkenbosch	heathland and forest with pools	> 3400 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)
Rana synkl. *esculenta*	Green frog complex	Meinweg, Herkenbosch	3 heathland pools only	> 870 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)
Rana kl. *esculenta*	Edible frog			-		
Rana lessonae	Pool frog			-		
Rana ridibunda	Marsh frog			-		
Rana temporaria	Common frog	Eerselen, Echt	ditches	250 egg clumps	1989	VAN BUGGENUM (1992)
		Haeselaarsbroek, Susteren	ponds and ditches	> 400 ♀♀	1994	VAN BUGGENUM (1997)
		Meinweg, Herkenbosch	heathland and forest with pools	> 1540 ♂♂+♀♀	1977	FRIGGE *ET AL.* (1978A)

populations, due to differences in geographic region, habitat, age and condition of the females (cf., JAKOB *ET AL.*, 1999; THOMAS *ET AL.*, 2002). Also, even after a number of consecutive years without reproduction, amphibians have the potential to build up a strong population. This implies that nature management measures on behalf of amphibians can still be meaningful after years of apparent absence of an amphibian species from a habitat. But also that estimation of numbers in one year has no point. From this, it will be clear why accurate counts from populations in the Netherlands are almost not available.

Population sizes of anurans are often expressed as the number of calling males (e.g., VAN DEN BERGH & STUMPEL, 1975, 1977, 1978). Such numbers give a relative view of the abundance in an area, but an in-depth population study is needed for an accurate estimation (cf., FELDMANN, 1978; STUMPEL, 1987B; STUMPEL & TESTER, 1993; see Chapter 4). Only a few studies of amphibian population dynamics have been carried out in the Netherlands during the nineteen seventies and eighties (e.g., VAN GELDER, 1973C; VAN GELDER & WIJNANDS, 1987). However, only presence and absence data are available from the majority of habitats in the data set that we have.

TABLE 6 is a summary of quantitative data collected in the Netherlands, judged by the author to be reliable. The data are certainly not complete, as such data are mostly published in rather unknown periodicals and therefore difficult to trace.

7.2.3 Conservation priorities

The national Red List (HOM *ET AL.*, 1996) lists nine species of amphibians of which five are vulnerable, three threatened and one endangered (cf., Chapter 1). These species are given special attention in the following sections, together with the Natterjack toad, which although not on the Red List, also needs conservation (TABLE 7). The priorities for conservation lie with these ten species. However, common amphibians, such as the Common frog, the Common toad, the Edible frog and the Smooth newt are declining as well. It should be noted that some species have a limited distribution as they reach the west or north borders of their range in the Netherlands. This is why the Alpine newt is rare at national level, although common locally in the southern part of the country.

TABLE 7. Amphibians in need of conservation in the Netherlands. Status according to Red List, Natterjack toad excepted.

Vernacular name	**Scientific name**	**Status**
Yellow-bellied toad	*Bombina variegata*	endangered
Fire salamander	*Salamandra salamandra*	threatened
Common spadefoot	*Pelobates fuscus*	threatened
European tree frog	*Hyla arborea*	threatened
Great crested newt	*Triturus cristatus*	vulnerable
Palmate newt	*Triturus helveticus*	vulnerable
Midwife toad	*Alytes obstetricans*	vulnerable
Moor frog	*Rana arvalis*	vulnerable
Pool frog	*Rana lessonae*	vulnerable
Natterjack toad	*Bufo calamita*	conservation dependent

Three National Action Plans are being carried out for four of these species, commissioned by the government. They concern the European tree frog (CROMBAGHS & LENDERS, 2001), Common spadefoot (CROMBAGHS & CREEMERS, 2001), and the Midwife and Yellow-bellied toads (LENDERS, 2000).

Amphibian habitats are mostly neglected, or only play a role in the last phases of town, country and environmental planning. Plans cannot be changed or there is no will to do so, with the result that the amphibians get the worst of it. And this despite the fact that, according to the Flora and Fauna Act, before any construction activity takes place, the location has to be checked for the occurrence of any protected species or habitat. This ought to be standard procedure for each local authority, province, water board, or other organisation involved in planning. For the interests of society, it would be much better if such organisations develop their own policy for nature conservation. This would also prevent many annoying confrontations between public bodies and nature conservationists (e.g., STUMPEL, 2001, 2003; STUMPEL & CAPPELLE, 2001).

7.2.4 Habitat

7.2.4.1 General

Amphibians are more widespread in the countryside than reptiles, and are also found more frequently outside protected areas. All indigenous species need an aquatic environment for their reproduction, and some remain in the water during the rest of the active season and also hibernate there. Most species spend the remaining part of the season on land.

Smooth newt
Triturus vulgaris
(Linnaeus, 1758)

Distribution worldwide: Palearctic. From Ireland and northern Scandinavia to the Altai Mountains in West Siberia and from central France via Italy, Greece and Turkey to the Caucasus.
Distribution in NL: All over the country.
Subspecies: 8. In NL: *Triturus vulgaris vulgaris* (Linnaeus, 1758).
Habitat in NL: Marshes, ponds, pools, ditches, canals.
Status in NL: Not threatened.
Threats: Loss of reproduction waters; drainage; land reclamation.
Conservation: Safeguarding of reproduction waters and their appropriate management.

With regard to the places where they mate and deposit their eggs or larvae, spend the summer, and hibernate, amphibians have special demands. These three sub-habitats may be situated within the same site or area, or separate from each other. They must all be present within certain proximity, dictated by the species' migration potential; there must be no barriers in between.

There is often a lot of exchange between individuals of different habitats and local populations are mostly connected by means of a metapopulation structure (e.g., VOS, 1999). For the long-term survival of amphibian populations in a landscape, a network of habitats is needed.

Some species have high-site tenacity regarding their sub-habitats, for example, returning each year to their natal pond; others are opportunistic vagrants. When amphibians have to move from one sub-habitat to another, such as between the reproduction and summer habitat, they generally have to cover, for such a small animal, great distances of up to over a kilometre. In addition, unsuitable places, such as roads, canals, fields, and residential areas, may lay across their path.

The need for a good quality aquatic habitat seems to be the most limiting factor for the survival of an amphibian population. The features of this habitat are quite conspicuous, and generally well understood. Much less is known about the characteristics of terrestrial habitats. Not congregating in one place as in aquatic habitats, animals are scattered over the landscape, being found in a greater variety of vegetation structures. This makes key factors difficult to determine, especially in the commoner species (e.g., GROOTEN & VAN GELDER, 1993).

The characterisation of the hibernation habitat is also a problem. As amphibians can hardly be found in the winter, this rests on more or less coincidental observations (STUMPEL, 1990B; VERGOOSSEN, 1990).

7.2.4.2 Aquatic habitat

The natural reproduction places for amphibians are marshes in the flood plains of rivers and streams, moorland and heathland pools, and bogs. However, marshes have become rare in the Netherlands, due to drainage, land reclamation and the straightening of streams. Nowadays, ponds are generally the most important reproduction habitat for amphibians in the countryside of the Netherlands. Ditches in the agricultural landscape can also be important for amphibians, especially those with a limited function for drainage, and therefore with little water circulation.

Many species of amphibians can be found together reproducing in a particular body of water. The richest waters in this respect are ponds and heathland pools containing up to ten species of amphibians, known at *Meinweg* (Herkenbosch), *Roelofsven* (Heumen), *Heerenven* (Bergen, Limburg) and *Grote Meer* (Ossendrecht). This indicates that there can be a great overlap between species in habitat characteristics at certain sites, especially in ponds. All species prefer clear water, and some need it, especially the tailed amphibians.

Although amphibians may spawn in all types of water bodies, each species has a preferred depth of water and vegetation structure (DANKERS & STUMPEL, 1971; FELDMANN, 1975, 1978; VAN HOUT & WILLEMS, 1975; STRIJBOSCH, 1979; RAHMEL & EIKHORST, 1988; AUGERT & GUYÉTANT, 1995; MIAUD, 1995); many species deposit their eggs on dense floating vegetation as well. The Common frog and Moor frog lay egg clumps in shallow water with a depth of 20 cm, whereas the European tree frog and Green frogs do so in much deeper water. The Natterjack and Yellow-bellied toad use the shallowest, and therefore the warmest parts of the water, whereas the Great crested newt and the Spadefoot toad are active in deeper waters with lush submerged vegetation. Most eggs are found in the top 40 centimetres of the water, where they are attached to plants; it is most unlikely that amphibians deposit eggs at lower depths. TABLE 5 summarises the most characteristic features of spawning, but a lot of variation is possible; the situation in the Netherlands may differ from that in other parts of Europe.

The aquatic habitats are influenced by human activity, either directly or indirectly, which may pose a threat to amphibians (STUMPEL, 1983B). In the first place, drainage means that many opportunities for reproduction are lost as waters disappear or become unsuitable. In the same way, many amphibians are deprived of the high water levels they need in spring and early summer for the deposition of eggs. The flooded shores of ponds and pools provide the right conditions in their shallows. In winter, high water levels are also needed by amphibians that hibernate under water. Obviously, these amphibian needs clash with agricultural interests: farmers need to lower the water level in order to have access to their pastures and fields early in the year.

In their reproduction period, amphibians share their aquatic habitat with fish. Only in waters with lush submerged vegetation, shallow parts, and complex bank vegetation can amphibians survive in their presence (CLAUSNITZER, 1983; PINTAR & SPOLWIND, 1998; BLAU, 2002).

There is still a lot of uncertainty about the exact effect of fish species on amphibians. It is clear that fish mostly have a negative impact, although species differ in their susceptibility to fish predation (BREUER & VIERTEL, 1990). Populations often seriously decline or disappear altogether (e.g., FILODA, 1981; BRÖNMARK & EDENHAMN, 1994; ARONSSON & STENSON, 1995; HECNAR & M'CLOSKEY, 1997; BRADFORD, 1989; TYLER *ET AL.*, 1998; SMITH *ET AL.*, 1999). Fish may predate upon juvenile and adult amphibians as well as their eggs and larvae, depending on the size (SEMLITSCH & GIBBONS, 1988) and species (GLANDT, 1983, 1984, 1985) of the fish concerned.

Many waters are stocked with fish; these are lost as a habitat for amphibians. Especially introduced species, such as the Pumpkinseed (*Lepomis gibbosus*) and Trout (*Salmo* species) are formidable predators (BOSMAN, 2003). The reproduction habitat can be destroyed by the Grass carp (*Ctenopharyngodon idella*) eating water plants, and most likely, they eat amphibian eggs as well (VAN LEEUWEN, 1979). Many other fish species are released for angling purposes.

However, the eggs or larvae can be toxic and therefore unpalatable (e.g., LICHT, 1968; KATS *ET AL.*, 1988). Furthermore, amphibians are able to detect the presence of fish and avoid them (e.g., PETRANKA *ET AL.*, 1987; MANTEUFEL, 1995).

In order to avoid any risk for threatened amphibian species, it is important to forbid the keeping of fish in artificial high densities in amphibian reproduction waters; neither should alien species be permitted. As a measure, it has been shown that the extirpation of predatory fish can be very effective, resulting in rapid colonisation by amphibians (MCLEE & SCAIFE 1992/1993; VREDENBURG, 2004). Moreover, any connection by ditches and gullies between amphibian aquatic habitats and waters containing fish must be cut off.

Common frog
Rana temporaria
(Linnaeus, 1758)

Distribution worldwide: Western Palearctic. From Ireland to the Urals and West Siberia, and from the North Cape in Scandinavia to Greece. Absent from Portugal and southern Italy.
Distribution in NL: All over the country.
Subspecies: Possibly 4. In NL: *Rana temporaria temporaria* Linnaeus, 1758.
Habitat in NL: Very varied with rough vegetation near their reproduction waters.
Status in NL: Not threatened.
Threats: Loss of reproduction water; land reclamation.
Conservation: Safeguarding of reproduction waters and their appropriate management.

Waterfowl can also have a negative impact on amphibians. How seriously, like fish, depends on the bird species and its numbers, as well as the size and structure of the water. Many smaller waters are stocked by species such as ducks, geese and swans. Many of them predate upon the eggs, tadpoles and juveniles of amphibians. Moreover, they bring about a negative change in the aquatic habitat by removing the vegetation, and by making the water muddy and over-manured (STUMPEL, 1983B). Reproduction waters of rare and threatened amphibians should be protected from intensive use by anatid birds.

Amphibians are sensitive to pollution and poisoning of the water; eutrophication often causes problems. Manure does not need to be harmful to amphibians: until the nineteen sixties, organic manure was quite common, but its composition was different from present-day manures. Today, in modern intensive agriculture, slurry is applied in great quantities and together with fertilisers they lead to low oxygen content and poisoning of the water.

Xenobiotic substances such as pesticides, herbicides, fungicides, cleansing agents, heavy metals and oils all have their impact on the reproduction of amphibians, and form a great threat if they get into their aquatic habitat. Recent work on pseudo-hormones suggests that such substances might have significant effects on the reproduction, even in low concentrations (DE POORTE *ET AL*., 1999).

Lastly, the negative effect on egg and larval development through the acidification of the amphibian reproduction waters by acid rain has resulted in many publications (e.g., LEUVEN *ET AL*., 1986; ANDRÉN & NILSON, 1988; BEEBEE *ET AL*., 1990; DUNSON *ET AL*., 1992; Chapter 6).

The increase of human habitation in the countryside threatens amphibian populations in several ways. Many reproduction waters are polluted and disturbed by playing children and dogs. Amphibian eggs and tadpoles, as well as juveniles and adults are collected, fish is released, and there is also predation by the domestic cats that roam about. Such activities can have a significant impact on local populations. As far as possible, they should be prevented. When rare and threatened populations of amphibians are involved, it should be made clear to people that harming them is not allowed by law.

7.2.4.3 Terrestrial habitat

Most amphibians spend the greatest part of the season on land, and can be found in a great variety of landscape and vegetation structures. The way in which the presence of an amphibian is related to these structures is little understood. If the land use is small-scale and not intensive, many amphibians find their terrestrial habitat in the countryside. Most species seem to live in places where short vegetation alternates with taller vegetation, such as tall herbs, grasses, rushes and sedges, and bushes, scrub and forest. Bogs, wet heathlands and flooded areas along streams come the closest to natural habitats. Semi-natural habitats, that is those influenced by man, are found in dry heathlands, nutrient-poor grasslands, and all kinds of forests.

Habitat types are often described in terms of vegetation types or ecotopes (STUMPEL-RIENKS, 1974). The latter include the so-called small landscape elements, which can generally be recognized and named (TABLE 8); they are good indicators for the presence of amphibians. Each element is a potential terrestrial habitat for amphibians, depending on its quality, size, position in the landscape, and in regard to its distance from a reproduction water and position with regard to the species' distribution range. Determinations of the potential number of species per element can be made, based on field experience, a useful way of illustrating the relative importance of such elements for amphibians (cf., STRIJBOSCH, 1980; STUMPEL, 1997A; VAN HOOF *ET AL*., 1999; TABLE 8).

TABLE 8. Small landscape elements in the countryside with potential value as a terrestrial habitat for amphibians. *Kade* is Dutch for a low, narrow earth bank for damming; *graft* for a steep embankment, raised to prevent erosion. The species are given in code using the initials of the scientific name. The estimated maximum number of species associated with each landscape element is given in column Max. spp. Ta: Alpine newt, Tc: Great crested newt, Th: Palmate newt, Tv: Smooth newt, Ao: Midwife toad, Bv: Yellow-bellied toad, Pf: Common spadefoot, Bb: Common toad, Bc: Natterjack toad, Ha: European tree frog, Ra: Moor frog, Re: Edible frog, Rl: Pool frog, Rr: Marsh frog, Rt: Common frog.

Landscape element	**Max. spp.**	**Ta**	**Tc**	**Th**	**Tv**	**Ao**	**Bv**	**Pf**	**Bb**	**Bc**	**Ha**	**Ra**	**Re**	**Rl**	**Rr**	**Rt**
Rough vegetation	13	●	●	●	●	●		●	●	●	●	●	●	●		●
Haymeadows, tall grass	11	●	●	●	●		●		●			●	●	●	●	●
Bushes	10	●	●	●	●		●	●	●		●	●				●
Heathland	10		●	●	●			●	●	●		●	●	●		●
Wooded banks	10		●	●	●	●	●	●	●		●	●				●
Copses	10	●	●	●	●	●	●		●		●	●				●
Gardens	9	●	●		●	●		●	●		●		●			●
Kade	7				●				●	●		●	●		●	●
Graft	6	●	●		●	●			●							●
Old buildings, ruins	6	●	●		●				●	●						●
Old churchyards	6	●	●		●	●			●							●
Quarries	6	●	●		●				●	●						●
Hedgerows	5				●	●			●		●					●
Parks	5				●				●				●		●	●
Brambles	4				●				●		●					●
Railway embankments	4				●				●	●						●
Road-side verges	4				●				●	●						●
Sand dunes	3							●	●	●						
Fields	2							●	●							

A thorough field survey is always needed to recognize the true value as potential terrestrial habitat for amphibians. When designing action plans, people often use topographical maps for the recognition and distinction of landscape elements. However, their legend is too poor for management purposes and habitat characteristics such as plant height, composition and structure cannot be read off.

Terrestrial habitats are exposed to many human activities that may pose a threat to amphibians (cf., Chapter 1). Too much space is taken up by urban development, industry and infrastructure, and the places with nature that remain are used intensively, and get more and more isolated by the continuing urbanisation. Safeguarding, or better, tolerance of the remaining habitats, such as unused and untidy places and heaps of rubble, is a first step in conservation, next to the creation of new habitat in the vicinity of reproduction waters.

7.2.4.4 Hibernation sites

Observations on amphibians in wintertime are mostly anecdotal. There is little information, as they are rarely reported, especially in scientific journals. However, it is known that amphibians hibernate either under water or on land, and that this choice is not bound to species (cf., HAGSTRÖM, 1982).

Aquatic hibernation is the least common, and is the most observed in species of *Rana* and *Triturus*. Dead animals are often found in early spring, when the water has had low oxygen content for a time. Frogs may show up under the ice by the pressure waves caused by skaters (STUMPEL, 1986).

Surveys on hibernating amphibians on land are difficult to carry out systematically. However, BOSMAN *ET AL*. (1996, 1997), studied hibernating behaviour of the Common and Natterjack toads in a flood plain of the river Rhine. Floodsafe areas were shown to be important, especially for the Natterjack toad. The Common toad moves vertically between preferred depths during hibernation (VAN GELDER *ET AL*., 1986). Animals do not seem to aggregate on land, although newts may be found in small numbers together under logs and stones.

The general view is that many animals hide in the ground, digging themselves into loose earth, between roots, under heaps of plants, and in burrows of mammals. They may also be found between rubble or in cellars; other observations have been made of hibernating amphibians in hollow walls (European tree frog; STUMPEL, 1990B), at the edges of wells (Common toad; own obs.) and in subterranean marl caves (Midwife toad; VERGOOSSEN, 1990). Although concrete instructions for the management of hibernation habitats are hard to give, extensive, small-scale land use often provides the required structures without further intervention.

7.2.5 Main habitat types

7.2.5.1 Marshes

Marshes are wetlands, sometimes of considerable size. There may be shallow bodies of water among the grassy vegetation, and also deeper waters, with taller vegetation on the shores. Some parts of the marsh are sunlit. Wet, cultivated meadows, and the littoral zones of isolated bodies of water, such as ponds, are not regarded as marshes, and wet forests and scrubs are also not included in this section. Marshes are home to many amphibian species, and the Grass snake also occurs (STUMPEL & PODLOUCKY, 1984; see also 7.1.5.7).

Marshes can be found in a whole range of environments, from eutrophic to oligotrophic. Different vegetation types can be present, dependent on the place where they are growing: along the shore on mineral substrate, zones of terrestrialisation, wet places on organic substrate, and bog depressions (SCHAMINÉE *ET AL.*, 1995). Due to the great variety in the depth of the water in the shallow parts of the marsh, the vegetation structure can be very heterogeneous, with a mosaic of bushes, lush vegetation, and bare patches.

Moor frog
Rana arvalis
(Nilsson, 1842)

Distribution worldwide: Western Palearctic. From the Netherlands to Lake Baikal. Widespread in northern and central Europe to beyond the Arctic Circle in Finland and Russia. Absent from the British Isles.
Distribution in NL: All over the country.
Subspecies: 2. In NL: *Rana arvalis arvalis* Nilsson, 1842.
Habitat in NL: Heathlands; moorlands; bogs; marshes; damp meadows.
Status in NL: Vulnerable.
Threats: Acidification of aquatic habitat; drainage; isolation.
Conservation: Control of acidification processes; raising of water-level; connection of habitats.

Generally, marshes have such a great variety in water depth, vegetation structure and microclimate that amphibian populations can survive without special management measures. For that reason, marshes are more important and less risky for amphibians than ponds. Threatened and vulnerable species which are largely dependent on ponds for their survival nowadays, such as the European tree frog and the Great crested newt, would do much better in extended marsh areas.

Present management

During the last fifty years, the area covered by marsh has decreased enormously; those remaining are mostly small and isolated. Many marshes have been drained on a large scale for agriculture, road building, industry and house building, and this is still continuing (e.g., STUMPEL & VAN BLITTERSWIJK, 2002). On the other hand, water levels have been raised again as part of nature conservation projects, such as in *Aamsveen* near Enschede and *De Regulieren* near Culemborg. Although generally marshes are not exploited or managed, certain parts may be put down to reed and hay production, and there may be some fishing. Moreover, there may be grazing for preventing the succession into forest. Ditches, which in my opinion should not be there at all, are cleaned with machines which allow for little consideration of the fauna (see 7.2.5.3).

There are parts of the marshes that are not easily accessible for man. Most people visit marshes by boat, and do not reach the denser and shallower parts where amphibians deposit their eggs. However, many casualties among migrating amphibians on the roads around marshy areas may occur.

Recommended management

The situation could be improved for amphibians by:

1. raising water levels to enlarge wet areas;
2. preventing further drainage;
3. connecting isolated marshy areas;
4. limiting activities, such as mowing or deepening ditches, to periods when all amphibian life stages are absent (cf., ditches);
5. protecting the water against pollution by manure, fertilisers and poisonous substances;
6. preventing large-scale succession to scrub and forest, by cutting part of this vegetation, keeping the mosaic structure needed (successful for European tree frogs at *Vildersveen*, Halle, and *Roeterinksbroek*, Geesteren, about twenty years ago);
7. keeping variation with regard to depth of the water and its vegetation. Avoids problem with predatory fish; fish do not come to the shallow and well-vegetated parts;

8. not stocking marshes with fish or water birds for recreation when set apart for nature conservation.

7.2.5.2 Ponds

Ponds are depressions in the landscape filled with stagnant water. They may differ considerably in their size, shape, depth, and in the origin of the soil they are in, their position in the landscape and the land use in the surroundings (e.g., VAN BERKEL & STEINHAUER, 1988; HANEKAMP, 1997; JAARSMA & VERDONSCHOT, 2000). Moorland and heathland pools are also regarded as ponds, although oligotrophic pools are of less interest to amphibians because the acidity is often too low for successful reproduction; mesotrophic and eutrophic pools do function as ponds. Some small and medium-sized water bodies are excluded from the category pond: watertanks and artificial basins are not considered to be ponds as their sides or banks are made of unnatural materials (cf., STUMPEL, 1999). However, ephemeral pools and puddles are included in this section.

In the past, ponds were made to provide fresh water at places where it was lacking, namely the salty areas in the southwestern part of the country, the higher sandy soils in the central and eastern parts, and the hills in the southeast. These are ponds that are fed either by rainwater, ground water, or springs (e.g., BOOTHBY, 1997; VAN DAMME *ET AL*., 1997). They were used for watering cattle, extinguishing fires, breeding fish, wood conservation, and the washing of clothes and sheep. Yet others were designed for their aesthetic value.

Most ponds have a rounded or oval shape. An estimate of the mean size of a typical pond in the Netherlands gave a diameter of 15-20 metres with a surface area of about 175-300 m^2. Depending on their origin, ponds vary in depth from very shallow ponds which dry out in the summer to very deep pools of more than four metres in depth, permanently filled with water, that are found along the main rivers, at places where the dyke had burst.

Nearly all ponds are well exposed to the sun, some of them in a completely open landscape, others in forested areas. Most ponds are situated in grassland, but they are also found in woodlands, in parks, in excavated places, as well as in sundry places as retention basin. Ponds are also found in, or in connection with marshes.

The composition of the vegetation at the pond edge is similar to that of marshes; growing in a narrow zone along the shore, the plants often form a ring around the open, central part of the water. Some parts of the shore may be bare if people or cattle have access to the pond. The submerged and floating vegetation varies, and belongs to the Duckweed, Stonewort and/or Pondweed classes (SCHAMINÉE *ET AL*., 1995). Often dense mats of floating plants are present that become emerged when the ponds dry up; duckweeds and related floating species can totally close a pond that is over-manured. Part of the water surface may also be closed by the floating leaves of White and Yellow water-lilies (*Nymphaea alba* and *Nuphar lutea*). Some ponds may lack any aquatic vegetation, for example, when they are situated in the shade, filled with fallen leaves, or stocked with fish or water birds.

The characteristics of ponds determine their potential as a reproductive habitat for amphibians (STUMPEL & VAN DER VOET, 1998; Chapter 5). Many ponds look more or less the same: rounded, with open water in the middle, an area with submerged vegetation, and at least part of the contours of the shore covered with vegetation. They harbour the common species of amphibians, such as the Common frog and the Smooth newt. Yet, other species may be more demanding with respect to the features of the pond and structure of the vegetation; there is often a relationship with the direct surroundings of the pond as well.

Water reservoirs with concrete walls may function as a pond and offer opportunities for reproduction. However, when their walls are steep or no emergency exits exist, most adults and juveniles cannot leave the water, those of the European tree frog and newts excepted. Water reservoirs with slanting concrete floors and at least one sloping bank also offer good opportunities for amphibians.

All indigenous species of amphibians apart from the Fire salamander can be encountered in ponds, although the Natterjack toad, Yellow-bellied toad and Midwife toad are less typical for ponds, being found more in ephemeral and shallow waters. The various species may be present in all kind of combinations; there are no typical assemblages. However, interactions between species can lead to the disappearance of a species or to shifts in their population densities. Field observations have shown that although the Great crested newt and European tree frog select the same types of ponds and may occur together, in smaller ponds the frog is often excluded by the newt. Likewise, the Edible frog is a voracious predator that can consume the majority of the juveniles leaving the pond, regardless of whether of their own or other species. Examples are known where they swept away all Yellow-bellied toad metamorphs. The presence of the Great crested newt in a pond may lower the density of the population of the Smooth newt. Moreover, introduced species, such as the American Bullfrog (*Rana catesbeiana*), pose potential threats to indigenous species (STUMPEL, 1992B). Larger ponds are better buffered against such interactions. It would be interesting and useful to investigate the ecological impact of all these observations.

A lot of research has been done at European level on the relationship between pond characteristics and the presence of amphibians using discriminant analysis. However, none of these studies led clear instructions being deduced for the management of ponds for selected amphibian species (summarised in STUMPEL

& VAN DER VOET, 1995, 1998; see also Chapter 5 of this thesis). An attempt to increase the predictive value of such analyses by improving the statistical foundations did not prove to be effective either. The predictive value of logistic regression models was assessed by cross-validation and we compared classical logistic regression that uses forward variable selection with Bayesian logistic regression (GOEDHART & STUMPEL, submitted), but the predictive power of regression models proved to be limited; apparently such approaches have reached the limit of their application. The simple tallying of features and determining the greatest common divisor (STUMPEL, 1987C), may be the most practical and effective way of getting to grips with the problem of which pond characteristics are relevant for management purposes, as long as no better ecological information is available.

Although each amphibian species has its own particular demands concerning the appearance of a pond, there is often a great overlap of characteristics as many species use the same pond.

Generally, a good pond for amphibians has the following features:

a. no shade;
b. depth of water in deepest part of over one metre;
c. stagnant water;
d. clear water, no turbidity;
e. clean water;
f. gradually sloping shores;
g. shore vegetation present;
h. lush aquatic vegetation;
i. no fish.

Large ponds are better than smaller ponds, as they are more heterogeneous, providing opportunities for more species. In addition, small ponds have more risk of drying up. This can be harmful to amphibians if the pond dries up before metamorphosis can be completed, but if it proceeds far enough to make the pond unsuitable for predatory fish, leading to their extinction, it can be an advantage.

A landscape with a range of all sizes of ponds offers the best opportunities, not only for amphibians but for all wildlife (OERTLI *ET AL.*, 2002). Although we know that amphibian populations take advantage of the presence of more than one pond in an area, spreading their risks and having more diversity in places for reproduction, the number of ponds needed is hard to say, due to differences in the land use in the surrounding area, and thus in the quality of terrestrial habitat (see 7.2.4.3).

Ponds are mainly situated in the countryside and used by farmers. If they are to be useful for amphibians, the ponds should not be over-manured or stocked with fish, and only partly accessible to cattle.

Due to the introduction of tap water and changes in land use, many ponds have disappeared during the last decades (BOOTHBY & HULL, 1997; STUMPEL, 1999). The creation of new ponds has proven to be successful: they can be quickly colonised by amphibians and they contribute to further distribution of species; the compensation for lost ponds should continue to go on (STUMPEL & VAN DER VOET, 1995).

Present management

Due to both loss of their historical function, and natural changes often associated with it, ponds for amphibians are facing a number of problems. Desiccation and vegetation succession have taken their toll, but also stocking with fish and waterfowl, over-grazing by cattle, pollution, dumping of rubbish, infilling, and their use for recreation.

Although the general deterioration of the Netherlands' landscape is still continuing, there has been a positive change of the situation at regional and local level since 1982. So-called Pond Action Plans are being carried out, funded by the government, whereby new ponds are created and old ones restored with the aim of providing good opportunities for reproduction for amphibians, allowing them to build up larger populations and to extend their distribution (e.g., BOSSENBROEK *ET AL*., 1982; CONSULENTSCHAP *ETC*., 1987; DE JONG, 1994; VAN DER KROGT, 1995). Some thousands of ponds have been created and restored. However, although the plans are meant for amphibians in general, they aim in many cases at threatened species, such as the European tree frog and the Great crested newt. Although generally they have been a success, and locally some Red List species have widened their distribution area, such as the Great crested newt in Northwest Drenthe and the European tree frog in the Achterhoek, there is room for improvement in the way these Pond Action Plans are set up:

1. Selection of the location. For rare species, strategy has to be developed from a core habitat with a key population. New ponds should be created in close vicinity to core habitat to start off colonisation.
   In practice, it often appears impossible to create a pond at a desired location, due to lack of cooperation from land owners, high costs, planning restrictions, or issued rules. Moreover, funds for new ponds have to be spent within a certain period; all reasons why ponds are made in less suitable or even unsuitable places as an alternative.

2. Management agreements. Many pond action plans do not include agreements for the maintenance and management of ponds after creation. Also, money is not put aside for this.
   In practice, ponds only function as reproduction habitat for a few years. In default of promised subsidies it is not surprising that farmers and other land owners quit the management and change the use of the pond.
3. Species' demands. For rare and threatened species, measures must be tailored to their particular needs (CREEMERS ET AL., 2000). Take into account not only the quality and characteristics of the pond itself, but also adjacent terrestrial habitat and position in the landscape. A general Pond Action Plan does not include the special conservation needs of species, such as the Common spadefoot, European tree frog, Great crested newt, and Pool frog.

In former days, cattle ponds were ideal for amphibians, as the farmer's activities hardly influenced them: there were few cows or horses, no pollution by fertilisers, and vegetation was removed not too rigorously and only when necessary. Nowadays, the usual management regimes for countryside ponds no longer have adequate measures. The use of modern farm machinery and herbicides work against the implementation of such measures, together with limited budgets and a lack of understanding of the requirements of amphibians. Often much effort is needed to convince farmers, wardens and volunteers that an adapted, carefully timed management regime, often using or imitating old traditional ways, should be practiced. Moreover, ponds are often polluted by riding out dung and when tanks that have been used for spraying herbicides are washed or filled up.
Nevertheless, an increasing number of specialised volunteers is at present involved in the upkeep of ponds all over the country, providing a good example of how it should be done. Some of these volunteers play an invaluable role in the care of threatened populations of amphibians (STUMPEL, 1999).

The problem of loss of ponds and ditches to the construction industry remains: many ponds and ditches are still being filled in for building houses, roads and industrial estates without considering that legally protected amphibians and other wildlife may occur; there is no judicial review (STUMPEL & VAN BLITTERSWIJK, 2002). Although such activities are tolerated on a large scale, more and more action groups are opposing this. Local authorities generally overestimate the possibilities for mitigation and compensation. Through lack of understanding, they do not appreciate the complex relationships within animal populations and the long time needed for the development of new habitat, if possible at all (cf., CAPPELLE & STUMPEL, 2003).

Palmate newt
Triturus helveticus
(Razoumowsky, 1789)

Distribution worldwide: Western Europe. United Kingdom and from northwest Germany via northern Switzerland to northern Iberia.
Distribution in NL: Southern half of the country.
Subspecies: None.
Habitat in NL: Ponds and pools in wooded areas.
Status in NL: Vulnerable.
Threats: Loss of reproduction waters; drainage; land reclamation.
Conservation: Safeguarding of reproduction waters and their appropriate management.

Natural ponds, such as moorland and heathland pools are threatened as they are not buffered against acidification from atmospheric pollution from intensive agriculture (VAN DAM & BUSKENS, 1993). Their pH is lowered to beneath the level where amphibians can reproduce successfully (cf., DUELLMAN & TRUEB, 1986). For this reason, the Moor frog, which of all the species in the Netherlands can tolerate the lowest pH, has disappeared from many heathland pools. The liming of a pond only tackles the symptom, and is of limited or temporary benefit to amphibians (BELLEMAKERS & VAN DAM, 1992). On the other hand, it may help populations through a bottleneck, and thus be a useful conservation measure.

Certain garden ponds can be attractive for amphibians, especially those in leafy suburbs and in the countryside. In towns, ponds are normally populated by the commoner species, having no significance for threatened ones. However, they can be more important to the common species than those in agricultural areas, some harbouring dense populations. Garden ponds can be of high educational value and thus have an additional advantage; they arouse the interest of the general public for amphibians.

Recommended management

All ponds need some degree of management to keep them for functioning as a habitat for amphibians (cf., VAN DAMME *ET AL*., 1997; STUMPEL & WEZEMAN, 2000). In practice, refined measures are required to create and maintain optimal situations for amphibians in general, and even more sophisticated ones for species that have very particular needs. Appropriate timing, both during the year and over the years, is of great importance when carrying out the controlled removal of vegetation and silt. No aquatic vegetation should be removed when eggs and larvae are present in the water. When cleaning a pond, only part of the surface area should be treated in such a way that some vegetation is left untouched for at least two breeding seasons. The best period for cleaning a pond is early October: there are no eggs in the water, most of the larvae have left the water, and most adults are on land and have not yet started migrating towards the pond for hibernation.

As the rationalised agriculture of the present day is less interested in ponds, the need for the management of ponds, and the creation of new ones, has increased in the Netherlands. Lack of management means that ponds fill up with vegetation, and after some years disappear. Ponds form part of a network, and so relationships between them are then lost. The isolated ponds that remain are essential for the amphibians' survival, and there is an increased risk for them if something goes wrong. As many different people may be involved in this management work, the design of a management plan is useful for guidance and also for guaranteeing a steady long-term management.

Although many new ponds have been created during the last twenty years, we are still nowhere near the numbers of one century ago and there are still many areas without sufficient ponds for amphibians. Pond Action Plans remain both useful and necessary, not only in the countryside, but also in our ever expanding urban area.

Concerning rare and threatened species, special provisions have to be made. Much ecological information is still lacking, and thus the knowledge of experienced field workers and their best professional judgement should be taken as a guide for how to manage ponds where they occur. This means that management is a continual process of learning and improving until ecological key factors have been clarified by research.

To summarise: when cleaning the pond by removal of vegetation and silt:

a. No aquatic vegetation is removed when eggs and larvae are present in the water.
b. Only part of pond is handled, leaving some vegetation undisturbed for at least two breeding seasons.
c. Best period for cleaning a pond is early October as avoids reproduction and hibernation period.

Recommended for management of ponds in general:
1. Keep up existing ponds.
2. Design Pond Action Plans for creation of new ponds in towns and countryside.
3. Ensure networks of ponds are maintained to prevent isolation.
4. Make special provisions for rare and threatened species.
5. Research to clarify key ecological factors.
6. Accept guidance from experienced field workers.
7. Learn and improve as management motto.

Great crested newt
Triturus cristatus
(Laurenti, 1768)

Distribution worldwide: Western Palearctic. From Wales to the Russian Kurgan province and from southern Scandinavia to Serbia.
Distribution in NL: East of the line The Hague - Groningen.
Subspecies: None.
Habitat in NL: Ponds, marshes, oxbow lakes, quarries.
Status in NL: Vulnerable.
Threats: Loss of reproduction water; drainage; land reclamation.
Conservation: Safeguarding of reproduction waters and their appropriate management.

Seven species of the indigenous amphibians, six of them on the Red List, are the most dependent on ponds and other small isolated waters; their situation is explained and requirements specified:

a. **Great crested newt** (*Triturus cristatus*). The Great crested newt is listed as vulnerable on the Red List and included in Appendices II and IV of the Habitat Directive of the European Union. It has suffered a strong decline through loss of ponds (CROMBAGHS *ET AL*., 1996), and received much attention from field herpetologists; recent surveys have revealed many new localities. Its distribution in the Netherlands is rather well mapped, and core areas well-known (ZOLLINGER *ET AL*., 2003). This is the largest of the indigenous newts. It has an extended aquatic phase, the adults tending to stay in the water much longer than other newts (cf., BLAB & BLAB, 1981; ARNTZEN, 2003). Typical reproduction waters are well-exposed to the sun, have a depth of at least 1.5 m and lush submerged vegetation. The water has a neutral or slightly alkaline pH, and lacks any fish. Large populations usually inhabit large ponds or a system of smaller ones. Isolated populations are able to survive in small ponds of no more than 75 m^2 for tens of years. Now that there are few marshes left in the river flood plains, it has become a typical species for ponds. Oxbow lakes and quarries provide other important habitats (cf., THIESMEIER & KUPFER, 2000). The aquatic habitats have tall vegetation, such as bushes and forest, in the neighbourhood and are situated in small-scale landscapes. Ponds where the Great crested newt occurs should be safeguarded and managed properly, controlling the vegetation growth if becoming too dense, and preventing water pollution and presence of fish. Ponds may dry up, but not before the second half of September and not every year. Creating new ponds may be beneficial (cf., LANGTON *ET AL*., 2001).

b. **Midwife toad** (*Alytes obstetricans*). The Midwife toad is a vulnerable species of the Red List, reaching the northern border of its West European range in South Limburg. Its natural habitat is formed by streams that have created steep edges and pools with their current. Nowadays, streams are regulated, and the natural dynamics has been lost. Secondary, man-made habitats are found in farmyards and quarries, where many different shallow waters can be found together. The Midwife toad is not very demanding of its reproduction waters, and can be found spawning in all kind of ponds, artificial water basins, puddles, and also in the slow-running water of wells and streams (cf., ARNTZEN, 1981). However, drainage, filling-in and neglect have caused most of such waters to disappear from our countryside, the main reason for its decline. It seems easy to create new reproduction waters, judging by the success of introductions elsewhere, in The Hague, Utrecht, Uffelte, and Pieterburen. This is also proven by the Pond Action Plan in South Limburg (BOSSENBROEK *ET AL*., 1982), which resulted in immediate colonisation of new ponds as long as close to existing populations. In this way, isolated habitats can be connected, the aim of the Species Action Plan (LENDERS, 2000). Management should ensure that ponds stay free of fish, and control the development of vegetation. As the larvae only start metamorphosis from August onwards, timing and intensity of cleaning measures is important, especially as larvae often overwinter in the water until the next summer.

Yellow-bellied toad
Bombina variegata
(Linnaeus, 1758)

Distribution worldwide: Europe. From France to Greece, including large parts of central Europe, Italy and the Balkans.
Distribution in NL: South Limburg.
Subspecies: 4. In NL: *Bombina variegata variegata* (Linnaeus, 1758).
Habitat in NL: Forests on slopes with temporary puddles.
Status in NL: Endangered.
Threats: Drainage; lack of low-level dynamics in habitat; collection.
Conservation: Appropriate habitat management; creation of new habitats; continuous monitoring.

c. **Yellow-bellied toad** (*Bombina variegata*). The Yellow-bellied toad is an endangered species, reaching the northern borders of its range in South Limburg (HANEKAMP & STUMPEL, 1984). In spite of creation of many new ponds in this part of the country during the 1980s, its distribution has not increased. Standard ponds are not the type of reproduction water it needs (BARANDUN & REYER, 1997; GOLLMANN *ET AL.*, 1999; STUMPEL & BLEZER, 1999), depositing its eggs in shallow water of a temporary nature without any vegetation, such as puddles, wheel tracks, even foot steps. Such waters are very short-lived, either drying out or becoming overgrown; they must be created repeatedly. Drying out is essential for avoiding predators, such as dragonfly larvae and water bugs, but newts are also greedy predators of their eggs. A Species Action Plan has been carried out since 2000, with attempts at arranging key areas and connecting habitats (LENDERS, 2000). The plan is still being carried out, and experiments with so-called base habitats (CROMBAGHS, 1998) have had promising results. Hollows of about 150 m^2 and 1 m depth are dug, given a concrete floor, and filled in again with the same soil. When it rains, water accumulates in the hollow on this artificial water level. The soil can be shaped to create tiny ponds of some square metres only, either by machine or by hand. Yellow-bellied toads deposit their eggs in these little ponds, and after metamorphosis and departure of the juveniles, the little ponds can be filled up, and new ones created elsewhere above the concrete floor. This process has to be repeated annually; if there is no time and money for this kind of management, the population will fall to its former level and probably disappear. An official co-ordinator is needed in charge of checking and executing the work. It is essential that the reproductive success is improved; the population of this species in the Netherlands is too small, about 250 adults and sub-adults in 2002; therefore it must be enlarged considerably to establish the strong key population needed for the colonisation of new areas. Informing the general public should be part of the conservation strategy for this species. The Yellow-bellied toad is very sought after as a pet for keeping in a terrarium. As long as the national population is so small (BOSMAN & CROMBAGHS, 2003), the collection of individuals is an irresponsible, as well as illegal activity. A yet unsolved problem is the presence of newts, in or close to the habitats of the Yellow-bellied toad. New ponds have attracted many newts, and from these bases they come foraging for toad eggs. Pond Action Plans should keep away from Yellow-bellied toad habitats, until the population is large enough to suffer from predators.

d. **Common spadefoot** (*Pelobates fuscus*). The Common spadefoot has been doing badly during the last ten years, and is absent from many former reproduction waters. (e.g., LENDERS, 1994). The reasons for decline can be attributed to acidification and nutrient enrichment of the reproduction water (LENDERS, 1984B; HUNINK & KRUYT, 2003), turbidity, a thick silt layer, and presence of fish (VAN DER EST & HERTVELD, 2003), as well as isolation of habitats, rarity of the species together with bad pond management, namely neglect or cleaning too often. In the Netherlands, *Pelobates* needs a mesotrophic pond (e.g., enriched heathland pools) for reproduction, within 500 m of terrestrial habitat on sandy soils (cf., STUMPEL *ET AL*., 1982). As far as understood, the aquatic habitat should be 1.5-2 m deep, with lush submerged vegetation; ponds covered with Duckweed and dead plant material, or with leaves at the bottom, also serve for this species (CROMBAGHS & CREEMERS, 2001). The presence of Marsh cinquefoil (*Potentilla palustris*) may indicate a suitable environment. Where their ranges overlap, the Spadefoot is found reproducing in the same ponds as the European Tree frog. Complete removal of the silt layer, often for botanical reasons, can be disastrous for the Spadefoot toad. If the vegetation growth has to be controlled, only treat part of the pond. Adapting management to the needs of this species asks for special attention. The national Species Action Plan aims at a minimum of two reproduction waters and a population size of 10-20 males per site (CROMBAGHS & CREEMERS, 2001). Most of the present habitats do not meet this criterion; there is an urgent need to improve them. The Species Action Plan and various regional studies (e.g., VAN DER LUGT *ET AL*., 2000; BOSMAN, 2004) provide detailed instructions for the management of each habitat in the Netherlands.

Natterjack toad
Bufo calamita
(Laurenti, 1768)

Distribution worldwide: Western and central parts of northern Europe. From Portugal to the extreme western part of Russia, including Ireland and the United Kingdom; absent from Italy and the Balkans.
Distribution in NL: All over the country.
Subspecies: None.
Habitat in NL: Heathlands; coastal sand dunes; saltmarshes; river forelands; quarries; areas with recently disturbed soil.
Status in NL: None, but conservation dependent.
Threats: Acidification of aquatic habitat; loss of dynamics and vegetation succession in land habitat.
Conservation: Control of acidification processes; maintenance of dynamics in their habitats.

e. **Natterjack toad** (*Bufo calamita*). The Natterjack toad is not yet listed on the Red List, but if its decline continues, within some years this toad will be classified as vulnerable (HOM *ET AL*., 1996). The Natterjack toad inhabits various types of habitat: a. Heathlands and coastal sand dunes; b. Edges of saltmarshes; c. Marshes in river forelands; d. Quarries; e. Man-made habitats resulting from excavation (cf., VAN DEN BERGH & STUMPEL, 1975; BEEBEE & DENTON, 1996). Spawning takes place either in shallow parts of unshaded ponds and pools with gradually shelving shores, or on top of floating vegetation in deeper parts of such waters. All habitats except heathlands are situated in an environment with natural or man-made dynamics. Many of the pools are ephemeral and weather-dependent, and their presence may vary from year to year. As a consequence, the density of populations of the Natterjack toad can vary enormously between years. The toad is declining in heathland habitats as a result of the acidification of the pools. Pools in salt marshes depend of inundation by high tides; they function as breeding ponds if the salinity has fallen to below 0.5% (BEEBEE & DENTON, 1996). Local populations are threatened by the loss of natural dynamics in such environments (e.g., *Markiezaatsmeer*, Bergen op Zoom). Loss of appropriate aquatic habitat and succession of the vegetation in the terrestrial habitat is supposed to be the major cause for the species' decline in dynamic environments. The toad used to be very common along the big rivers (VAN DEN BERGH & STUMPEL, 1975), but many forelands have lost much of their dynamics through the construction of groynes and closing of brickworks, meaning no more clay pits; many remaining populations are much smaller than in former times. However, the largest population in the 1970s, at *Jezuïtenwaay*, Duiven, estimated to consist of over 1000 calling males then, still occurs as a large population. Pools in quarries only function as a habitat as long as the site is being exploited; vegetation succession makes the habitat unsuitable soon after it has been abandoned. Other dynamic environments are found in places with construction activity, where sites are being cleared, such as for excavations for building houses and industrial estates. Large-scale excavation work can create aquatic habitats in the form of shallow pools and puddles. They can be colonised immediately if a population is nearby. As such waters are only temporary, the habitat is soon lost, and unless new construction activities take place in adjacent areas, the Natterjack toad will disappear. Vegetation succession should be controlled by imitation of the lost dynamics. Existing populations can be boosted and new habitats created by small-scale, well-timed excavation.

f. **European tree frog** (*Hyla arborea*)**.** The European tree frog is widely distributed throughout Europe, its northern border running across the Netherlands from southwest to northeast (STUMPEL & CROMBAGHS, 1995; STUMPEL, 1997B; STUMPEL *ET AL*., 2004). It is a threatened species; its decline is mainly caused by loss, deterioration, fragmentation and isolation of its habitat. Population density is expressed as the number of calling males; it may fluctuate greatly from year to year (STUMPEL, 1987B; Chapter 4 of this thesis), thus numbers should be examined critically. Moreover, the tree frog may either be silent and still reproduce, or call without participating in reproduction. Ponds are nowadays the most important aquatic habitat, but the frogs are also found in moorland pools that have become eutrophic, ditches, garden ponds, and all sizes and kinds of artificial basins. Typical aspects of the aquatic vegetation are formed by Floating sweet-grass (*Glyceria fluitans*), Water crowfoot (*Ranunculus* species) and other plants with finely pinnate leaves (STUMPEL, 1987C). Tree frogs are very demanding regarding their terrestrial habitats. The national Tree frog Action Plan (CROMBAGHS & LENDERS, 2001) makes provision for safeguarding, reinforcement, connectivity and extension of the habitats: conditions are met by so-called base habitats, proven to be very successful (BRAAD, 2000; CROMBAGHS & LENDERS, 2001). A base habitat covers an area of 2-3 hectares, and has at least one reproduction water and terrestrial habitat at a bridgeable distance from each other. Base habitats together form key areas of more than 50 ha, needed for the long-term survival of local populations. The Action Plan distinguishes between large (1000-2000 m^2) and small (500 m^2) reproduction waters; large waters are supposed to be source of juveniles. For each site or area in the Netherlands (46 in 2001), the required number of sub-habitats has been quantified. The plan aims at 6000 ha of habitat and 180 km of corridors by 2005; it gives examples of habitats with detailed measurements for the sizes of sub-habitats and distances between them. Its success depends on the possibilities for realising the plan, including monitoring and co-ordination of the management measures after the period covered by the plan. Management should be directed at the combination of the reproduction pond and land habitat. If such base habitats cannot be constructed, a network of ponds can also provide sustainable habitat for this frog (STUMPEL, 1987B; Chapter 4 of this thesis). As the species is able to cover distances of many kilometres (STUMPEL & HANEKAMP, 1986; FOG, 1993), new ponds at similar distances from key habitats still have a big chance of getting colonised, provided there are no barriers in the landscape (cf., STUMPEL *ET AL.*, 1987).

g. **Pool frog** (*Rana lessonae*). The Pool frog is the smallest species of the Green frog complex, and is widespread in the southeastern half of the Netherlands. Pure populations of the Pool frog are very rare as it mostly occurs in mixed populations with the Edible frog (*Rana* kl. *esculenta*), and is practically always outnumbered. At present, only few sites are known harbouring pure populations; they are spread over the east of the country (e.g., Glimmen, Groningen; Diever, Drenthe; Nunspeet, Gelderland; Herkenbosch, Limburg). However, more may be discovered during a special survey in 2004. The languishing population at Diever has a unique genetic composition (J. WYCHERLEY, pers. comm.) and deserves exceptional conservation attention, at least for scientific reasons. But it is the flourishing Nunspeet population that is the best reference for the typical habitat in the Netherlands. All the aquatic habitats are pools on poor soils in heathland and poor grassland. Their isolated position means that they are very vulnerable to such threats as water pollution, fish release and vegetation succession. Management measures should include limiting access by tourists (preventing walking on shores and swimming of dogs), extirpation of fish (sturgeons [!] have been observed at Nunspeet), controlling grazing by cattle and sheep (prevent disruption and manuring of the water), and opening up vegetation if shading dominates. Moreover, people should be very careful with mixed green frog populations with a high proportion of pool frog, as they are very rare, and have a great potential for establishing pure new populations elsewhere. Yet in 2001, the habitat of a large key population was destroyed illegally (VAN DORP & DONKER, 2001; STUMPEL & VAN BLITTERSWIJK, 2002); measures taken afterwards for compensation appeared to be extremely difficult and to contain a lot of uncertainties (VAN BLITTERSWIJK *ET AL.*, 2003). The ease with which people still trivialise such effects on a protected species, and wrongly believe in the simple compensation of its habitat, is alarming.

Pool frog
Rana lessonae
(Camerano, 1882)

Distribution worldwide: Western Palearctic. From Brittany to east of Moscow (but eastern border not well known), and from northern Germany to central Europe. Absent from the British Isles.
Distribution in NL: Mainly in the southeastern half of the country.
Subspecies: None.
Habitat in NL: Isolated pools in heathland, moorland, bogs and poor grassland.
Status in NL: Vulnerable.
Threats: Acidification of aquatic habitat; drainage; sharing habitat with Edible frog.
Conservation: Control of acidification processes; raising of water-level; isolation of habitats from that of the other Green frogs.

Some vulnerable and declining species lack detailed knowledge about their aquatic habitat, such as the Moor frog (*Rana arvalis*) and the Palmate newt (*Triturus helveticus*). Both species are threatened by the loss and isolation of their reproduction waters, together with the fragmentation of their terrestrial habitats. For those that reproduce in ponds, the general terms for management should be applied. Action plans based on the creation of new ponds nearby are urgently needed to improve the often marginal situation of the small populations that remain.

7.2.5.3 Ditches

Ditches are long, narrow excavations in the countryside, usually containing water, that have been dug for the purpose of both drainage and water supply, transport, separation of parcels, and as a watering place for cattle (NIJBOER, 2000). They can be found both in agricultural and natural areas. A ditch is part of an artificial system where the water level is controlled. The water usually has little or no current; occasionally when sluices are opened, there may be a temporary one. Their width and depth can vary; usually they are not more than 8 m wide and 1.5 m deep. Many ditches are rich in fish.

Edible frog
Rana kl. *esculenta*
(Linnaeus, 1758)

Distribution worldwide: Western Palearctic. From Brittany to east of Moscow (but eastern border not well known), and from southern Sweden to central Europe. Absent from the British Isles.
Distribution in NL: All over the country.
Subspecies: None.
Habitat in NL: A great variety of water bodies.
Status in NL: Not threatened.
Threats: Loss of reproduction waters; release of fish; water pollution.
Conservation: Safeguarding of reproduction waters and their appropriate management.

Ditches generally harbour the common species such as Common frog, Common toad, Smooth newt and Edible frog, but other species may also be found if there is suitable terrestrial habitat nearby. Even vulnerable species, as the European tree frog and Great crested newt may select ditches with well-developed aquatic vegetation.

The highest density of ditch systems is in the Holocene part of the Netherlands in the west and north of the country; ditches are generally wider here than in the Pleistocene part. The total length of ditches in the Netherlands is approximately 350 000 kilometres, constituting a huge potential for amphibian habitat.

The vegetation of ditches depends of the depth, composition and dynamics of the water, and the soil type, and resembles that of ponds (7.2.5.2). Ditches are cleaned frequently in order to prevent terrestrialisation and ultimately, losing them. Unmanaged ditches can temporarily function as marshes.

As ditches are connected to each other, fish easily spread over the whole system and will often reduce the population density of amphibians. The advantage of a pond, being free of fish, can never be shared by a ditch.

A ditch is in fact a long, narrow pond, and provides amphibians with a similar habitat. In fact, they have the same requirements in both. The best ditches for amphibians are those without a current and with lush aquatic vegetation. Such vegetation enables amphibians to live together with fish. Ditches with abundant, somewhat disordered vegetation on their banks, alternating with bare parts, are generally favoured by amphibians. During hibernation and their reproduction period, thus in winter, spring and early summer, amphibians need high water levels. The best ditches run in an east-west direction, so having large parts of their banks in the sun, important for these ectothermic animals. Ditches often have a monotonous vegetation structure, reflected in a lower diversity of amphibians. Since only a few species find terrestrial habitat in arable fields, ditches running through them are of less value to amphibians than those in pastures and meadows.

Present management

Since the Second World War, ditches have been subject to much change. Due to rationalised agriculture, many have been filled in, water levels are changed much more over the season, and there has been a strong increase in manuring. Especially the low water levels in the winter and spring have had a greatly negative impact on amphibians. The silt layer can then freeze and thus hibernating amphibians die. Moreover, flooded shore zones for egg deposition are no longer present. Nowadays, many ditches are situated in agricultural areas where amphibians occur more by chance than design; the present land use does not often correspond with their needs (TWISK *ET AL.*, 2000; BOS *ET AL.*, 2004).

Ditches with a drainage function are under the control of the Water Boards, and have to be cleaned out yearly. The result of this system is that many ditches are cleaned unnecessarily, and certainly too frequently for amphibians. Ditches are cleaned with large machines and the timing takes no account of amphibian activities, thus causing damage to populations. It is common practice to remove silt and aquatic vegetation when there are eggs and larvae in the water. Such operations could be planned in consultation with nature conservation bodies and in fact, having in mind the regulations of the Flora and Fauna Act, should be. Unfortunately, there is no control regarding compliance with those regulations. Ditches in nature areas come off somewhat better, but even there they are too often cleaned by uninterested contract workers.

Recommended management

Amphibians need clean, unshaded and well-vegetated ditches for their reproduction. If these conditions are met, the habitat will maintain itself for a number of years without any human intervention.

The ideal management is the old-fashioned cleaning that was carried out by hand, only when strictly needed; this is no longer practiced. A similar result can be achieved by:

1. careful planning of management activities, with a spread in time and space: best period for such actions is October, never when adult amphibians, eggs and larvae are present;
2. using small machines;
3. maintaining high water levels in winter and spring;
4. removing plants only when succession has proceeded too far;
5. dredging silt only when too much has accumulated and lack of oxygen occurs;
6. digging holes in the bottom of the ditch to provide opportunity for hibernating out of reach of the frost when water is low;
7. protecting good ditches from becoming too rich in nutrients by asking farmers to a) transport polluted water via a detour, b) block off parts of ditch, c) keep a distance when injecting manure;
8. keeping a distance when spraying xenobiotic substances;
9. explaining the significance of the measures to contract workers: creates interest and increases the chance that amphibians are taken into account during work; especially important when key populations are at issue;
10. when site belongs to a key population, informing all people that could possibly have an influence on the site about the importance of protecting it;
11. when species concentrate at the dead end of ditch, considering closure of such a part with removal of all fish; especially for Red List species.

When amphibians are already present, improving the current situation would re-create a lot of habitat for amphibians. When farmers are careful with ditches with abundant populations, much damage can be prevented.

Marsh frog
Rana ridibunda
(Pallas, 1771)

Distribution worldwide: Western Palearctic. From the Netherlands to China and from Latvia to the Balkans and further southeastwards to the Arabian peninsula, Iran and Afghanistan. Absent from the British Isles and southwestern Europe.
Distribution in NL: Mainly in the northwestern half of the country.
Subspecies: None.
Habitat in NL: Pools, lakes, canals, ditches, marshes.
Status in NL: Not threatened.
Threats: Release of fish; intensive cleaning of canals and ditches; water pollution.
Conservation: Appropriate habitat management.

7.2.5.4 Canals

Canals are man-made waters, dug for transport and for controlling the water-level. They are often intensively used by shipping, causing the waves to beat the banks continually. Consequently, vegetation cannot develop along the banks, and submerged aquatic vegetation does not grow either.

Although canals are generally not important to amphibians, cut canals are of great value and may be regarded as ponds. Yet the canals in fenland with their luxuriant vegetation are the most attractive to these animals. Canals with brackish water play no role at all as a habitat because of the quality of the water.

However, some of the smaller canals are no longer used for barges, and if vegetation is allowed to develop in the water and along the banks, some amphibians may find a habitat in such waters. Mostly the Edible frog, Marsh frog and Common toad are attracted as they may also deposit their eggs in deeper water. However, as soon as the bank vegetation becomes 0.5 m wide, other species may colonise, such as the Common frog and Smooth newt.

The importance of canals for amphibians can be increased if management measures are taken to encourage the development of a wide zone both of well-developed bank vegetation and submerged vegetation; even a potential habitat for less common species might be created. Fish, though, limit colonisation by amphibians and are always present; the presence of vegetation under water can lessen their impact.

7.2.5.5 Lakes and oxbow lakes

Large bodies of water, such as lakes and oxbow lakes, can be very attractive for amphibians if vegetation is present, both submerged and on the banks. Still, as lakes are used and managed for angling or water sports, and moreover, often attract big flocks of water birds, they are unsuitable for amphibian reproduction, and thus generally not so important. Yet there are lakes in the low-lying parts in the west and north of the country that provide a favourable environment, being connected to ditch systems; in these situations, the Edible frog and Marsh frog may build up strong populations.

Oxbow lakes, the cut-off arms of rivers, can be of much more importance. They are in fact huge ponds, and have matching qualities. Some oxbow lakes are still important for the threatened Common spadefoot and the vulnerable Great crested newt, although many were transformed and became unsuitable for them during the last decades. However, if these old river-arms are going to be used as bypasses to the main river, as planned for many forelands (DE BOO, s.a.), their significance for amphibians will be lost. Up till now, the release of fish and terrestrialisation of the vegetation have been the main causes for habitat deterioration, leading to species disappearance.

If it were possible to give oxbow lakes back to nature, a potentially very important habitat for the survival of Red List amphibians would be established. Reintroducing such species might be considered if genetically related donor populations can be found that are strong enough for harvesting eggs or larvae.
Lakes too, if the vegetation is managed in the same way as that of canals (7.2.5.4), will provide some species with a habitat.

7.2.5.6 Streams

A stream is a body of running water in a landscape with topography. The greater the fall, the faster it runs, and in the Netherlands, the less it is then of value to amphibians. Amphibians are only found in still-standing water near the shore, or in places with hardly any current, such as hollows in the stream bed or between roots of trees.

Only the Fire salamander is a typical inhabitant of streams, albeit that the adults and juveniles live on land. The larvae develop in the water, which should be clear, oxygen-rich and free of fish. In addition, there must be opportunities for shelter in the form of plants, stones and branches, and the site should be situated in a suitable terrestrial habitat. Larvae of the Midwife toad can also be found in slowly running streams, but this is rather unusual in the Netherlands. There is only one site left with a viable population of the Fire salamander in the Netherlands, spread over three sub-populations in the *Bunderbos* in Geulle-Bunde, a nature area.

Fire salamander
Salamandra salamandra
(Linnaeus, 1758)

Distribution worldwide: Western Palearctic. From Iberia to Iran and from northern Germany to North Africa, absent from north and northeastern Europe, the United Kingdom and Ireland.
Distribution in NL: South Limburg, possibly near the German border in the province of Gelderland.
Subspecies: 11. In NL: *Salamandra salamandra terrestris* Lacépède, 1788.
Habitat in NL: Forests with little streams.
Status in NL: Threatened.
Threats: Release of predatory fish, disturbance of the hydrologic system, inappropriate cleaning of streams.
Conservation: Strict protection of all sites and appropriate habitat management.

Streams in such areas are usually left undisturbed, maintaining themselves by their natural dynamics. However, there have been some unacceptable incidents. Plant cleaning activities took place in the stream at the edge of the nature area, and the vegetation was removed many metres inside the area, destroying just the places where larvae of the Fire salamander had collected downstream. Such thoughtless actions can destroy the greater part of an annual reproduction effort; if this happens regularly, the population will certainly be affected. This is unacceptable, especially as the only other populations that are known to exist, near Epen, are very small, less protected and maybe even not all identified yet (cf., GUBBELS, 1992); their conservation is receiving unsatisfactory attention. Moreover, all these habitats, as well as other potentially suitable streams and wells, ought to be guarded against sluicing. This might happen when there is a need to drain away excess water through the area for reasons of agricultural engineering in the surrounding countryside.

It is unclear whether the small populations of the Fire salamander in Gelderland at Laren and Winterswijk, and at Ootmarsum in Overijssel still exist (cf., BERGMANS & ZUIDERWIJK, 1986); their potential habitats should be well surveyed. If they prove to exist, depending on the local situation, a management strategy should be developed.

7.2.5.7 Terrestrial habitats

Amphibians are hard to find on land, making systematic investigation almost impossible. As they are often come across by chance, information is mostly based on observations made on a few individuals. The terrestrial habitats are therefore much less understood than the aquatic ones.

The edge of forest and scrub, and also bushes seem to play an important role as habitat for many species. Damp grassland is important too. In many areas, the change of pasture into arable land is seen as a major cause for the decline of amphibians. Due to large-scale drainage, many land habitats in the Netherlands are not moist enough for amphibians.

For some species, more details are known; they are given below, together with an outline of their relevance for conservation.

a. **Great crested newt** (*Triturus cristatus*). The terrestrial habitats of the Great crested newt are found in such places as rough grassland, gardens, scrub and deciduous woodland as long as in close distance of water suitable for reproduction (cf., SCHIEMENZ & GÜNTHER, 1994). Habitats with a well-developed litter layer, dead wood and heaps of stone are favoured. Refuges can be made artificially, if needed (cf., LANGTON *ET AL*., 2001).
b. **Midwife toad** (*Alytes obstetricans*). The terrestrial habitat of the Midwife toad is not far away from its aquatic habitat. In natural areas, its habitat is found in caved-in banks of streams, and in man-made landscapes, similar features are found in stony soils with a friable structure, providing loose earth for digging. Many Netherlands' populations occur in abandoned quarries. The essence is that they have to have sufficient dry shelter near the pond or pool. The species is found in quarries, farmyards, churchyards, gardens, hedges and steep banks where it hides in burrows in the ground, in walls and heaps of stones, and under logs. The site where the largest population occurred, in *Meertensgroeve* near Vilt, was protected as a Nature Monument. Unfortunately, the subsequent management did not include adequate measures for the terrestrial habitat, and the population declined dramatically. Grazing by sheep and goats had only kept

the area free of trees and bushes, but the ground was compacted, and hardly any of the bare parts needed were left. The best management is to ensure that the soil remains suitable for burrowing: it must not get compacted and overgrown with vegetation. Measures include regular mechanical disturbance of the soil and the slopes. This is a new way of thinking in nature management and will at first take getting used to. The creation of artificial refuges, such as heaps of stones or pits with rubble, have proven to be useful (cf., STUMPEL & BLEZER, 2003).

Midwife toad
Alytes obstetricans
(Laurenti, 1768)

Distribution worldwide: Western Palaearctic. Southwestern Europe, from central Germany to central Iberia, including Switzerland, and North Marocco.
Distribution in NL: South Limburg.
Subspecies: 3. In NL: *Alytes obstetricans obstetricans* (Laurenti, 1768).
Habitat in NL: Streams; marl, sand and gravel pits; farmyards; churchyards; meadows with ponds and steep embankments.
Status in NL: Vulnerable.
Threats: Loss of ponds; drainage; vegetation succession (result of abandoning pits).
Conservation: Creation and restoration of ponds; appropriate pond management; regular mechanical disturbance of soil in land habitats.

c. **Yellow-bellied toad** (*Bombina variegata*). The exact conditions required by the Yellow-bellied toad for its terrestrial habitat are not yet fully understood. These toads are found in stable environments where local dynamics in the form of flooding, excavation, or other disturbance to the soil, creates open places with shallow water. The presence of forest on hillside slopes characterises its habitat. The animals spend most of the summer at the water's edge, but when it is too warm or dry, they take refuge in the forest, hiding in sheltered places, such as under stones and logs (GOLLMANN & GOLLMANN, 2002). They also hibernate in the forest, in all kinds of hollows and crevices. Yellow-bellied toads are vagrants and may temporarily use random shelters in the surrounding landscape. This non-burrowing species easily accepts artificial shelters, such as logs, stones and even pieces of litter. In man-made habitats, such as quarries, the presence of artificial shelters may be important (NIEKISCH, 1990). Furthermore, it is important that potential terrestrial habitat is developed between isolated aquatic habitats.

Common spadefoot
Pelobates fuscus
(Laurenti, 1768)

Distribution worldwide: Western Palearctic. From France to West Siberia. In Europe from southern Sweden to central France, northern Italy and Bulgaria. Absent from the British Isles and Iberia.
Distribution in NL: The Pleistocene soils in the southern and eastern parts of the country.
Subspecies: 2. In NL: *Pelobates fuscus fuscus* (Laurenti, 1768).
Habitat in NL: Sandy soils with ponds and pools. River dunes, river banks, heathland, arable fields.
Status in NL: Threatened.
Threats: Pond loss; acidification and neglect neglect of habitat; fish release.
Conservation: Pond creation and restoration; appropriate habitat management.

d. **Common spadefoot** (*Pelobates fuscus*). The terrestrial habitat of the Common spadefoot is found on sandy soils, especially in river dunes, in parts that have loose open sand. In nature areas, the habitat is characterised by vegetation with Heather and Juniper (*Juniperus communis*). In a cultivated landscape, they are found in potato and asparagus fields, and in vegetable gardens. The sandy river dunes are clearly preferred, and on a summer evening after dark, many may be encountered on and beside sandy paths (BOSMAN & VAN DEN MUNCKHOF, 1993). Hibernation has been observed in the litter layer of oak forests (W. BOSMAN, pers. comm.).
The typical small-scale landscape, with ponds and fields in a mosaic pattern where it used to occur, has become rare. Nowadays, the countryside is dominated by large fields, with maize and other tall crops, such as sunflowers. Furthermore, oak, birch and pine are closing up open woodland and heathland, posing another threat to this toad.
Succession in heathland and open woodland must be stopped in these places. In addition, the old-fashioned landscape structures should be retained or re-created, but experience in doing this has still to be developed. Experiments are being done to create new terrestrial habitat in farmland close to the reproduction ponds using adapted ploughing regimes and sowing winter rye and summer wheat (BOSMAN & CROMBAGHS, 2002).
e. **Natterjack toad** (*Bufo calamita*). The terrestrial habitat of the Natterjack toad is found on loose, sandy soils where they can burrow. It consists of open, unshaded areas that have very short vegetation with bare patches. Such features can be found in sand dunes, but also on the slopes of sea and polder dykes, and in road verges. The Natterjack toad is able to migrate over large distances and has a very loud call. Therefore, although not ideal, the land habitat can be situated as far as one kilometre away from the breeding pond. Air pollution by nitrogen is increasing the rate of vegetation succession, causing many terrestrial habitats to lose their bare parts. Management measures should focus on keeping large patches of open ground. The maintenance of systems of sandy paths, such as bridle paths or firebreaks, is also beneficial; the heathland management recommended for the Sand lizard (7.1.4.3) covers the needs of this toad. Large stones can provide important places for shelter (SINSCH, 1989).

European tree frog
Hyla arborea
(Linnaeus, 1758)

Distribution worldwide: Western Palearctic. From Portugal to the Caucasus and from southern Sweden southwards all over Europe, except southern France and southeastern Spain. Also absent from the British Isles.
Distribution in NL: West Zealand Flanders, central North-Brabant, central Limburg, Achterhoek, Twente, southern Drenthe.
Subspecies: 4. In NL: *Hyla arborea arborea* (Linnaeus, 1758).
Habitat in NL: Marshes and ponds with bushes and tall herbs.
Status in NL: Threatened.
Threats: Pond loss; isolation; intensive land use.
Conservation: Creation and restoration of ponds and marshes. Connection of habitats. Appropriate management of land habitat.

f. **European tree frog** (*Hyla arborea*). The quality of its terrestrial habitat possibly determines the presence of the European tree frog more than that of the aquatic one (STUMPEL, 1993). Tree frogs are found in trees, bushes, tall perennial herbs, and plants on the shore in places with a rather high ground water level. Remarkably, many observations of them have been made in brambles (*Rubus* species). In early spring, the frogs can be found on the bare ground and in grass tussocks. They tend not to be randomly spread over an area, remaining concentrated in places with a complex vegetation structure, well-exposed to the sun and with a rich invertebrate fauna. They are often found in the verge vegetation of forests, roads, paths, ditches, meadows and even fields, and in abandoned parts of gardens (STUMPEL, 1993). While most other amphibians only stay on the ground, the European tree frog also has a vertical distribution. They are commonly observed at heights of between zero and three metres, but also in tree canopies of between six and ten metres above the ground (e.g., STUMPEL & HANEKAMP, 1986). Although the Tree frog has an impressive migratory power, on some days travelling up to several kilometres, at good sites its terrestrial habitat is found within a radius of three hundred metres from the reproduction pond. However, if suitable vegetation structures are lacking in the immediate neighbourhood of the pond, terrestrial habitat can also be found up to a kilometre away (J. BURNY, pers. comm.). It is not only the distance from the pond that matters; the size of the terrestrial habitat is of equal importance (e.g., VOS & STUMPEL, 1996). It will be hard to manage habitats of Tree frogs in the well-drained, over-manured and intensively used landscape of the Netherlands, but it must be possible to select areas for appropriate management measures. The vegetation must only be cut or mown irregularly, both on a very small scale and at intervals of many years. Only in this way can the complex vegetation structure that the Tree frog requires, develop and be maintained.

Conclusion to management in practice

Besides current nature management, where the emphasis is mainly on plants, the strong decline and difficult position of many species of reptiles and amphibians impels us to give attention to their management as well. The recommendations given in this chapter are for this purpose. Moreover, the management of their habitats can serve as a model for that of other small animals, the invertebrates especially, that has until now been neglected. It will be plain, that management can be adapted with relatively little energy and few means, and by doing so, the quality of nature in the Netherlands can be considerably improved.

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Summary

This thesis deals with the nature conservation of reptiles and amphibians in the Netherlands, the present practices and what should be done to improve them. Most of the species of the herpetofauna, as these groups together are known, are in a state of continuing decline. Obviously something is wrong; apart from the role played in this decline by loss of habitat, measures in the field are not effective for the sustainable survival of these species. This thesis has been written to rectify this; based on current knowledge of the ecology of these protected animals and on own experiences with nature management, it is meant to provide a guide and practical tool when carrying out the appropriate measures in the field.

The introduction describes work that has been done internationally, especially at European level, to protect the herpetofauna. Further, how this has influenced policy plans and legislation in the Netherlands. It also points out the shortcomings, both in the approach of the policymakers, as well as in the current training of nature managers, and how these are reflected by the measures taken in the field. This information provides a background for chapter 7, the last chapter of this thesis, where the practice of management is discussed.

The remaining chapters include five articles on ecological research; they also show how much time is needed to improve our knowledge on the ecology of these animals. Also, not understanding it can unwittingly create marginal conditions for a species, as was the case for the Slow-worm and Sand Lizard with the forest management on the *Utrechtse Heuvelrug* in the 1980s; this is described in the first two articles.

That long-term surveys of population dynamics are more than necessary, is shown by the great fluctuations in the presence and activity of the European tree frog over the six years it was studied in the southwest of the Netherlands. Methodology is also discussed in this third article, and a practical formula given for estimating population size.

Pond characteristics form the subject of the next article, wherein statistical analysis illustrates how they can indicate the possible presence and therefore the suitability of a pond for amphibians. Practical indications are given, useful when constructing new ponds as part of the Pond Action Plans.

The last article has implications for the reintroduction of species into new or former habitats. That there is phenotypic variation within species of amphibians occurring within 200 kilometres of each other, shows that, to avoid failure, this

should be taken into account in the selection both of the source population and the location of the habitat into which the animals are to be introduced.

All these aspects are brought together in the final chapter where the practice of the conservation of both groups is discussed in turn. The habitats are the point of departure, and it is shown how conservation measures with plants or landscapes in mind can bring about deterioration or loss of habitat for a particular species of reptile or amphibian. The integration of management goals should be the approach for as far as is possible, but legal obligations may force us to take species specific measures into account for herpetofauna. Heathlands are of utmost importance for reptiles and the most relevant features of the management for this type of habitat are highlighted. For their part, amphibians find their major aquatic habitat in ponds. Details are given of the management for various amphibian species, both in ponds, and as far as we know it, in their habitat on land.

The extensive literature on these subjects, found at the end of Chapters 1 and 7, as well as that of the articles, provides opportunity for going further into depth.

The recommendations from Chapter 7, dealing with the structure of the vegetation to a considerable extent, should improve the situation of the herpetofauna in the Netherlands.

Samenvatting

Natuurbeheer voor reptielen en amfibieën

Dit proefschrift gaat over natuurbeheer voor reptielen en amfibieën in Nederland. De meeste soorten van deze twee diergroepen, samen de herpetofauna genoemd, vertonen een voortdurende achteruitgang. Bij deze achteruitgang speelt het verlies van leefgebied een belangrijke rol, maar er is meer aan de hand. Blijkbaar zijn de maatregelen die in het veld worden genomen niet voldoende effectief voor de duurzame instandhouding van reptielen en amfibieën. Dit proefschrift is geschreven om daaraan iets te doen. Het behandelt het gangbare natuurbeheer in Nederland en geeft aan wat in de praktijk nodig is om dat te verbeteren ten behoeve van de herpetofauna. Op grond van bestaande kennis over de ecologie van deze beschermde dieren en eigen ervaringen met het natuurbeheer worden praktische richtlijnen gegeven om in het veld de meest geschikte maatregelen uit te voeren.

De inleiding beschrijft wat internationaal is gedaan om de herpetofauna te beschermen, met name op Europees niveau. Vervolgens wordt aangegeven hoe dit van invloed is geweest op beleidsplannen en wetgeving in Nederland. De tekortkomingen worden daarvan genoemd, zowel in de aanpak van de beleidsmakers als in de opleiding van natuurbeheerders, en welke gevolgen die hebben voor de maatregelen die in het veld worden uitgevoerd. Deze informatie vormt de achtergrond voor het laatste hoofdstuk, waarin de praktijk van het natuurbeheer wordt bediscussieerd.

De overblijvende hoofdstukken omvatten vijf artikelen over ecologisch onderzoek, die ook illustreren hoeveel tijd nodig is om de kennis over de ecologie van deze dieren te vergroten. Soms kunnen door toeval geschikte omstandigheden voor soorten worden geschapen, zoals de twee eerste artikelen beschrijven voor de Hazelworm en de Zandhagedis bij het beheer van bossen op de Utrechtse Heuvelrug in de jaren tachtig.

Dat langdurig onderzoek aan de dynamiek van dierpopulaties onontbeerlijk is, wordt duidelijk gemaakt door de grote schommelingen in aantallen en in de activiteit van Boomkikkers gedurende de zes jaren dat deze soort werd bestudeerd in Zeeuws-Vlaanderen. In dit derde artikel worden de veldmethoden kritisch besproken en wordt een formule gegeven om de hoeveelheid dieren op een bepaalde plaats te schatten.

In het volgende artikel komen de kenmerken van poelen aan de orde. Door middel van statistische analysen wordt aangetoond hoe deze de aanwezigheid van amfibieën kunnen verklaren en daarmee de geschiktheid van een poel voor deze dieren. Er worden praktische aanwijzingen gegeven die nuttig zijn wanneer in het kader van poelenprojecten nieuwe poelen worden aangelegd.

Het laatste artikel gaat over implicaties voor het herintroduceren van soorten in nieuwe of herstelde leefgebieden. Er blijkt fenotypische variatie te zijn bij amfibieën van dezelfde soort, die op 200 kilometer afstand van elkaar voorkomen. Met dit gegeven moet rekening worden gehouden bij het kiezen van zowel de bronpopulatie als de plaats waar de dieren zullen worden uitgezet, teneinde de kans op een mislukking te verkleinen.

Al dergelijke en veel meer aspecten komen aan bod in het laatste hoofdstuk, dat gaat over de praktijk van de bescherming van reptielen en amfibieën. Uitgaande van hun leefgebieden wordt uitgelegd hoe beschermingsmaatregelen ten behoeve van planten of landschappen kunnen resulteren in aftakeling of verlies van die leefgebieden. Ondanks dat zoveel mogelijk naar een integratie van verschillende beheerdoelstellingen moet worden gestreefd, kunnen niettemin wettelijke verplichtingen ons dwingen om soortgerichte maatregelen te nemen ten behoeve van de herpetofauna.

Heide is van uitzonderlijk belang voor reptielen en om die reden wordt het beheer van dit type leefgebied uitgebreid onder de loep genomen. Voor amfibieën zijn daarentegen poelen in het cultuurlandschap de belangrijkste plaatsen voor hun voortplanting. Daarom worden details gegeven over het beheer van een aantal soorten amfibieën in poelen. Ook plaatsen op het land die voor amfibieën van belang zijn, krijgen aandacht.

De literatuurlijsten, vooral die op het einde van de hoofdstukken 1 en 7, geven toegang tot meer gedetailleerde gegevens.

De aanbevelingen uit hoofdstuk 7, die in belangrijke mate over de structuur van de vegetatie gaan, moeten leiden tot het verbeteren van de situatie van de herpetofauna in Nederland.

Notes: