Ecological impact of fire place use in urban forests and consequences for visitor management

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Table of Contents

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Summary

Urban forests are popular recreation areas in Europe. At the same time, these forests are important habitats for plants and animals and often harbour a high biodiversity. Recreational activities, for example picnicking and grilling and in particular the creation and usage of fire rings outside official picnic sites ("wild" fire rings), can cause extensive damage to soil and vegetation. Firewood collection depletes woody debris, leading to a loss of habitat for specialized organisms. Economical consequences of forest recreation include maintenance costs of recreational infrastructure and diminishing revenues due to visitor-related damage to trees and subsequent reduction in timber quality.

In the present thesis I examined the effects of fire place use on the forest soil, including soil microbial biomass and enzyme activity, ground vegetation, shrubs, trees and amount of woody debris. In addition, the reduction in timber value resulting from recreational damage to trees was estimated. In order to develop and implement measures, it is important to find out why forest visitors create and use "wild" fire rings instead of official picnic sites. Therefore, I conducted a forest visitor survey focusing on visitor preferences concerning fire places. An experiment was conducted with four new fire places designed to fulfil forest visitors' requirements, and a follow-up survey documented visitors' reactions. A survey aimed at forestry experts in the whole of Switzerland provided valuable information on foresters' perceptions concerning the consequences of picnicking and grilling and forest recreation in general.

At frequently used fire places we found reduced plant species densities in the ground vegetation and shrub layer and changes in plant species composition. Picnicking and grilling also reduced the height and changed the age structure of shrubs and young trees. The amount of woody debris was lower in disturbed plots than in control plots.

Soil microbial biomass (C_{mic} and N_{mic}) and dehydrogenase activity were differently affected by short- and long-term trampling. In a short-term experiment, these soil characteristics decreased at low and medium, but not at high trampling frequencies. In contrast, the same soil characteristics decreased with increasing trampling intensity in a long-term field survey at fire places that had been in use for more than a decade. The activity of β-glucosidase was only affected by short-term trampling. Phosphomonoesterase activity was most severely affected by long-term trampling, most probably as a result of the loss of plants.

The reduction in timber value due to visitor-related damage to trees ranged from 19 to 53 € per hectare and year in two suburban forests. Total recreation-induced costs, i.e. additional expenses and reductions in timber value exceeded 10% of the total annual expenditures of the two forest enterprises examined.

The forest visitor survey revealed a preference for fire places near streams, away from forest roads and close to open spaces. While some visitors highly appreciated the well-equipped official sites, others preferred more natural infrastructure with pieces of stones forming a fire ring rather than concrete rims, and logs to sit on instead of benches. Experimental fire places consisting of a ring of stones and logs fulfilled the needs concerning infrastructure of visitors who normally use "wild" sites. However, the location of fire places was termed more important than their infrastructure. Forestry experts' perceptions regarding reasons for "wild" site creation differed largely from the results of the forest visitor survey. According to experts, an insufficient number of barbecue pits, available firewood and forest visitors seeking adventure and romanticism repeatedly lead to the creation of "wild" fire rings.

General Introduction

Ecological and Economical Effects of Forest Recreation

Recreation in natural areas (nature-based recreation) is increasing in various parts of the world, due to economic growth and the subsequent increase of living standards and leisure time (Niemelä et al. 2005). In densely populated areas of Europe, urban forests play an important role in outdoor recreation (Janse and Ottitsch 2005). At the same time, these forests are important refuges for plants and animals and often harbour a high biodiversity (Niemelä 1999). Urban forests are therefore no longer used exclusively for wood production, but have become multifunctional, fulfilling ecological, economical and social services (Führer 2000, Mather 2001). The increasing recreational and conservational needs are giving rise to major conflicts between the different forest functions (Niemelä et al. 2005).

Recreation ecology examines the effect of recreation on the natural environment (Liddle 1997). More specifically, recreation ecology examines, assesses and monitors visitor impacts to natural areas and their relationship to influential factors (Leung and Marion 2000). As managers of recreation areas face growing numbers of recreationists, insights from recreation ecology studies can help managers to identify and to evaluate impacts on natural resources, to understand causes and effects and to manage problems more effectively (Leung and Marion 2000). Field surveys provide information on the amount of change that has occurred by recreational use (e.g. Bratton et al. 1982, Kutiel and Zhevelev 2001, Malmivaara et al. 2002, Andrés-Abellán et al. 2005). Controlled trampling experiments are used to examine the influence of frequency of use, type of use, environmental conditions and period of use (Cole 1995, Gallet and Roze 2001, Thurston and Reader 2001, Growcock 2005, Roovers 2005).

Picnicking and grilling are popular recreational activities in urban forests. The presence of humans invariably leads to trampling around the fire ring and in the surrounding forest. Therefore, activities such as picnicking, barbecuing and camping can degrade large forest areas and damages can spread to previously untouched areas. Effects on the forest include soil compaction, a reduction of height and cover of the ground vegetation, a shift in species composition towards trampling-tolerant and ubiquitous plant species, loss of leaf litter, damage to trees, the depletion of woody debris due to firewood collection and changes in the soil microbial community (Bratton et al. 1982, Jim 1987, Marion and Cole 1996, Zabinski and Gannon 1997, Amrein et al. 2005, Reid and Marion 2005).

Apart from the ecological effects, forest recreation has substantial economical consequences. The provision and maintenance of recreational infrastructure and additional security measures during logging operations and after windstorms are largely financed by the forest owner. Information and education of forest visitors and the reinforcement of laws costs additional time and money. Damage to trees, frequently observed in the vicinity of picnic sites, can lead to a significant reduction in timber quality, forcing forest owners to take diminishing revenues into account (Bartelheimer and Baier 1991, Dupasquier 1996, Bilecen and Kleiber 2002, Kleiber and Bilecen 2003). On the other hand, the local population draws benefits of high monetary value from forest recreation and greatly appreciates the possibilities for outdoor activities (Schelbert et al. 1988, Elsasser 1996, Tyrväinen 2001, Bernath et al. 2006). Other consequences of the intense recreational use of forests are social conflicts between different user groups and the perception of crowding (West 1982, Ramthun 1995, Heer et al. 2003, Arnberger and Haider 2005).

Approaches to Visitor Management

The numerous ecological, economical and social conflicts have made visitor management indispensable. In the early 1960s, the concept of carrying capacity was applied to recreation to describe how natural conditions deteriorate with increasing levels of use (Wagar 1964). The concept aims to define a maximum level of use that can be sustained without unacceptable or irreversible damage to the site (Curry 1994). These originally biological models did not transfer well into ecosystems being managed for recreation. Further research led to the development of several visitor management frameworks in North America, namely the Recreation Opportunity Spectrum ROS (Clark and Stankey 1979), Limits of Acceptable Change LAC (Stankey et al. 1985), Visitor Impact Management VIM (Graefe et al. 1990), Visitor Activities Management Process VAMP (Parks Canada 1991) and Visitor Experience and Resource Protection VERP (Manning et al.

1995). Common to all these frameworks is that they provide a logical structured approach for making management decisions. First, recreation opportunities are defined. Next, ecological and social indicators are monitored to determine if current conditions meet quality standards. If these standards are not met, some type of management is implemented (Brown et al. 2006).

Visitor management in Europe has been far less coordinated. Indeed, there have been several voices criticizing the lack of effective monitoring of visitor use and characteristics, especially for ecological purposes (Reynolds and Elson 1996, Cope et al. 2000). Nevertheless, in several European countries efforts are being made to integrate visitor preferences into forest management planning. Studies from Denmark showed that managers' perceptions can differ widely from forest visitors' preferences, for example regarding forest structure and recreation facilities (Jensen 1993). In Flanders, Belgium, Roovers et al. (2002) gave a comprehensive description of visitor characteristics in two urban, state-owned forests, providing basic knowledge for the administration. A national outdoor recreation demand and supply inventory (LVVI) in Finland aimed to improve services to meet visitor expectations better and allocate resources more effectively (Erkkonen and Sievänen 2002). An initiative in Greece examined knowledge and attitudes of visitors to a recreation area before converting the area into a national park (Machairas and Hovardas 2005).

Forest Recreation in Switzerland

In Switzerland, legislation allows free access to forested areas (Civil Code, Art. 699, 1907). The population makes good use of this privilege and 58% of the people visit the forest at least once a week (Buwal 1999). In heavily frequented urban forests the number of people leaving the footpaths, for example to picnic and barbecue, have led to severe impacts on the forest soil and vegetation. Furthermore, conflicts between different user groups have been observed (Bernasconi et al. 1998, Baur 1999, Buwal 1999, Baur 2003, Heer et al. 2003, Freuler 2006).

The project "Effects of recreational activities on the biodiversity in suburban natural areas" begun in 1997 with investigations in urban forests in the vicinity of Basel. Human trampling has been found to reduce plant height and cover, cause changes in the species composition of the ground vegetation and the soil seed bank, lower the ectomycorrhiza formation of beech trees and seedlings and affect the communities of ground-dwelling invertebrates (Baur 1999, Rusterholz et al. 2000, Waltert et al. 2002, Amrein et al. 2005, Rusterholz 2005). Further research focused on the economical consequences of forest recreation. Results show that additional costs due to recreation add up to 5–12% of the total annual expenditure of forest enterprises (Bilecen and Kleiber 2002, Kleiber and Bilecen 2003). In addition, several forest visitor surveys were carried out. They provide information on visitor characteristics, forest perception and knowledge and social conflicts between different user groups (Heer et al. 2003, Rusterholz and Baur 2003).

Focus of this Thesis

Grilling sausages in the forest is a traditional pastime in Switzerland. There is no law prohibiting the lighting of fires outside official picnic sites (Federal Forest Law 1991). In urban forests, the constant use of picnic sites and especially the creation of fire rings in previously untouched areas allow damages to spread uncontrollably throughout the forest. The **aim of this thesis** was to quantify the effects of fire place use on the forest. Additionally, measures were developed in order to reduce "wild" (non-official) fire rings.

Chapter 1 comprises the results of a survey aimed at forestry experts in the whole of Switzerland. The results show that picnicking and grilling are among the most frequent leisure activities in Swiss forests, especially in urban forests, where the density of "wild" fire rings is estimated to be double the density in rural forests and by far exceeds the density of official picnic sites. In urban forests, 48% of the experts reported conflicts and damage due to picnicking and grilling. The results confirmed that picnicking and grilling in urban forests are perceived as a problem not only by conservation scientists, but also by foresters.

In **chapter 2** the effects of fire place use on the above-ground vegetation and the amount of woody debris were examined by comparing plots containing fire rings with undisturbed control plots. Ground vegetation responded to human trampling with a reduction of plant height, plant cover and species density. The amount of leaf litter was also significantly reduced. Soil compaction and soil pH were elevated due to human trampling and the release of alkaline ions from the ash of the fire. The number of shrub species was lower in the vicinity of fire places than in corresponding control areas. Furthermore, shrub height was reduced by picnicking and grilling. At fire places, 39% of the trees were damaged, compared to 18% of the trees in control areas. Woody debris was depleted up to a distance of about 16 m from the fire rings covering an area of about 800 m^2 around each fire ring.

The forest vegetation is largely dependent on processes in the soil mediated by soil microorganisms. In **chapter 3**, the impact of long-term fire place use on soil microbial biomass and enzyme activity was studied by analysing soil samples taken at previously defined distances from the fire rings. A short-term trampling experiment conducted at the same sites enabled the comparison of short- and long-term effects of human trampling. Soil microbial biomass (C_{mic} and N_{mic}) and dehydrogenase activity (an indicator for general metabolic activity) were affected by short- and long-term trampling. In contrast, β-glucosidase activity (an enzyme involved in the decomposition of leaf litter) was reduced by short-term trampling, but not by long-term fire place use. Phosphomonoesterase activity (an enzyme of the P-cycle) exhibited the most pronounced effects to long-term trampling.

Damage to trees by forest visitors leads to a reduction in timber quality. **Chapter 4** focuses on profit losses of forest enterprises due to recreational use of the forest. In two forests in the vicinity of Basel tree damage was recorded in the entire forest area and the reduction in timber value and subsequent financial losses were estimated. The reduction in timber value ranged from 38 to 73 € per hectare per year in Allschwil forest (median: 53 €) and from 15 to 27 € per hectare per year in Sichtern forest (median: 19 €).

In forest areas under high recreational pressure, management actions are necessary to reduce the number of "wild" fire places. **Chapter 5** shows the results of a forest visitor survey conducted in two forests. At official picnic sites as well as at "wild" sites, 214 people were interviewed about their preferences. Forest visitors using official picnic sites were on the whole satisfied with the facilities provided. Visitors at "wild" sites preferred more natural sites without concrete fire rings and made with less infrastructure.

Based on these findings, four new fire places were installed in Allschwil forest (BL) in collaboration with the local authorities. The findings of the follow-up survey documenting forest visitors' reactions to these fire places consisting solely of a ring of stones and logs to sit on are presented in **chapter 6**. Users of "wild" fire rings and users of the new experimental fire places exhibited similar preferences concerning the infrastructure, indicating that the new fire places did fulfil the needs of visitors normally using "wild" sites. However, the survey also showed that the location of fire places is more important than their infrastructure. Therefore, the new type of fire place suggested can only help to reduce "wild" sites if the location is chosen appropriately.

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Chapter 1

Die Bedeutung der Erholungsnutzung des Waldes am Beispiel von Picknicken und Grillieren: Ergebnisse einer gesamtschweizerischen Umfrage bei Forstfachleuten und Waldeigentümern

K. Tessa Hegetschweiler, Antoinette Skorupinski, Hans-Peter Rusterholz und Bruno Baur

Schweizerische Zeitschrift für Forstwesen 158: 39–49

Die Bedeutung der Erholungsnutzung des Waldes am Beispiel von Picknicken und Grillieren: Ergebnisse einer gesamtschweizerischen Umfrage bei Forstfachleuten und Waldeigentümern[1] *(reviewed paper)*

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Keywords: Survey; forestry experts; outdoor recreation; picnicking; grilling; Switzerland FDK 46 : 907 : (494)

Abstract: This study presents the results of a survey aimed at forestry officials, foresters and public forest owners carried out in April/May 2005 in Switzerland. The study points out common problems and interests as well as differences in recreation in forests of various regions and shows differences between urban and rural forests. The relevance of recreation is compared to other forest functions. Special attention is given to the activity picnicking and grilling and building fires at non-official picnic sites.

Abstract: Die vorliegende Arbeit stellt die Ergebnisse einer Umfrage vor, welche bei Forstingenieuren, Förstern und Eigentümern von nicht-privaten Wäldern im April/Mai 2005 in der ganzen Schweiz durchgeführt wurde. Die Studie weist auf Gemeinsamkeiten und Unterschiede in der Erholungsnutzung des Waldes in verschiedenen Regionen hin und zeigt Beziehungen zur Grösse der Agglomerationen auf. Die Bedeutung der Erholungsfunktion wird mit anderen Waldfunktionen verglichen. Ein besonderes Augenmerk wird auf die Freizeitaktivität Picknicken und Grillieren gelegt, wobei speziell das Entstehen von «wilden» Feuerstellen behandelt wird.

Hegetschweiler, K.T.; Skorupinski, A.; Rusterholz, H-P.; Baur, B.: Die Bedeutung der Erholungsnutzung des Waldes am Beispiel von Picknicken und Grillieren *(reviewed paper)*

1. Einleitung

Der Wandel von der Arbeits- zur Freizeitgesellschaft in den vergangenen 50 Jahren hat zu einer Zunahme der Freizeitaktivitäten in stadtnahen Wäldern geführt (Becker 1983; Dahrendorf 1983; Jäger 1997). In Gebieten mit hoher Bevölkerungsdichte und geringer Waldfläche bekommt die Erholungsfunktion der Wälder eine zunehmende Bedeutung (Janse & Ottitsch 2005). Urbane Wälder sind zu eigentlichen Erholungswäldern geworden, was in gewissen Gebieten sowohl zu Konflikten zwischen der Erholungsfunktion und den übrigen Waldfunktionen wie auch zu ökologischen Schäden geführt hat (Liddle 1997; Heer *et al*. 2003a). Dabei weisen auf Wegen durchgeführte Aktivitäten wie Wandern, Biken oder Reiten im Allgemeinen ein geringeres Schadenspotenzial auf als Freizeitaktivitäten, die neben den Waldwegen durchgeführt werden und grössere Flächen in Anspruch nehmen (z.B. Picknicken und Grillieren). Mehrere Untersuchungen zeigen, dass intensive Erholungsnutzung einen grossen Einfluss auf das Ausmass der Bodenverdichtung, die Entwicklung der Kraut- und Strauchschicht mit den Jungbäumen und ganz generell auf die Vielfalt der Krautpflanzen und bodenlebenden Wirbellosen hat (Cole 1995; Liddle 1997; Baur 1999; Rusterholz *et al*. 2000; Malmivaara *et al*. 2002).

Eine beliebte Freizeitaktivität ist Picknicken und Grillieren. Viele Waldbesucher rasten bei Picknickplätzen mit fest installierten Feuerstellen. An Feiertagen mit günstigen Wetterbedingungen ist jedoch das Angebot an installierten Feuerstellen zu klein. Zudem sind die bestehenden Feuerstellen für einige Gruppen von Erholungssuchenden unattraktiv[2]. So werden immer wieder neue, so genannte «wilde» Feuerstellen von den Besuchern angelegt (Baur 2003). Das Erstellen und häufige Benutzen von «wilden» Feuerstellen kann zu grossflächigen Schäden an den umgebenden Waldbeständen führen (Jim 1987; Kutiel & Zhevelev 2001; Reid & Marion 2005; Amrein *et al*. 2005; Rusterholz 2005). Auch wird das Waldbrandrisiko erhöht. Zur Verminderung der Waldbrandgefahr kann mittels kantonaler Gesetze und Verordnungen ein begrenztes Feuerverbot ausgesprochen werden (Beispiel: Kanton Tessin; LLI, Art. 4).

Wichtige Komponenten zur Lösung von Konflikten zwischen der Erholungsnutzung und den anderen Waldfunktionen sind die in den Waldentwicklungsplänen (WEP) vorgesehenen direkten (z.B. Betretungsverbote) und indirekten (z.B. Wegsystem) Lenkungsmassnahmen (Bernasconi *et al*. 1998). Zur Entwicklung von Lenkungsmassnahmen wurden in der Schweiz bereits mehrere Befragungen von Waldbesuchern durchgeführt. Die Ergebnisse geben Aufschluss über die Ansprüche und Wünsche der Bevölkerung an den Erholungswald wie auch über die ökonomische Bedeutung der urbanen Wälder als Erholungsraum (Schelbert *et al*. 1988; Nielsen 1992; Buwal 1999; Heer *et al*. 2003a; Rusterholz & Baur 2003).

In der vorliegenden Arbeit werden die Ergebnisse einer in der ganzen Schweiz bei Forstingenieuren, Förstern und Eigentümern von nicht-privaten Wäldern durchgeführten Umfrage über Kenntnisse, Einschätzung und Wahrnehmung der Erholungsnutzung der Wälder vorgestellt. Aspekte der allgemeinen Freizeitnutzung werden anhand von Fragen zum Picknicken und Grillieren im Wald konkretisiert, da diese Aktivität aufgrund der flächenhaften Ausübung für den Wald besonders belastend sein kann. Die Umfrage lässt sich in fünf Teile gliedern. Erstens stellt sich die Frage nach der Wichtigkeit der Erholungsfunktion im Vergleich zu den übrigen Waldfunktionen. Zweitens ermöglicht die Umfrage eine Einschätzung der jeweiligen Bedeutung der verschiedenen Freizeitaktivitäten. Sie erlaubt auch einen Vergleich der Bedeutung des Picknickens und Grillierens mit der Bedeutung der übrigen Freizeitaktivitäten. Im dritten Teil geht es hauptsächlich um die Frage, weshalb Waldbesucher «wilde» Feuerstellen errichten und benutzen. Als viertes wird das Ausmass der durch Freizeitaktivitäten entstehenden ökologischen Schäden untersucht. Auch hier wird ein spezielles Augenmerk auf Picknicken und Grillieren gelegt. Im fünften Teil werden Angaben zum personellen und finanziellen Aufwand sowie gewünschte For-

[1] Es ist jeweils die weibliche Form mitgemeint.
[2] Hegetschweiler *et al*.: Fire place preferences of forest visitors in northwestern Switzerland: Implications for the management of picnic sites (im Druck).

men der Unterstützung in Bezug auf die Erholungsnutzung von Wäldern dargestellt. Eine Übersicht über bereits ergriffene Massnahmen zur Verringerung von freizeitinduzierten Schäden am Wald weist auf die Vielfalt der Ansätze hin.

Ziel der Untersuchung ist es, die bestehenden Umfragen bei Waldbesuchern mit der Sichtweise der Forstfachleute zu ergänzen, einen gesamtschweizerischen Vergleich der Experteneinschätzungen zum Thema Erholungsnutzung zu ermöglichen und Anregungen zu einem Meinungsaustausch über sprachliche, regionale und geografische Grenzen hinweg zu bieten.

2. Material und Methoden

Zur Erfassung verschiedener Aspekte der Erholungsnutzung wurde eine gesamtschweizerische Umfrage bei Förstern, Forstingenieuren und Eigentümern von nicht-privaten Wäldern durchgeführt. Somit handelt es sich bei allen Antworten um Einschätzungen, die mit einer gewissen Vorsicht zu interpretieren sind. 1090 Fragebögen (880 in deutscher Sprache, 160 auf Französisch und 50 auf Italienisch) erreichten die Zielgruppen als Beilage der Schweizerischen Zeitschrift für Forstwesen im April 2005. Da nicht alle Ansprechpartner zur Leserschaft der Zeitschrift gehören, wurden weitere 1225 Fragebögen (722 deutsche, 285 französische und 218 italienische) per Post an die gleichen Zielgruppen verschickt. Insgesamt wurden also 2315 Fragebögen versandt. Davon wurden 562 Fragebögen (385 deutsche, 103 französische und 74 italienische) ausgefüllt zurückgeschickt (24,3 %). Die Rücklaufquote lag je nach Sprachregion zwischen 23 % und 27 %.

Der Fragebogen umfasste 24 Einzelfragen[3]. Davon waren 18 geschlossene Fragen, zu denen eine Auswahl verschiedener Antwortmöglichkeiten vorgegeben war. Inhaltlich war der Fragebogen in fünf Teile gegliedert. Um die Wichtigkeit der Erholungsfunktion im Vergleich zu den übrigen Waldfunktionen einordnen zu können, wurde im ersten Teil nach der jeweiligen Bedeutung von Holznutzung, Schutz, Naturschutz und Erholung im betrachteten Waldgebiet gefragt. Der zweite Teil setzte sich mit der allgemeinen Freizeitnutzung auseinander. Gefragt wurde nach der Art der beobachteten Freizeitaktivitäten, den Veränderungen der Freizeitnutzung in den letzten zehn Jahren in Bezug auf die Besucherzahl und die Intensität, nach der zeitlichen Verteilung der beobachteten Freizeitnutzung sowie nach der vorhandenen Infrastruktur. Im dritten Teil wurde anhand der Freizeitaktivität Picknicken und Grillieren das Thema Freizeitnutzung konkretisiert. Unter Picknicken und Grillieren verstehen wir in diesem Zusammenhang die Benutzung von Picknickplätzen und Feuerstellen, unabhängig davon, ob ein Feuer entfacht wird oder nicht. Dieser Schwerpunkt befasste sich mit Anzahl, Lage und Ausstattung der festen und «wilden» Feuerstellen, mit den Gründen für das Errichten «wilder» Feuerstellen sowie der Art (Schulklassen, Familien, Einzelpersonen usw.) und Anzahl ihrer Besucher. Solche Informationen sind unerlässlich, um Massnahmen zur Reduktion von Schäden durch Picknicken und Grillieren entwickeln zu können. Den vierten Teil bildeten Fragen zu Konflikten und Schäden durch die Freizeitnutzung. Im fünften Teil wurde die Höhe des personellen Arbeitsaufwands und der Kosten im Bereich Freizeitnutzung erfragt. Ausserdem wurden durch offene Fragen Informationen über Massnahmen zur Begrenzung der Schäden durch Freizeitnutzung und über gewünschte Formen der Unterstützung zur Bewältigung der Aufgaben auf diesem Gebiet gesammelt.

Ausgehend von den angegebenen Postleitzahlen in den Fragebögen wurde jeder Forstkreis, jedes Revier und öffentliche Waldeigentümer mit Hilfe der «Karte der Schweiz mit Postleitzahlen» den verschiedenen Gemeinden zugeteilt (Die Post 2003). Jede Gemeinde wird bei der eidgenössischen Volkszählung einer der 55 Agglomerationen der Schweiz oder dem ländlichen Raum zugeordnet, so dass diese Einteilung übernommen werden konnte (Schuler 2003). Anhand der Einwohnerzahlen (Haug & Schuler 2003) erfolgte die Gruppierung der Agglomerationen zu Grossagglomerationen (> 250 000 Einwohner), mittelgrossen Agglomerationen (50 000 bis 250 000 Einwohner) und Kleinagglomerationen (< 50 000 Einwohner; Are 2005). Bei der Auswertung wurden mittlere und kleine Agglomerationen nochmals zusammengefasst. Sie werden im Folgenden als kleine Agglomerationen bezeichnet. Des Weiteren wurden die Forstkreise, Reviere und Waldeigentümer den geografischen Regionen Jura, Mittelland, Voralpen, Alpen und Tessin zugeordnet.

Signifikante Unterschiede in den Antworten in Abhängigkeit von der Agglomerationsgrösse, der geografischen Region, der Sprachregion und der Funktion der Fachperson wurden mittels Kontingenztests, bei intervallskalierten Daten mittels Varianzanalysen ermittelt.

3. Ergebnisse

3.1 Waldfunktionen

Insgesamt ordnen die Fachleute den vier Waldfunktionen Holznutzung, Schutz, Naturschutz und Erholung das gleiche Gewicht zu. Die Bedeutung der einzelnen Funktionen ist jedoch in grossen und kleinen Agglomerationen und im ländlichen Raum unterschiedlich ($Chi^2 = 20{,}9$, df = 6, p = 0,002). In grossen Agglomerationen werden Erholung und Holznutzung als sehr wichtig betrachtet, während im ländlichen Raum, zu welchem auch die meisten Berggebiete gehören, der Schutzfunktion und Holznutzung wichtige Rollen zugeordnet werden. Je nach geografischer Region wird die Bedeutung der einzelnen Waldfunktionen unterschiedlich eingeschätzt ($Chi^2 = 114{,}8$, df = 12, p < 0,001). Auffallend ist der Unterschied in der Einschätzung der Schutzfunktion zwischen den Alpen und dem Jura. In den Alpen wird der Schutzfunktion eine grosse Bedeutung beigemessen, im Jura hingegen wird sie häufig als unwichtig eingestuft.

3.2 Allgemeine Freizeitnutzung

Die von den Fachleuten während des Sommerhalbjahres beobachteten Freizeitaktivitäten unterscheiden sich tendenziell in ihrer Bedeutung in grossen und kleinen Agglomerationen und im ländlichen Raum (*Abbildung 1*; Wilcoxon Test: $Chi^2 = 4{,}9$, df = 22, p = 0,086). In allen Gebieten sind Spazieren und Wandern die häufigsten Aktivitäten. In grossen und kleinen Agglomerationen stehen Aktivitäten wie Joggen und Biken im Vordergrund, im ländlichen Raum ist Pilze und Beeren sammeln eine beliebte Aktivität. Picknicken und Grillieren steht jeweils an zweiter oder dritter Stelle und gehört somit zu den beliebten Freizeitaktivitäten im Wald. Im Winterhalbjahr hingegen sind keine Unterschiede zwischen den beiden Agglomerationstypen und dem ländlichen Raum auszumachen ($Chi^2 = 2{,}2$, df = 22, p = 0,35). Spazieren, Wandern, Joggen, Jagen und Reiten sind im Herbst und Winter in allen Gebieten die häufigsten Aktivitäten.

In den letzten zehn Jahren hat die Häufigkeit der Freizeitaktivitäten im Schweizer Wald zugenommen. 80 % der Antwor-

[3] Die Fragebögen in deutscher, französischer und italienischer Sprache sind unter http://www.conservation.unibas.ch/research/recreation/index.d.html (8. März 2007) abrufbar.

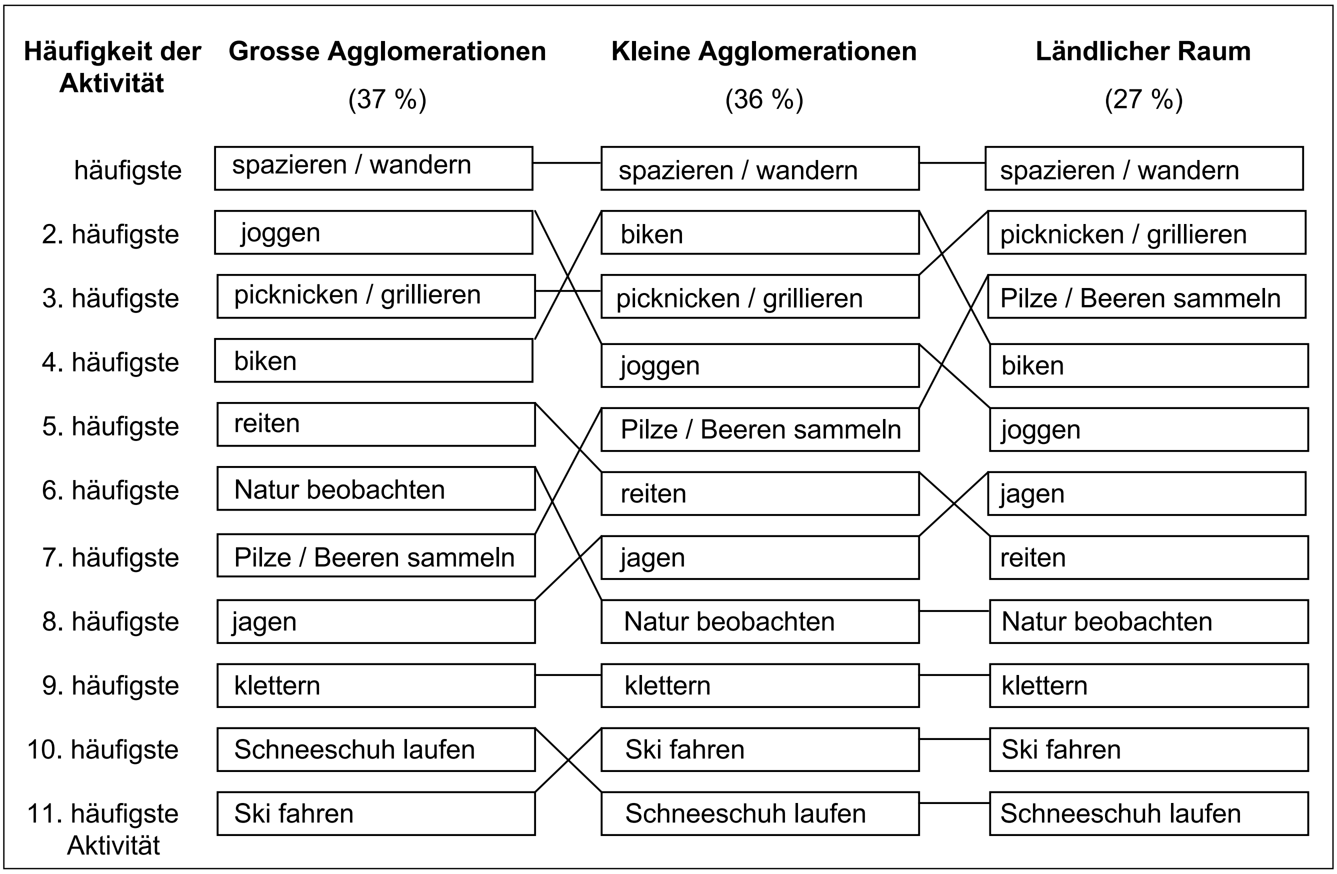

Abbildung 1: **Häufigkeit der Freizeitaktivitäten während des Sommerhalbjahres in grossen und kleinen Agglomerationen sowie im ländlichen Raum, geordnet in abnehmender Reihenfolge.**

Prozentzahlen in Klammern geben den Anteil der Bevölkerung im jeweiligen Agglomerationstyp und im ländlichen Raum an (Are 2003).

Figure 1: Frequency of leisure activities during summer in large and small urban areas and in rural areas presented in order of declining frequency. Percentages in parentheses represent the proportion of the population living in each urban or rural area (Are 2003).

tenden verzeichneten eine Zunahme der Besucherzahlen in ihrem Waldgebiet. Am stärksten zugenommen haben die Freizeitaktivitäten in Wäldern von grossen Agglomerationen sowie in denjenigen des Juras, in welchen in den letzten zehn Jahren 38 % bzw. 34 % mehr Besucher beobachtet wurden. Am wenigsten zugenommen hat die Anzahl der Waldbesuche im Tessin: Hier berichteten 65 % der Antwortenden über eine Zunahme, und die Anzahl Besucher ist im Schnitt um 17 % gestiegen. Allgemein scheinen die Freizeitaktivitäten in den Deutschschweizer Wäldern stärker zugenommen zu haben als in der Romandie und im Tessin ($Chi^2 = 14{,}0$, $df = 4$, $p = 0{,}007$).

In grossen und kleinen Agglomerationen wird der Wald schon vormittags rege genutzt. 31 % der Fachleute aus grossen und 29 % der Fachpersonen aus kleinen Agglomerationen geben an, der Wald werde vormittags häufig oder sehr häufig genutzt, im Gegensatz zu 16 % aus dem ländlichen Raum.

Tabellen 1a **und** ***b:*** **Unterschiede im Infrastrukturangebot zwischen grossen und kleinen Agglomerationen und dem ländlichen Raum (a) und den verschiedenen geografischen Regionen der Schweiz (b).**

Die Anzahl Nennungen (in Klammern die prozentualen Anteile der Antworten aus jeder Region) sind dargestellt (einige Befragte gaben keine Antwort auf diese Frage).

Tables 1a and b: Differences in the supply of infrastructure between large and small urban areas and rural areas (a) and in the various geographical regions of Switzerland (b). The number of answers (in parentheses the percentage of responses from each region) is shown (not all respondents answered this question).

a) Agglomerationstypen und ländlicher Raum

	Grosse Agglomerationen	Kleine Agglomerationen	Ländlicher Raum	Chi^2 – Tests
Picknickplätze / Feuerstellen	53 (91,4)	177 (75,3)	199 (81,9)	p = 0,010
Vita parcours / Finnenbahnen	32 (55,2)	83 (35,3)	85 (35,0)	p = 0,014
Radwege	23 (39,7)	114 (48,5)	107 (44,0)	n.s.

b) Geografische Regionen

	Jura	Mittelland	Voralpen	Alpen	Tessin	Chi^2 – Tests
Picknickplätze / Feuerstellen	18 (81,8)	230 (90,2)	89 (83,2)	62 (83,8)	24 (33,3)	$p < 0{,}001$
Vita parcours / Finnenbahnen	8 (36,4)	107 (42,0)	35 (32,7)	34 (45,9)	11 (15,3)	$p < 0{,}001$
Radwege	9 (40,9)	110 (43,1)	47 (43,9)	52 (70,3)	21 (29,2)	$p < 0{,}001$

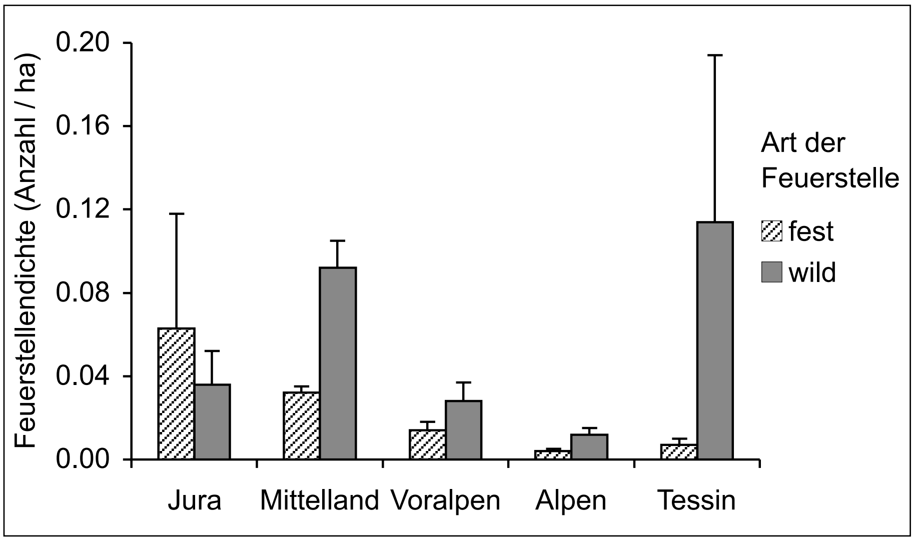

***Abbildung 2:* Anzahl feste und «wilde» Feuerstellen pro ha Wald in den verschiedenen geografischen Regionen der Schweiz.**

Dargestellt sind Mittelwerte ± 1 SE.

Figure 2: Number of official and non-official fire places per ha forest area in various geographical regions of Switzerland. Mean values ± 1 SE are shown.

Dort wird der Wald meistens erst am Nachmittag aufgesucht. Die Agglomerationstypen und der ländliche Raum unterscheiden sich ebenfalls im Besucheraufkommen an den Werktagen ($Chi^2 = 35{,}4$, df = 10, $p < 0{,}001$). 43% der Wälder in grossen Agglomerationen werden an Werktagen häufig oder sehr häufig besucht, 24% der Wälder sind es in kleinen Agglomerationen und 14% der Wälder im ländlichen Raum. An Feiertagen und Wochenenden wurden hingegen keine Unterschiede zwischen den Agglomerationstypen festgestellt.

Das Infrastrukturangebot unterscheidet sich in den verschiedenen Agglomerationstypen und in den geografischen Regionen kaum (*Tabellen 1a* und *b*). Einzig Picknickplätze und Feuerstellen sowie Vitaparcours- und Finnenbahn-Anlagen kommen in Wäldern von grossen Agglomerationen häufiger vor als in anderen Wäldern. Am seltensten sind Picknickplätze und Feuerstellen, Vitaparcours- und Finnenbahn-Anlagen sowie Radwege im Tessin. Bei der Ausstattung mit Wanderwegen, Reitwegen, Lehrpfaden und Waldhütten wurden keine Unterschiede zwischen den einzelnen Regionen der Schweiz festgestellt.

3.3 Picknicken und Grillieren

Die Dichte an fest installierten Feuerstellen (Anzahl Feuerstellen pro Hektare Wald) ist in beiden Agglomerationstypen und im ländlichen Raum etwa gleich (0,02 bis 0,04 Feuerstellen pro Hektare). Hingegen gibt es Unterschiede in der Dichte an so genannten «wilden», das heisst von den Waldbesuchern angelegten Feuerstellen ($F_{2, 349} = 4{,}88$, $p = 0{,}008$). In grossen Agglomerationen ist ihre Dichte mit durchschnittlich 0,14 Feuerstellen/ha mehr als doppelt so hoch wie im ländlichen Raum mit 0,05 Feuerstellen/ha. Geografische Unterschiede in der Dichte gibt es sowohl für feste (*Abbildung 2*; $F_{4, 430} = 5{,}63$, $p < 0{,}001$) wie auch für «wilde» Feuerstellen ($F_{4, 341} = 3{,}54$, $p = 0{,}007$). Die höchste Dichte an festen Feuerstellen findet man im Jura, die geringste im Tessin. Das Tessin weist aber im Gegensatz dazu die höchste Dichte an «wilden» Feuerstellen auf. Im Alpenraum ist die Dichte an «wilden» Feuerstellen eher gering.

In der Deutschschweiz hat es mit 0,024 Feuerstellen/ha Wald ungefähr die gleiche Dichte an festen Feuerstellen wie in der Romandie mit 0,025 Feuerstellen/ha. In der Romandie entspricht die Dichte der «wilden» Feuerstellen (0,024 Feuerstellen/ha) ungefähr derjenigen der festen Feuerstellen, während in der Deutschschweiz die Dichte der «wilden» Feuerstellen (0,071 Feuerstellen/ha) dreimal höher ist als diejenige der festen Feuerstellen. Im Tessin liegt die Dichte der «wilden» Feuerstellen bei 0,114 Feuerstellen/ha. Somit unterscheiden sich die drei Sprachregionen tendenziell bezüglich der Dichte an «wilden» Feuerstellen ($F_{2, 355} = 2{,}74$, $p = 0{,}066$). Laut Beobachtung der Fachleute werden in der Deutschschweiz und in der Romandie feste Feuerstellen häufiger benutzt als «wilde». Im Tessin hingegen werden feste Feuerstellen seltener benutzt als «wilde» ($Chi^2 = 37{,}6$, df = 2, $p < 0{,}001$).

Je nach Funktion der Fachperson sind die Angaben bezüglich Dichte an festen Feuerstellen unterschiedlich ($F_{2, 435} = 12{,}64$, $p < 0{,}001$). Diese Unterschiede sind vor allem auf die Angaben der Waldeigentümer zurückzuführen, welche im Durchschnitt viermal mehr Feuerstellen (0,04 Feuerstellen/ha) angegeben haben als Förster (0,01 Feuerstellen/ha) und fünfmal mehr als Forstingenieure (0,008 Feuerstellen/ha). Auch die Einschätzungen, wie viele «wilde» Feuerstellen sich in einem Waldgebiet befinden, variieren je nach Funktion der Fachperson ($F_{2, 343} = 9{,}02$, $p < 0{,}001$). Förster geben die tiefsten Zahlen an (0,023 Feuerstellen/ha), Forstingenieure schätzen die Anzahl «wilder» Feuerstellen viermal (0,089 Feuerstellen/ha), Waldeigentümer fünfmal (0,107 Feuerstellen/ha) höher ein als die Förster.

Feste und «wilde» Feuerstellen unterscheiden sich teilweise in ihrer Lage. Laut Einschätzung der Fachleute hat es entlang von Waldrändern mehr feste als «wilde» Feuerstellen ($Chi^2 = 11{,}5$, df = 1, $p < 0{,}001$). Unmittelbar neben Waldstrassen liegen viele feste, hingegen fast keine «wilden» Feuerstellen ($Chi^2 = 75{,}0$, df = 1, $p < 0{,}001$). Letztere befinden sich häufig weiter als 60 m ($Chi^2 = 27{,}8$, df = 1, $p < 0{,}001$) oder sogar weiter als 200 m ($Chi^2 = 31{,}3$, df = 1, $p < 0{,}001$) von einer Forststrasse entfernt.

Als Gründe für das Einrichten von «wilden» Feuerstellen werden meistens das ungenügende Angebot an festen Feuerstellen, bereits vorhandenes Brennholz sowie der Wunsch nach Abenteuer, Romantik und Individualismus angegeben. Hingegen wird das Entstehen «wilder» Feuerstellen kaum auf die unattraktive Lage oder mangelhafte Ausstattung der festen Feuerstellen zurückgeführt. Je nach geografischer Region werden andere Gründe in den Vordergrund gestellt (*Abbildung 3*; $Chi^2 = 59{,}7$, df = 16, $p < 0{,}001$). Im Tessin gaben über 40% der Fachleute an, «wilde» Feuerstellen seien auf das ungenügende Angebot an festen Feuerstellen zurückzuführen. In den Bergregionen (Jura, Voralpen, Alpen) scheinen Abenteuer, Romantik und Individualismus für das Einrichten «wilder» Feuerstellen ausschlaggebend zu sein. Im Mittelland wird häufig das bereits vorhandene Brennholz aus Holzschlägen als Grund für das Einrichten der «wilden» Feuerstellen angenommen.

Die Hauptgründe für das Einrichten von «wilden» Feuerstellen unterscheiden sich auch je nach Sprachregion ($Chi^2 = 38{,}1$, df = 8, $p < 0{,}001$). Abenteuer, Romantik und Individualismus scheinen vor allem in der Romandie eine wichtige Rolle zu spielen, während in der Deutschschweiz das

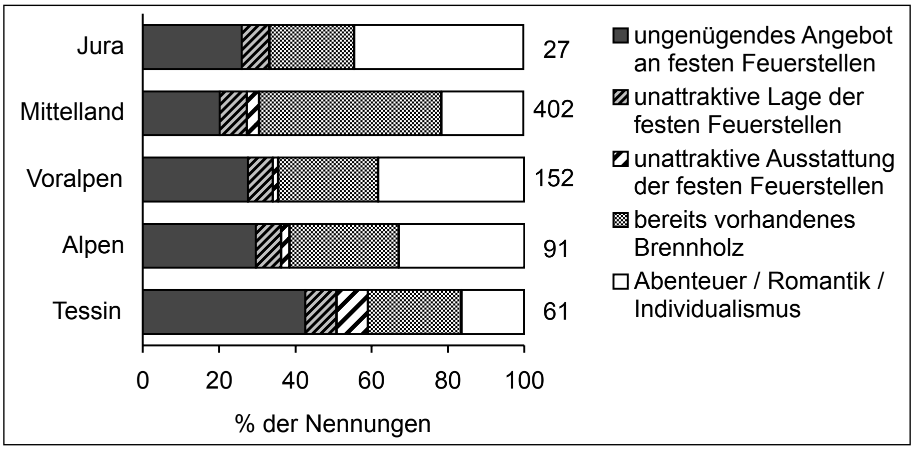

Abbildung 3: **Prozentuale Verteilung der Gründe für das Einrichten von «wilden» Feuerstellen in den verschiedenen geografischen Regionen der Schweiz.**

Die Zahlen neben den Balken bezeichnen die Anzahl Antworten. Mehrfachnennungen waren möglich (562 Personen gaben 733 Antworten).

Figure 3: Frequency distribution (in %) of the reasons for building fires outside official sites in the various geographical regions of Switzerland. Figures next to the bars represent the number of answers. Multiple answers were possible (562 respondents gave 733 answers).

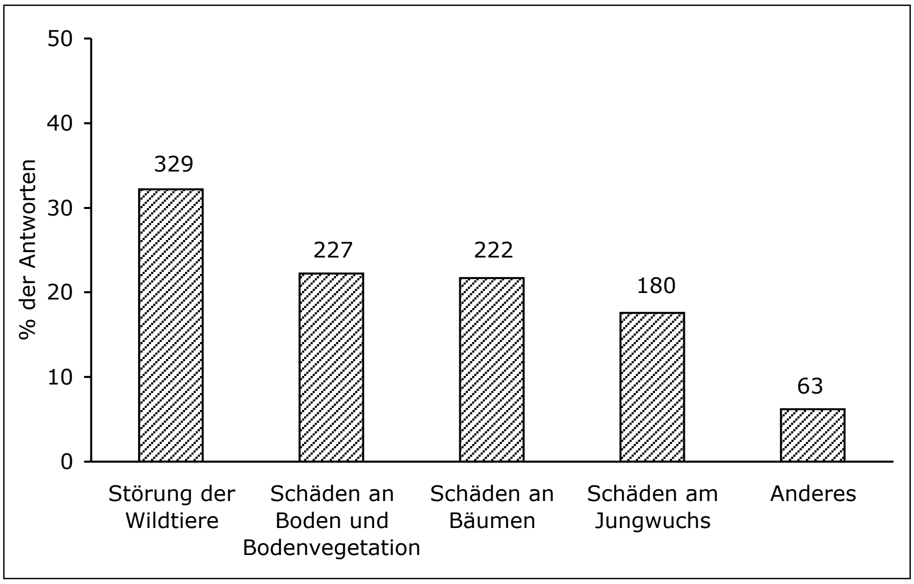

Abbildung 4: **Prozentualer Anteil der Antworten bezüglich freizeitnutzungsbedingter Störungen von Wildtieren und Schäden an Boden, Bodenvegetation, Bäumen und Jungwuchs.**

Die Zahlen über den Balken bezeichnen die Anzahl Antworten. Mehrfachnennungen waren möglich (562 Personen gaben 1021 Antworten).

Figure 4: Percentage of responses concerning disturbances to wildlife and damages to the ground and ground vegetation, trees and young trees due to recreational activities in their forest area. Figures above the bars represent the number of answers. Multiple answers were possible (562 respondents gave 1021 answers).

bereits vorhandene Brennholz als wichtigster Grund angegeben wird.

Förster, Forstingenieure und Waldeigentümer schätzen die Gründe für das Einrichten von «wilden» Feuerstellen unterschiedlich ein ($Chi^2 = 79{,}9$, df = 8, $p < 0{,}001$). Während Förster und Forstingenieure ein ungenügendes Angebot an festen Feuerstellen und Individualismus sowie das Bedürfnis nach Abenteuer und Romantik als Hauptgründe vermuten, wird von den Waldeigentümern bereits vorhandenes Brennholz als Hauptgrund angegeben.

Laut den Angaben der Fachleute unterscheiden sich die Spektren der Besucher von festen und «wilden» Feuerstellen (*Tabelle 2*; Chi^2-Test). An «wilden» Feuerstellen sind vor allem Kleingruppen und Einzelpersonen sowie Pfadfinder und ähnliche Gruppierungen zu finden. Andere Grossgruppen bevorzugen feste Feuerstellen. Nur Familien benutzen feste und «wilde» Feuerstellen etwa gleich häufig.

3.4 Konflikte und Schäden durch allgemeine Erholungsnutzung

Die Fachleute beobachten am häufigsten Konflikte zwischen der Erholungsfunktion und der Jagd sowie zwischen der Erho-

Tabelle 2: **Charakterisierung der Besuchergruppen von festen und «wilden» Feuerstellen.**

Die Anzahl Nennungen (in Klammern die prozentualen Anteile) sind dargestellt (einige Befragte gaben keine Antwort auf diese Frage).

Table 2: Characterisation of user groups of official and non-official fire places. The number of answers (in parentheses the percentage) is shown (not all respondents answered this question).

	Feste Feuerstellen	«Wilde» Feuerstellen	Chi^2 – Tests
Einzelpersonen	53 (30,8)	119 (69,2)	$p < 0{,}0001$
Familien	351 (51,7)	328 (48,3)	n.s.
Kleingruppen	210 (46,7)	240 (53,3)	$p = 0{,}0019$
Gruppen bis 15 Personen	254 (78,2)	71 (21,8)	$p < 0{,}0001$
Gruppen ab 16 Personen	172 (84,3)	32 (15,7)	$p < 0{,}0001$
Grossgruppen ab 16 Personen			
Kindergarten	146 (90,7)	15 (9,3)	$p < 0{,}0001$
Schulklassen	231 (85,9)	38 (14,1)	$p < 0{,}0001$
Pfadfinder / Jungschar	102 (43,2)	134 (56,8)	$p = 0{,}0005$
Vereine	220 (83,7)	43 (16,3)	$p < 0{,}0001$
Naturschutzgruppen	75 (92,6)	6 (7,4)	$p < 0{,}0001$

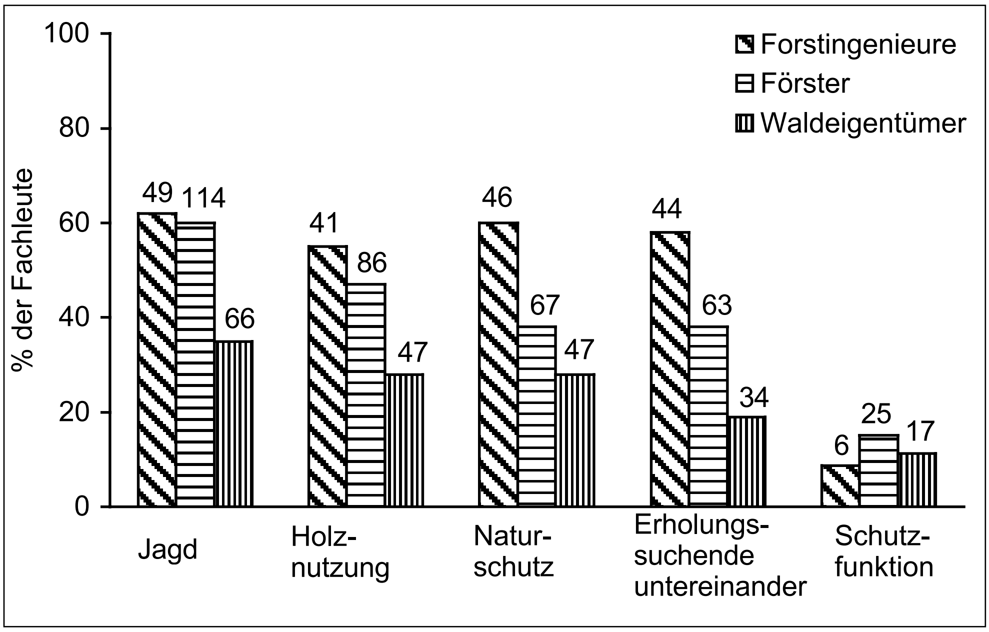

Abbildung 5: **Prozentualer Anteil der Fachleute, welche Konflikte zwischen der Erholungsfunktion und den übrigen Waldfunktionen Holznutzung, Naturschutz, Schutz sowie zwischen Erholung und Jagd und zwischen Gruppen von Erholungssuchenden beobachteten.**

Die Zahlen über den Balken bezeichnen die Anzahl Antworten. Mehrfachnennungen waren möglich. 70 bis 79 Forstingenieure, 164 bis 190 Förster und 150 bis 190 Waldeigentümer gaben Antwort auf diese Frage.

Figure 5: Percentage of forestry experts who reported conflicts between recreation and the other forest functions wood production, nature conservation, avalanche and landslide protection, as well as conflicts between recreation and hunting and between groups of recreationists. Figures above the bars represent the number of answers. Multiple answers were possible. 70 to 79 forestry officials, 164 to 190 foresters and 150 to 190 forest owners answered this question.

lungsfunktion und der Holznutzung. Konflikte von Erholungssuchenden untereinander spielen laut den Fachleuten eine vergleichsweise geringe Rolle, und Konflikte zwischen der Erholung und der Schutzfunktion werden kaum festgestellt. Entsprechend wird bei durch Erholungsnutzung entstandenen Schäden die Störung der Wildtiere am häufigsten genannt *(Abbildung 4).* Weiter entstehen durch die Erholungsnutzung Schäden am Waldboden und an der Bodenvegetation sowie an den Bäumen und in etwas geringerem Ausmass am Jungwuchs.

Generell werden Konflikte in Wäldern von grossen Agglomerationen häufiger beobachtet als Konflikte in kleinen Agglomerationen oder im ländlichen Raum. Dies gilt insbesondere für Konflikte zwischen Erholungssuchenden und der Forstwirtschaft ($Chi^2 = 11,0$, $df = 2$, $p = 0,004$) und Erholungssuchenden und dem Naturschutz ($Chi^2 = 12,1$, $df = 2$, $p = 0,002$). In grossen Agglomerationen werden auch die meisten Schäden registriert – und zwar solche am Waldboden und an der Bodenvegetation ($Chi^2 = 10,6$, $df = 2$, $p = 0.005$) wie auch solche an Bäumen ($Chi^2 = 16,6$, $df = 2$, $p < 0,001$) und am Jungwuchs ($Chi^2 = 19,1$, $df = 2$, $p < 0,001$). Nur die Störung der Wildtiere wird in Wäldern von kleinen Agglomerationen und im ländlichen Raum gleich häufig wie in Wäldern von grossen Agglomerationen angegeben ($Chi^2 = 3,2$, $df = 2$, $p = 0,2$, ns).

Konflikte irgendwelcher Art scheinen vor allem in der Deutschschweiz häufig vorzukommen. Einen Konflikt mit der Jagd geben 54 % der antwortenden Fachleute aus der Deutschschweiz an, 40 % der Fachleute aus dem Tessin und 35 % aus der Romandie ($Chi^2 = 11,7$, $df = 2$, $p = 0,003$). Konflikte mit dem Naturschutz werden von 41 % der Antwortenden aus der Deutschschweiz, 32 % aus der Romandie und 20 % der Antwortenden aus dem Tessin beobachtet ($Chi^2 = 7,5$, $df = 2$, $p = 0,023$). Auch Konflikte zwischen verschiedenen Gruppen von Erholungssuchenden treten laut den Fachleuten in der Deutschschweiz häufiger auf (36 % der Antworten) als in der Romandie (26 % der Antworten) und im Tessin (20 % der Antworten; $Chi^2 = 7,2$, $df = 2$, $p = 0,027$).

Auch in der Häufigkeit der beobachteten Schäden unterscheiden sich die Sprachregionen. Eine Störung der Wildtiere wird in der Deutschschweiz häufiger wahrgenommen (77 % der Antworten) als in der Romandie und im Tessin (je 56 % der Antworten; $Chi^2 = 19,6$, $df = 2$, $p < 0,001$). Schäden an den Bäumen sind offenbar im Tessin kaum ein Thema (13 % der Antworten), während in der Romandie 50 % und in der Deutschschweiz 57 % der Antwortenden diesbezüglich Schäden registrierten ($Chi^2 = 28,4$, $df = 2$, $p < 0,001$). Analog verhält es sich mit den Schäden am Jungwuchs, welche von 21 % der antwortenden Fachleute aus dem Tessin, 46 % aus der Romandie und 44 % der Antwortenden aus der Deutschschweiz genannt werden ($Chi^2 = 9,0$, $df = 2$, $p = 0,011$). Lediglich Schäden am Waldboden und an der Bodenvegetation werden in allen drei Sprachregionen gleich häufig erkannt ($Chi^2 = 4,6$, $df = 2$, $p = 0,1$, ns).

Waldeigentümer schätzen das Ausmass der verschiedenen Konflikte geringer ein als Förster und Forstingenieure *(Abbildung 5).* Während Forstingenieure und Förster etwa gleich häufig Konflikte mit der Jagd angeben, stellen weitaus weniger Waldeigentümer einen Konflikt in diesem Bereich fest ($Chi^2 = 30,3$, $df = 2$, $p < 0,001$). Dasselbe Bild ergibt sich bei Konflikten mit der Forstwirtschaft. 55 % der Forstingenieure und 47 % der Förster nehmen Konflikte mit der Forstwirtschaft wahr, aber nur 28 % der Waldeigentümer ($Chi^2 = 20,0$, $df = 2$, $p < 0,001$). Auch Konflikte zwischen Erholungssuchenden und dem Naturschutz nehmen Forstingenieure häufiger wahr als Förster und Waldeigentümer ($Chi^2 = 22,7$, $df = 2$, $p < 0,001$). Des Weiteren beobachten Forstingenieure am häufigsten Konflikte zwischen verschiedenen Gruppen von Erholungssuchenden. Solche Konflikte wurden wiederum in geringerem Ausmass von den Förstern und den Waldeigentümern beobachtet ($Chi^2 = 39,5$, $df = 2$, $p < 0,001$). Schäden werden ebenfalls von Forstingenieuren am stärksten und von Waldeigentümern am geringsten wahrgenommen und zwar unabhängig davon, ob es sich dabei um Schäden am Waldboden und an der Bodenvegetation ($Chi^2 = 22{,}0$, df = 2, $p < 0{,}001$), an Bäumen ($Chi^2 = 14{,}1$, df = 2, p = 0,003), am Jungwuchs ($Chi^2 = 6{,}0$, df = 2, p = 0,049) oder um eine Störung der Wildtiere ($Chi^2 = 17{,}4$, df = 2, $p < 0{,}001$) handelt.

3.5 Konflikte und Schäden durch Picknicken und Grillieren

Als Konflikte und Schäden, welche durch Picknicken und Grillieren entstehen können, nannten die Fachleute in erster Linie liegen gelassenen Abfall, Beeinträchtigung der Natur (Jungwuchs, Bäume, Wildtiere), Lärm und Waldbrandgefahr. Konflikte kommen in grossen Agglomerationen mit 48 % der Antworten am häufigsten vor ($Chi^2 = 14{,}0$, df = 2, p = 0,001), und ihre Häufigkeit nimmt mit abnehmender Agglomerationsgrösse ab. Im ländlichen Raum liegt ihre Häufigkeit mit 23 % der Antworten unter dem Schweizer Durchschnitt (25 % der Antworten). Mit den Schäden verhält es sich analog. Interessant sind die regionalen Unterschiede (Konflikte: $Chi^2 = 12{,}7$, df = 4, p = 0,013, Schäden: $Chi^2 = 13{,}1$, df = 4, p = 0,011): Im Jura entspricht die Häufigkeit an beobachteten Konflikten etwa dem schweizerischen Durchschnitt, die auftretenden Schäden liegen jedoch darunter. Das heisst, dass im Jura Konflikte im Zusammenhang mit Picknicken und Grillieren relativ häufig wahrgenommen werden, Schäden aber eher selten im Vergleich zur restlichen Schweiz. Im Mittelland werden sowohl Konflikte wie auch Schäden als hoch eingestuft, in den Voralpen und Alpen als tief. Im Tessin ist die Situation umgekehrt zur Situation im Jura: Hier werden häufig Schäden durch Picknicken und Grillieren registriert, die wahrgenommenen Konflikte hingegen liegen unter dem Schweizer Durchschnitt. Die vielen Schäden scheinen dort also vergleichsweise selten zu Konflikten zu führen.

Die drei Sprachregionen der Schweiz unterscheiden sich nur bezüglich der Konflikte durch Picknicken und Grillieren, welche in der Romandie als ein kleineres Problem wahrgenommen werden als in der restlichen Schweiz ($Chi^2 = 9{,}9$, df = 2 p = 0,007). Die Häufigkeit der dabei entstehenden Schäden wird in den drei Sprachregionen gleich eingestuft ($Chi^2 = 2{,}3$, df = 2, p = 0,3, ns). Konflikte und Schäden werden durch die Fachleute unterschiedlich eingeschätzt ($Chi^2 = 10{,}6$, df = 2, p = 0,005, bzw. $Chi^2 = 7{,}2$, df = 2, p = 0,027). Forstingenieure beobachten am häufigsten Konflikte und Schäden, Waldeigentümer am seltensten.

3.6 Lenkungsmassnahmen

67 % der Fachleute geben an, in ihrem Waldgebiet Lenkungsmassnahmen zur Begrenzung der Konflikte und Schäden durch allgemeine Freizeitnutzung ergriffen zu haben. Die Massnahmen lassen sich in die beiden Kategorien direkte Besucherlenkung (Verbote, Absperrungen) und indirekte Besucherlenkung (Information, Lenkung durch Infrastrukturangebote) einteilen *(Tabelle 3)*. Massnahmen werden je nach Funktion der Fachperson in unterschiedlichem Ausmass umgesetzt ($Chi^2 = 18{,}1$, df = 2, $p < 0{,}001$). So hatten bisher 80 % der Forstingenieure Massnahmen getroffen, 73 % der Förster und 55 % der Waldeigentümer.

Arbeitsaufwand und Kosten im Bereich Erholung betragen bei über 85 % der antwortenden Fachleute weniger als 10 % ihres Gesamtaufwandes bzw. ihrer Gesamtkosten. In grossen Agglomerationen hingegen liegt der Arbeitsaufwand bei rund einem Viertel der Fachleute bei über 10 % ihres Gesamtaufwandes, und die dadurch entstehenden Kosten betragen in 40 % der Fälle mehr als 10 % der Gesamtkosten. In kleinen Agglomerationen entsprechen Aufwand und Kosten dem schweizerischen Durchschnitt, im ländlichen Raum liegen sie darunter (Arbeitsaufwand: $Chi^2 = 10{,}2$, df = 2, p = 0,006; Kosten: $Chi^2 = 25{,}0$, df = 2, $p < 0{,}001$).

63 % der Fachleute wünschen sich eine finanzielle Unterstützung im Bereich der Erholungsnutzung, und 54 % wünschen mehr Unterstützung in der Informationspolitik. Davon entfallen 15 % auf den Wunsch nach mehr Öffentlichkeitsarbeit und 51 % auf den Wunsch nach mehr Verhaltensregeln. Im administrativen (19 %) und personellen (17 %) Bereich scheint eine vermehrte Unterstützung weniger dringend zu sein. Nur in grossen Agglomerationen wird mehr Personal gewünscht (33 % der Antworten; $Chi^2 = 8{,}08$, df = 2, p = 0,018). Obschon in der ganzen Schweiz mehr Finanzen zur Bewältigung der Aufgaben im Bereich Erholungsnutzung im Wald gewünscht werden, ist dieses Bedürfnis nicht überall gleich gross. In der Romandie und im Tessin wünschen 74 % bzw. 71 % der Fachleute finanzielle Unterstützung, in der Deutschschweiz 59 % ($Chi^2 = 9{,}2$, df = 2, p = 0,010). Unter den Fachleuten sind es vor allem die Förster (75 %), die mehr finanzielle Mittel wünschen, bei den Forstingenieuren sind es 56 %, bei den Waldeigentümern 54 % ($Chi^2 = 20{,}4$, df = 2, $p < 0{,}001$). 41 % der Forstingenieure plädieren für mehr Verhaltensregeln, im Gegensatz zu 27 % der Förster und 25 % der Waldeigentümer ($Chi^2 = 7{,}1$, df = 2, p = 0,029). Mehr Verhaltensregeln wären auch in der Romandie willkommen (40 % der Antworten), mehr als in der Deutschschweiz (26 % der Antworten) und im Tessin (25 % der Antworten; $Chi^2 = 6{,}0$, df = 2, p = 0,049).

***Tabelle 3:* Lenkungsmassnahmen zur Begrenzung von Konflikten und Schäden durch allgemeine Freizeitnutzung im Schweizer Wald, eingeteilt in direkte und indirekte Besucherlenkung.**

Table 3: Management actions to reduce conflicts and damages resulting from recreational activities in Swiss forests, split into direct and indirect actions.

Direkte Besucherlenkung	Indirekte Besucherlenkung
Fahr- und Reitverbot	Natürliche Hindernisse aufstellen / Dorngestrüpp wachsen lassen
Wege absperren	Lenkung durch Infrastrukturangebot (feste Feuerstellen, Holzschnitzelpfade, Teich für Froschbeobachtungen usw.)
Einzäunen gewisser Gebiete (z.B. Jungwuchsflächen)	
Leinenzwang (z.T. zeitlich und räumlich beschränkt)	Entflechten verschiedener Nutzungen, z.B. mit einer öffentlichen Bikerroute
Vermehrte Kontrollen, Bussen, Verzeigungen	Gespräch mit Clubs, Vereinen usw. suchen
Wildschutzzonen	Besucherinformation (Hinweistafeln, Plakate, Informationsanlässe, Waldtage mit Schulen, Information via Presse)
Planerische Massnahmen mittels WEP (Zonen mit Erholung als Vorrang)	

4. Diskussion

4.1 Waldfunktionen

Die Untersuchung ergab, dass in grossen Agglomerationen Erholung und Holznutzung, im ländlichen Raum Schutz und Holznutzung von den Fachleuten als wichtig erachtet werden. Auch die Ergebnisse des zweiten schweizerischen Landesforstinventars (LFI2) weisen darauf hin, dass Gebiete mit grosser oder sehr grosser Erholungsnachfrage in den Städten und Agglomerationen des Mittellandes liegen (Brassel & Brändli 1999). Die Bedeutung der Holznutzung in Agglomerationsnähe zeigt aber auch, dass die Erholungsfunktion die traditionelle Funktion des Waldes als Holzlieferant nicht einfach abgelöst hat, sondern dass der Wald heute mehrere Funktionen gleichzeitig zu erfüllen hat (Koch & Kennedy 1991; Führer 2000).

4.2 Allgemeine Freizeitnutzung

Die am häufigsten beobachteten Freizeitaktivitäten im Wald sind Spazieren/Wandern, Joggen, Biken und Picknicken/Grillieren. Diese Beobachtungen decken sich grösstenteils mit den Ergebnissen einer Umfrage bei der Schweizer Bevölkerung (Zeidenitz 2005). Der grösste Unterschied findet sich bei der Aktivität «Natur beobachten», welche bei Zeidenitz (2005) an dritter Stelle steht. Diese Diskrepanz ist möglicherweise darauf zurückzuführen, dass es für die Fachleute nicht immer offensichtlich ist, ob sich jemand zur Naturbeobachtung im Wald aufhält oder eine andere Aktivität ausübt. Pilze und Beeren sammeln ist im ländlichen Raum die am dritthäufigsten beobachtete Freizeitaktivität. Pilze und Beeren waren ursprünglich ein Teil der Ernährung der ländlichen Bevölkerung. Gerade für das Pilzesammeln braucht es spezielle Kenntnisse bezüglich geniessbarer Arten und Wuchsstandorten und die Fähigkeit zur Orientierung im Wald. Diese Fähigkeiten und Kenntnisse sind für Leute, die weit weg vom Wald wohnen und nur einen geringen Bezug zum Wald haben, schwierig zu erwerben (Sievänen *et al*. 2004). Dies mag ein Grund sein, warum Pilze und Beeren sammeln im ländlichen Raum häufiger vorkommt als in den Agglomerationen.

Laut Einschätzung der Fachleute nimmt das Ausmass an Freizeitaktivitäten im Wald weiterhin zu. Diese Zunahme dürfte mehrere Gründe haben. Einerseits haben die Menschen heutzutage mehr Freizeit als früher, andererseits wächst der Wunsch nach freier Natur in der heutigen technisierten und virtualisierten Welt (Müller 2005). Die beobachtete Nutzung von Agglomerationswäldern an Werktagen und ländlichen Wäldern an Wochenenden und Feiertagen deckt sich mit den Aussagen von Janse & Ottitsch (2005), wonach stadtnahe Wälder hauptsächlich für die tägliche Erholung genutzt werden, während Gebiete mit viel Wald und einer geringen Bevölkerungsdichte eher dem Tourismus dienen.

4.3 Picknicken und Grillieren

Die Dichte an «wilden» Feuerstellen ist in grossen Agglomerationen mehr als doppelt so hoch wie im ländlichen Raum. Dies weist erneut auf den hohen Nutzungsdruck in urbanen Wäldern hin. Auch im Tessin und im Mittelland hat es wesentlich mehr «wilde» als feste Feuerstellen. Die Fachleute führen das Einrichten von «wilden» Feuerstellen meistens auf das ungenügende Angebot an festen Feuerstellen, auf vorhandenes Brennholz und den Wunsch der Waldbesucher nach Abenteuer, Romantik und Individualismus zurück. Im Tessin wurde bei der Befragung die geringe Anzahl an festen Feuerstellen grösstenteils mit der Waldbrandgefahr und dem damit verbundenen Feuerverbot (LLI, Art. 4) begründet. *Abbildung 2* zeigt allerdings, dass das Tessin von allen Regionen die höchste Dichte an «wilden» Feuerstellen aufweist, woraus zu schliessen ist, dass durch ein fehlendes Angebot an festen Feuerstellen die Waldbesucher nicht vom Feuermachen abgehalten werden können.

Interessant ist das Ergebnis, dass sehr wenige Fachleute «wilde» Feuerstellen auf die ungeeignete Lage oder unattraktive Ausstattung der festen Feuerstellen zurückführen. Allerdings liegen laut Angaben der Fachleute viele feste Feuerstellen unmittelbar neben Waldstrassen, während die meisten «wilden» Feuerstellen weit weg von Waldstrassen zu finden sind. Benutzer von «wilden» Feuerstellen halten sich offenbar ungern direkt neben Waldstrassen auf. Die Fachleute beobachten auch unterschiedliche Benutzergruppen an festen und «wilden» Feuerstellen. Die Ergebnisse einer im Jahr 2004 bei Besuchern im stadtnahen Allschwiler Wald und auf dem eher ländlichen Schönmattplateau durchgeführten Umfrage weisen ebenfalls auf verschiedene Benutzergruppen mit unterschiedlichen Ansprüchen hin[4]. Laut den Ergebnissen genügen die Lage und Ausstattung der heutigen festen Feuerstellen den Bedürfnissen jener Benutzergruppen nicht, welche eine naturnahe Umgebung und eine natürliche Infrastruktur bevorzugen. Dies könnte ein Grund für das Entstehen «wilder» Feuerstellen sein. Eine Umfrage in Dänemark zeigte, dass die Bevölkerung einen Wald ohne spezielle Erholungseinrichtungen bevorzugte, obwohl Experten annahmen, dass derartige Einrichtungen bei den Waldbesuchern erwünscht wären (Jensen 1993). In drei Erholungsgebieten in den Staaten Oregon und Washington (USA) nahmen Verantwortliche von Erholungswäldern an, die Besucher würden den Ausbau der Infrastruktur schätzen, was tatsächlich aber nicht der Fall war (Hendee & Harris 1970). Diese Untersuchungen zeigen, wie wichtig es ist, die Planung von Erholungseinrichtungen auf die tatsächlichen Präferenzen der Waldbesucher abzustützen und nicht ausschliesslich auf die Intuition der Fachleute.

4.4 Konflikte und Schäden

Konflikte zwischen der Erholungsfunktion und der Jagd wurden von den Fachleuten am häufigsten angegeben. Dementsprechend wird auch die Störung der Wildtiere durch Erholungssuchende als häufigster Schaden genannt, und zwar im ländlichen Raum und in kleinen Agglomerationen gleich häufig wie in grossen Agglomerationen. Auswirkungen von Freizeitaktivitäten auf Wildtiere wurden in verschiedenen Studien untersucht (Ingold 2005). Murmeltiere flüchten bei der Anwesenheit von Wanderern abseits der Wanderwege in ihren Bau (Mainini *et al*. 1993), Gämsen verlassen beim Auftauchen eines Gleitschirms ihre Weidegebiete (Enggist-Düblin & Ingold 2003). Waldvögel werden durch herannahende Besucher aufgescheucht, selbst wenn sie sich auf den Bäumen befinden und somit nicht direkt «bedroht» sind (Fernandez-Juricic *et al*. 2004). Solche Fluchtreaktionen auf Störungen führen zu einer verringerten Nahrungsaufnahme und einer Beeinträchtigung des Raum-Zeit-Verhaltens (Ingold 2005). Diese Auswirkungen beunruhigen die Jäger (Hackländer 2004)[5]. Auch der Landverbrauch für touristische Infrastruktur stört die Jäger, wird dadurch doch der Lebensraum der einheimischen Wildtiere vermindert (Hackländer 2004; Fally 2005)[6].

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[4] Hegetschweiler *et al.:* Fire place preferences of forest visitors in northwestern Switzerland: Implications for the management of picnic sites (im Druck).

[5] Jagd und Tourismus – ein oder kein Gegensatz? http://www.bljv.at/infoblaetter/infblatt2004_02/inf_m_lr_jagdundtourismus.htm, 4. April 2006.

[6] Jagd und Naturschutz. Info-Blatt des Burgenländischen Jagdverbandes, 2/2005: 10. http://www.bljv.at/ueu_m_oljv_ref_natur_umwelt.htm, 4. April 2006.

Der Ausbau von Strassen, um den Freizeitverkehr zu bewältigen, verringert den Austausch von Individuen zwischen Wildpopulationen. Zudem fallen viele Tiere dem Strassenverkehr zum Opfer (HACKLÄNDER 2004). Es kann aber auch zu direkten Konflikten zwischen Erholungssuchenden und der Jägerschaft kommen. So wies der Jagdaufseher des Allschwiler Waldes (Kanton Baselland) darauf hin, dass die Jagd in diesem stadtnahen Wald wegen der vielen Waldbesucher auf jährlich drei Tage reduziert werden musste (GLASS 2002). Der Bund Bayrischer Berufsjäger erwähnt, dass es an der Schnittstelle Jagd/Erlebnissuchende zu Konflikten kommt und dass es Aufgabe der Jäger sei, durch ihr Verhalten und durch Information zu einem gemeinsamen naturverträglichen Miteinander beizutragen[7]. Als Gründe für Konflikte werden «wenig Verständnis seitens der Waldbesucher für Sinn und Notwendigkeit der Jagd, mangelnde gegenseitige Akzeptanz und gegenseitige Störung und Erschwerung des Jagdbetriebs durch extensive Freizeitnutzung» angegeben[8].

Am zweithäufigsten nennen die Fachleute Konflikte zwischen der Erholung und der Holznutzung. Solche Konflikte können beispielsweise entstehen, wenn Bäume durch Ritzereien an der Rinde oder durch Nägel verletzt werden und deswegen nur noch als Brennholz verkauft werden können (BRATTON *et al*. 1982). Zudem muss bei Holzschlägen die Sicherheit der Waldbesucher gewährleistet werden, was in stark frequentierten Wäldern zu hohen zusätzlichen Kosten führt (LACK 2003). Möglicherweise entstehen solche Konflikte auch, weil die meisten Waldbesucher zuerst an Erholung und an einen natürlichen Lebensraum denken und nicht an die Holznutzung (HEER *et al*. 2003a). Die meisten Waldbesucher sind sich der ökonomischen Werte des Waldes nicht bewusst. Diese unterschiedlichen Ansprüche an den Wald treten auch in einer kanadischen Studie zutage, in welcher die Bevölkerung das Management von Wäldern primär zur Erholung befürwortete, im Gegensatz zu Förstern, welche der Holznutzung den Vorzug gaben (WAGNER *et al*. 1998).

Konflikte von Erholungssuchenden untereinander wurden von den Fachleuten nicht als sehr gravierend betrachtet. Allerdings zeigen Befragungen von Waldbesuchern, dass es in stark frequentierten Gebieten durchaus zu Konflikten zwischen Besuchergruppen kommen kann (BUWAL 1999; HEER *et al*. 2003a; RUSTERHOLZ & BAUR 2003).

Die von den Fachleuten beobachteten Schäden an Boden, Bodenvegetation und an den Bäumen sind mehrfach dokumentiert. Durch die Tritteinwirkung wird der Boden verdichtet, die Bodenvegetation geschädigt und die Samenbank verändert (COLE 1995; LIDDLE 1997; AMREIN *et al*. 2005). Ausserdem werden, wie bereits erwähnt, immer wieder Bäume durch die Waldbesucher verletzt (BRATTON *et al*. 1982).

Konflikte und in der Regel auch Schäden werden in der Deutschschweiz häufiger wahrgenommen als in der Romandie und im Tessin. Eine Ausnahme bilden Schäden durch Picknicken und Grillieren, welche im Tessin als gleich hoch eingestuft werden wie in der restlichen Schweiz. Die im Tessin durch Picknicken und Grillieren hervorgerufenen relativ hohen Schäden können durch die vielen «wilden» Feuerstellen erklärt werden. Allerdings scheinen diese Schäden aus der Sicht der Fachleute nicht zu Konflikten zu führen. Die im Vergleich zur lateinischen Schweiz höhere Konfliktwahrnehmung in der Deutschschweiz könnte auf kulturelle Unterschiede zurückzuführen sein. Die Bevölkerung der Deutschschweiz hat offenbar mehr Mühe mit der Wegwerfmentalität und den Abfallbergen als diejeinige der lateinischen Schweiz und wünscht sich stärker, dass in Zukunft «bei allem Fortschritt die natürlichen Grenzen nicht angetastet werden» (MEIER-DALLACH 1991). Die Bevölkerung der lateinischen Schweiz attestiert den Schweizern bereits ein hohes Umweltbewusstsein und befürchtet eher eine aufkommende Umweltbürokratie. Die Haltung, dass «man einander leben lässt», ist in der Romandie am ausgeprägtesten, was zu einer Entschärfung von Konflikten führt (MEIER-DALLACH 1991).

Am meisten Konflikte und Schäden werden von den Forstingenieuren angegeben, gefolgt von Förstern und Waldeigentümern. Forstingenieure sind für die forstliche Planung verantwortlich und müssen dabei vorhandene und potenzielle Konflikte und Schäden berücksichtigen. Auch die Förster, die für die Planung und Durchführung der Waldbewirtschaftung zuständig sind, werden mit den Konflikten und Schäden konfrontiert, während die Waldeigentümer oft nicht direkt damit zu tun haben.

4.5 Lenkungsmassnahmen

Lenkungsmassnahmen werden am häufigsten von Forstingenieuren, am seltensten von Waldeigentümern getroffen. Für das Ergreifen und Umsetzen von Lenkungsmassnahmen sind in erster Linie Forstingenieure und Förster zuständig, nicht die Waldeigentümer. Dies könnte auch ein Grund für die unterschiedliche Wahrnehmung von Konflikten und Schäden sein. Diejenigen, die Massnahmen zur Eindämmung von Konflikten und Schäden ergreifen müssen, nehmen diese auch am stärksten wahr.

Arbeitsaufwand und Kosten im Bereich Erholung sind in Wäldern von grossen Agglomerationen am höchsten. Auch darin zeigt sich wieder die hohe Bedeutung der Erholungsfunktion stadtnaher Wälder. Eine Mehrheit der Fachleute wünscht eine bessere finanzielle Unterstützung im Bereich Erholung. Verständlich, wenn man bedenkt, dass erholungsnutzungsbedingte Ausgaben mehr als 10 % der Gesamtausgaben eines Forstbetriebs ausmachen können und dass öffentliche Forstbetriebe seit den 1980er-Jahren kaum mehr Gewinne erwirtschaften konnten (KLEIBER & BILECEN 2003). Ebenfalls gross ist der Wunsch nach einer vermehrten Unterstützung im Bereich Informationspolitik, insbesondere beim Aufstellen und Durchsetzen von Verhaltensregeln. In der Tat könnte es sich lohnen, in diesen Bereich mehr zu investieren, da sich verschiedentlich gezeigt hat, dass Informationen die Kenntnisse von Erholungssuchenden über den Zustand des Waldes verbesserten und die Akzeptanz von Pflegemassnahmen erhöhten (JENSEN 2000; HEER *et al*. 2003b). Eine bessere Information der Waldbesucher über die Folgen ihrer Aktivitäten und das Aufzeigen von Alternativen könnte zumindest bei einigen Besuchern zu einem ökologisch verträglicheren Verhalten führen, was wiederum dazu beitragen würde, Konflikte und Schäden einzudämmen.

5. Schlussfolgerungen

Im Bereich der Erholungsnutzung gibt es in den verschiedenen Regionen der Schweiz sowohl Gemeinsamkeiten wie auch Unterschiede. Gerade die grossen Agglomerationen heben sich durch eine intensive Freizeitnutzung des Waldes von der übrigen Schweiz ab. Ein regelmässiger Erfahrungsaustausch zwischen den zuständigen Forstfachleuten könnte helfen, die gemeinsamen Probleme anzugehen und Lösungen zu entwickeln. Da die Einschätzungen der Forstfachleute zum Teil

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[7] Jagd, Wildtiermanagement und Biotophege – Naturschutz für Bayern. Der Berufsjäger – wichtiger denn je. Bund Bayrischer Berufsjäger e.V.: 10 http://www.berufsjaeger-bayern.de/dokumente/broschuere_2005.pdf, 4. April 2006.

[8] Persönliche Mitteilung von B. Freuler (WSL).

auseinander gehen und sich nicht immer mit den Wahrnehmungen der Waldbesucher decken, ist es bei der Erholungsplanung wichtig, die Meinung aller Beteiligten, inklusive der Waldbesucher, einzuholen.

Zusammenfassung

Die Erholungsfunktion des Waldes hat in agglomerationsnahen Gebieten eine hohe Bedeutung. Picknicken und Grillieren gehören zu den beliebtesten Freizeitaktivitäten in Schweizer Wäldern. Während es in Wäldern von grossen und kleinen Agglomerationen und im ländlichen Raum etwa gleich viele fest installierte Feuerstellen pro Hektare Wald gibt, ist die Dichte von so genannten «wilden» Feuerstellen in grossen Agglomerationen besonders hoch. Nach Angaben von Fachleuten führen eine ungenügende Anzahl an festen Feuerstellen, vorhandenes Brennholz und der Wunsch der Waldbesucher nach Abenteuer und Romantik immer wieder zur Entstehung «wilder» Feuerstellen. Freizeitaktivitäten im Wald führen öfters zu Konflikten. Vor allem Konflikte mit der Jagd scheinen in allen Regionen der Schweiz besonders ausgeprägt zu sein. Dabei wird die Störung von Wildtieren durch Erholungssuchende als grosses Problem betrachtet. Zur Entschärfung solcher Konflikte werden vielerorts Massnahmen in Form von direkter und indirekter Besucherlenkung ergriffen.

Résumé

L'importance de la forêt comme lieu de récréation, à l'exemple des pique-niques et des grillades: résultats d'une enquête menée dans l'ensemble de la Suisse auprès des professionnels de la forêt et des propriétaires forestiers

La fonction récréative de la forêt revêt une grande importance dans les régions situées à proximité des agglomérations. Les pique-niques et les grillades font partie des activités récréatives favorites exercées dans les forêts suisses. Alors que le nombre de foyers permanents installés par hectare dans l'aire boisée entourant les grandes et petites agglomérations correspond à peu près à celui des aménagements en zone rurale, la densité des foyers dits «sauvages» est particulièrement élevée au voisinage des grands centres urbains. Selon les indications fournies par des spécialistes, le manque de foyers aménagés, de bois de feu à disposition et le désir d'aventure et de romantisme des visiteurs seraient à l'origine de l'apparition des nouveaux foyers «sauvages». Les activités récréatives en forêt engendrent fréquemment des conflits. Les différends relatifs à la chasse semblent particulièrement marqués dans toutes les régions de Suisse. Le dérangement du gibier par les visiteurs de la forêt est par conséquent considéré comme un problème important. Des mesures de gestion directe et indirecte du flux de visiteurs sont prises à de nombreux endroits pour désamorcer ce genre de conflits.

Traduction: Claude Gassmann

Summary

The relevance of forest recreation exemplified by picnicking and grilling: Results of a nationwide survey aimed at forestry experts and public forest owners in Switzerland

The recreational function of forests is highly relevant in urban areas. Picnicking and grilling are two of the most popular recreational activities in Swiss forests. While the density of official picnic sites with barbecue pits (number per ha) is similar in forests near large and small urban areas and in rural areas, the density of fire rings outside official picnic sites is especially high in forests that surround large urban areas. According to experts, the low concentration of barbecue pits and available firewood coupled with forest visitors seeking adventure and romanticism often lead to the creation of «wild» fire rings. Recreational activities in the forest often lead to conflicts. Conflicts between recreation and hunting, in particular, seem to be pronounced in all areas of Switzerland. The disturbance of wildlife by recreationists is regarded as a major problem. In many places, direct and indirect management actions are implemented in order to reduce these conflicts.

Translation: Angela Rast-Margerison

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Chapter 2

Effects of fire place use on forest vegetation and amount of woody debris in suburban forests in northwestern Switzerland

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Abstract

Urban forests are popular recreation areas in Europe. Several of these temperate broad-leaved forests also have a high conservation value due to sustainable management over many centuries. Recreational activities, in particular the use of fire places, can cause extensive damage to soil, ground vegetation, shrubs and trees. Firewood collection depletes woody debris, leading to a loss of habitat for specialized organisms. We examined the effects of fire place use on forest vegetation and the amount of woody debris by comparing disturbed and control plots in suburban forests in northwestern Switzerland. At frequently used fire places we found reduced species densities in the ground vegetation and shrub layer and changes in plant species composition due to human trampling within an area of 150–200 m^2. Picnicking and grilling also reduced the height and changed the age structure of shrubs and young trees. The amount of woody debris was lower in disturbed plots than in control plots. Pieces of wood with a diameter of 0.6–7.6 cm were preferentially collected by fire place users. The reduction in woody debris volume extended up to a distance of 16 m from the fire ring, covering an area of 800 m^2 at each picnic site. In order to preserve the ecological integrity of urban forests and to maintain their attractiveness as important recreation areas, we suggest depositing logging residues to be used as firewood and to restrict visitor movements near picnic sites.

Keywords picnicking, grilling, outdoor recreation, firewood collection, human trampling, nature conservation, sustainable forest management

Introduction

Outdoor recreation in forests has become an important part of many people's lives, especially in urban areas, where forests are often the only freely accessible natural areas to spend some leisure time (Jacsman 1998, Niemelä 1999). Several of these temperate, broad-leaved forests were sustainably managed over centuries to support a high number of oak (*Quercus* sp.) trees, which gives them a high conservation value (Delarze and others 1999). Nowadays, forests have become multifunctional, fulfilling ecological, economical and social services (Führer 2000, Mather 2001). Large numbers of forest visitors can lead to conflicts between recreation and nature conservation and between recreation and wood production (Liddle 1997, Baur 2003). Numerous ecological studies have reported impacts of recreational activities on soil and vegetation (e.g. Cole 1995, Malmivaara and others 2002, Waltert and others 2002, Roovers and others 2004). The extent of damage depends on the kind of recreational activity and frequency of visitors, but also on the type of soil and vegetation (Cole 1987, Kuss 1986). In particular, activities such as picnicking, barbecuing and camping can impact large areas and allow damages to spread to previously untouched areas (Jim 1987, Marion and Cole 1996, Kutiel and Zhevelev 2001, Amrein and others 2005).

The use of picnic sites to grill and barbecue can cause impacts other than trampling damage associated with picnicking and camping. A survey in Switzerland revealed that on average 50% of fire place users collect firewood from the surrounding area (Rusterholz and others 2000). The collection of firewood can deplete woody debris in the vicinity of fire places and lead to soil compaction and damages to shrubs and trees that extend further than the vegetation loss normally documented (Reid and Marion 2005). Several studies have shown that the amount of dead wood available is the key factor determining species richness of numerous specialized organisms including mosses, lichens, fungi and invertebrates, especially insects (Haase and others 1998, Kruys and Jonsson 1999, Jabin and others 2004, Jonsell and others 2007). In spite of this important ecological role of dead wood, only a few studies have examined the impact of fire building on the abundance of woody debris. Notable exceptions are Bratton and others (1982), Hall and Farrell (2001) and Smith and Newsome (2002) who found that the use of campfires reduced the biomass of woody debris.

Suburban oak-beech forests in northwestern Switzerland harbor a remarkably diverse ground vegetation and are considered as local hot spots for insect diversity (Haase and others 1998, Delarze and others 1999). During the twentieth century, the area of this particular forest type decreased dramatically due to changes in forest management. Today, this forest type only covers 2.0% of the total forest area in Switzerland (Bonfils and others 2005). At the same time, these oak-beech forests are appreciated as recreation sites by the urban population due to their proximity to towns and cities (Baur 2003).

Grilling sausages in the forest is a traditional pastime in Switzerland. A nation-wide survey aimed at forestry experts showed that picnicking and grilling is the third most frequently observed activity in urban forests during the summer months (Hegetschweiler and others 2007). In the following, we present a study designed to examine the effects of fire place use on forest soil and vegetation and on the amount of woody debris. To our knowledge, this is the first study in Europe to quantify the depletion of woody debris and the subsequent habitat loss for specialized organisms due to the collection of firewood for recreational purposes. The following questions were addressed: (1) To what extent do ground vegetation characteristics, amount of leaf litter and soil characteristics change as a result of picnicking and grilling? (2) What is the impact of picnicking and grilling on the shrub and tree layers and how far do forest-visitor induced changes extend? (3) To what extent is the amount of woody debris depleted by building fires and what is the spatial dimension of this depletion?

Material and Methods

Study Sites

The study was conducted at nine fire places in oak-beech forests in the vicinity of Basle in northwestern Switzerland (Table 1). Common tree species in these forests are beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*), oak (*Quercus robur*), and hornbeam (*Carpinus betulus*). Frequent species in the understorey include *Ranunculus ficaria*, *Hedera helix*, *Carex sylvatica,* and *Galium odoratum*. Mean annual temperature at the study sites ranges from 8.9 to 10.4 °C and annual precipitation from 778 to 979 mm (MeteoSwiss 2005a and b). All forests are frequently used for recreation by the public from the towns nearby.

Table 1 Characteristics of the nine study sites in forests near Basle, Switzerland

Study site	Altitude (m a.s.l.)	Forest vegetation type[a]	Soil type[b]	Type of fire place[c]	Impacted area Z1 + Z2 (m^2)
1 Chuestelli	357	*Galio odorati-Fagetum Luzuletosum*	Gleyic cambisol	O	1943
2 Vögtenhägli	320	*Luzulo silvaticae-Fagetum typicum*	Haplic luvisol	V	343
3 Geiser	355	*Galio odorati-Fagetum typicum*	Gleyic cambisol	V	7518
4 Fiechtenrain	414	*Galio odorati-Fagetum typicum*	Gleyic cambisol	V	86
5 Bruderholz	360	*Galio odorati-Fagetum typicum*	Haplic luvisol	V	248
6 Rütihard	300	*Galio odorati-Fagetum Luzuletosum*	Haplic luvisol	V	72
7 Rothalle	410	*Galio odorati-Fagetum Pulmonarietosum*	Haplic luvisol	V	164
8 Eigental	461	*Galio odorati-Fagetum Pulmonarietosum*	Haplic luvisol	V	57
9 Galms	345	*Galio odorati-Fagetum typicum*	Gleyic cambisol	O	172

[a]Burnand and Hasspacher (1999)
[b]Walthert and others (2004)
[c]O = official picnic site, V = visitor-created fire ring

In each study site a plot containing a fire place was chosen. Plot size ranged from 30 x 50 m to 100 x 100 m, depending on the size of the impacted area. Each plot was divided into three zones as recommended by Cole (1989): A core zone Z1 around the fire ring (heavily impacted; cover of ground vegetation <10%), an intermediate zone Z2 (moderately impacted; vegetation cover 10–50%) and a periphery zone Z3 (visually unimpacted; vegetation cover 50–100%; width 20 m). Data analysis revealed that the median vegetation cover in zone Z1 was 1%, in Z2 40% and in Z3 70% (n = 9 in each case). As a control, an undisturbed plot of equal size was chosen at 50–150 m from the disturbed plot and divided into corresponding zones (C1–C3) of equal size. Within the control plots, there were no apparent gradients. The median vegetation cover was 50% in all three zones (n = 9 in each case). Pairs of disturbed and control plots did not differ in type of forest vegetation, soil type and forest management.

Vegetation Mapping and Soil Sampling

Ground vegetation (<30 cm height) and soil characteristics were examined in five randomly chosen 1 x 1 m subplots in each zone between August and October 2003. Species composition, mean plant height and number of individuals were recorded in each subplot and total plant cover was visually estimated using the Domin-Krajina scale (Mueller-Dombois and Ellenberg 1974). Leaf litter was collected from an area of 0.25 x 0.25 m in each subplot and weighed after oven drying at 80 °C for 24 h. To control for the influence of different light conditions, light intensity was measured at 25 randomly chosen points within each zone, using a quantum meter with separate sensor (Apogee Instruments Inc., Model QMSS-ELEC). In order to calculate relative values, the light intensity was also measured in full sunlight outside the forest stand at the same time. Soil compaction was measured as soil penetration resistance using a handpenetrometer (Eijkelkamp Typ IB) at five randomly chosen points in each subplot. Furthermore, a soil sample was taken to a depth of 5 cm using a soil corer (100 cm^3) in each subplot. Soil moisture (%) was determined from the fresh weight/dry weight ratio. Soil pH was measured in distilled water (1 : 2.5 soil : water; Allen 1989). Total soil organic matter content (SOM) was assessed as loss-on-ignition of oven-dried soil at 500

°C for 24 h (Allen 1989). Total soil organic nitrogen content was determined using the standard method of Kjeldahl (Bremner 1965).

The shrub layer (woody plant species, 30–150 cm height) was assessed along a 50-m transect starting at the edge of the fire ring and orientated perpendicular to the forest edge. At a distance of 0, 4, 8, 12, 16, 22, 28, 34, 42, and 50 m from the fire ring, species composition, plant height and number of individuals were recorded in 2 x 2 m subplots. Light intensity was measured once at the starting edge of each subplot and outside the forest stand.

All young and mature trees in the study plot were measured for diameter at breast height (dbh). Trees were classified and counted as either damaged by humans (e.g. nails driven in, broken branches, trunk scars) or undamaged.

Amount of Woody Debris

The line intersect method of Van Wagner (1968) was used to estimate the amount of woody debris in disturbed and control plots. Woody material was recorded along three randomly orientated transects radiating from the edge of the fire ring and ending at the outer edge of the periphery zone. In control plots, transects ran from forest edge to forest interior. Pieces of wood with a big end diameter ≥0.5 cm intersecting the sample line at each 20-cm mark were measured for length and diameter at both ends. All branching segments of a single branch or twig were recorded as separate pieces. Pieces that were bent significantly were measured as separate, roughly linear sections (Woldendorp and others 2004).

Data Analysis

Non-parametric statistics were used throughout, because the data did not fit normal distributions. The impact of picnicking and grilling on ground vegetation and soil parameters was examined by calculating relative changes expressed by the difference between median values of each disturbed zone and median values of corresponding control zones divided by the median value of the entire control plot (Cole 1989). Negative values indicate a loss, positive values a gain of the respective parameter (Appendix). Logistic regression models with the factors study site and zone were used to analyze relative changes of the soil and vegetation parameters. In the vegetation models, relative light intensity was added as a co-factor. Sign-tests were used to determine whether there were significant deviations from zero in the relative changes.

Spearman rank correlations showed which vegetation parameters correlated with the cover of ground vegetation. As the division of the plots into zones was based on vegetation cover, parameters correlating with vegetation cover were left out of the analysis. This was the case for density of plant individuals (individuals/m^2; $r_s = 0.67$, $n = 9$, $P = 0.025$).

The recorded plant species were assigned to different ecological groups (typical forest, ubiquitous, ruderal or trampling-tolerant species) following Grime and others (1988). Contingency tables were applied to analyze differences between the three zones and the control plots in the proportion of species belonging to different ecological groups. The relative change of shrub layer parameters was calculated in the same way as for the ground vegetation and soil parameters, using distances from the fire ring instead of zones (Appendix).

Young trees (diameter ≤5 cm) were assigned to 10 size classes: (1) 0–0.5 cm; (2) 0.6–1 cm; ...; (10) 4.6–5 cm, and mature trees (diameter >5 cm) to further 8 size classes: (1) 5–15 cm; (2) 16–25 cm; ...; (8) >85 cm. Contingency tables were applied to analyze differences in diameter and number of damaged trees between disturbed and control plots.

Woody debris were assigned to four size classes according to their mean diameter: (1) <0.6 cm; (2) 0.6–2.5 cm; (3) 2.6–7.6 cm; and (4) >7.6 cm (Hall and Farrell 2001). The volume was calculated according to the formula for a cut cone (Nordén and others 2004a). For data analysis, each transect was split into the following sections (0–4; 4–8; 8–12; 12–16; 16–22; 22–28; 28–34; 34–42; 42–50 m). The total volume of woody debris was summed up for each section and expressed as volume per meter. The relative change in woody debris volume was calculated analogously to relative changes of soil and vegetation parameters (Hall and Farrell 2001; Appendix). Logistic regression models included the factors study site, distance from the fire ring and debris size class.

SPSS, version 11.0 was used for statistical analyses (SPSS 2002). Logistic regression models were calculated using JMP, Version 6.0 (SAS 2005).

Results

Ground Vegetation and Soil Characteristics

Figure 1 illustrates the ground vegetation and soil characteristics in the three zones of disturbed and control plots. Picnicking and grilling reduced the height of ground vegetation (logistic regression, relative change of ground vegetation: χ^2 = 49.66, *df* = 2,13, *P* < 0.001), species density (χ^2 = 18.09, *df* = 2,13, *P* < 0.001) and the amount of leaf litter (χ^2 = 27.08, *df* = 2,10, *P* < 0.001) in the zones of disturbed plots. Light intensity did not affect vegetation height (χ^2 = 1.35, *df* = 1,13, *P* = 0.25), but there was an interaction between zone and light intensity (χ^2 = 12.91, *df* = 2,13, *P* = 0.002), indicating that vegetation height was differently influenced by light intensity in different zones. Light intensity also tended to affect plant species density (χ^2 = 3.24, *df* = 1,13, *P* = 0.07) and to influence species density in different zones (χ^2 = 5.90, *df* = 2,13, *P* = 0.05). Soil compaction and soil pH were both higher in the zones of disturbed plots than in the corresponding zones of control plots (relative change of soil compaction: χ^2 = 18.72, *df* = 2,10, *P* < 0.001; pH: χ^2 = 16.66, *df* = 2,10, *P* < 0.001). Soil moisture, however, was not affected by picnicking and grilling (χ^2 = 0.30, *df* = 2,10, *P* = 0.86), reaching median values of 18.5% in disturbed plots and 21.0% in control plots. Similarly, soil organic matter content (SOM) was not influenced by picnicking and grilling (median of disturbed plots was 10.8%, of control plots 8.5%; χ^2 = 1.86, *df* = 2,10, *P* = 0.39). In disturbed plots, total organic nitrogen amounted to 0.25% and in control plots to 0.22%.

Vegetation height, species density, leaf litter, soil compaction and soil pH were significantly affected in the core zones compared to the corresponding control zones (sign-tests: *P* < 0.05). On average, the core zones comprised an area of 165 m^2. Soil compaction was also enhanced in the intermediate zones (*P* = 0.04). In the periphery zones, however, all ground vegetation and soil characteristics remained unimpacted.

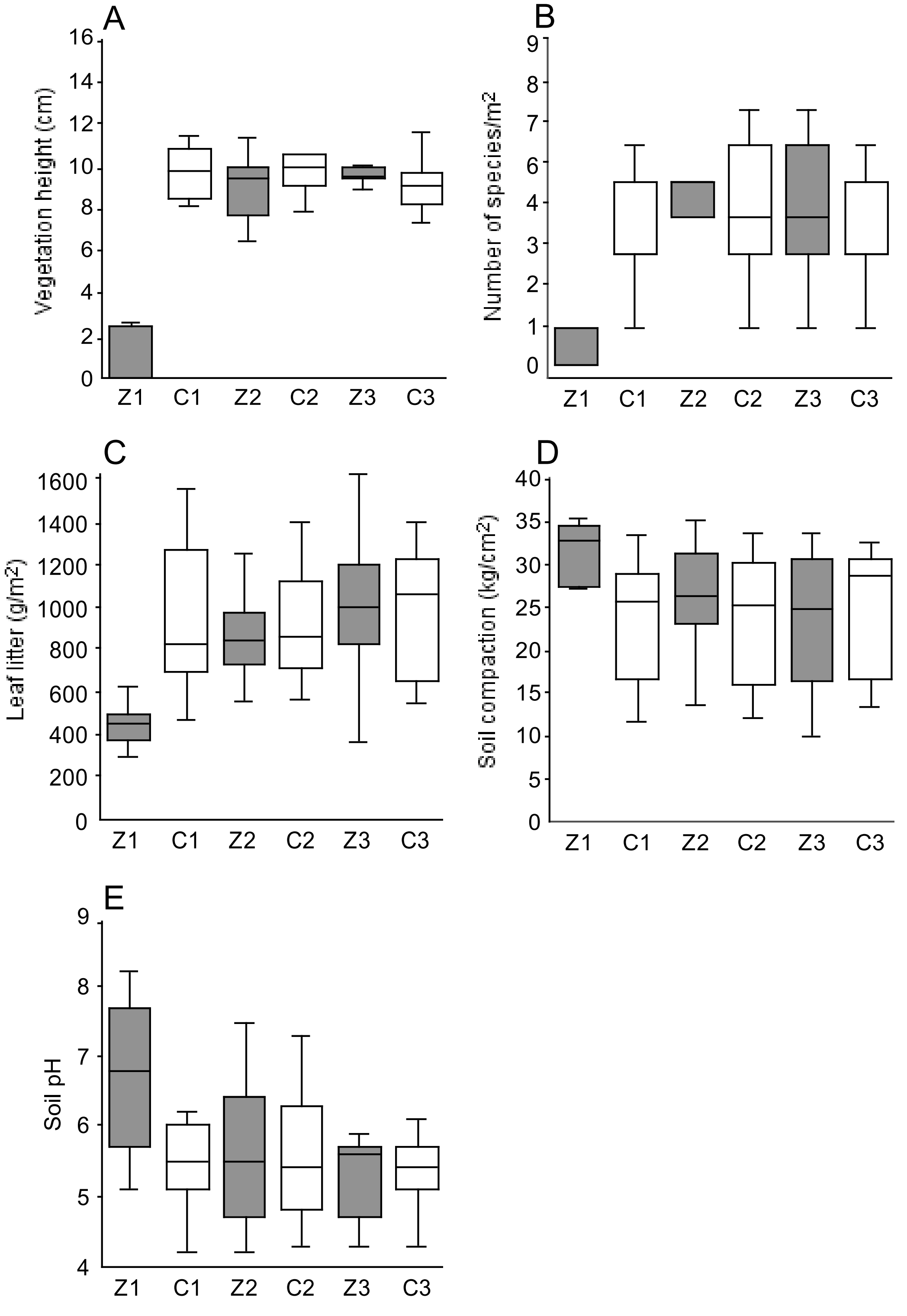

Fig. 1 Ground vegetation and soil characteristics in the core (Z1), intermediate (Z2) and periphery (Z3) zones of disturbed plots and in the zones of corresponding control plots (C1/C2/C3) at nine fire places in northwestern Switzerland: (A) ground vegetation height, (B) plant species density, (C) amount of leaf litter, (D) soil compaction, (E) soil pH. Boxplots show medians, 25% and 75% percentiles and ranges (minimum and maximum)

Picnicking and grilling changed the proportions of plants belonging to different ecological groups. In the core zones of disturbed plots (Z1), 52% of the recorded plant species were non-forest species, belonging either to the ruderal, ubiquitous or trampling-tolerant plants (Figure 2A). The proportions of non-forest species were only 36% in the intermediate and 21% in the periphery zones. Picnicking and grilling did not significantly change the proportion of forest and non-forest species in the three zones and the corresponding controls ($\chi^2 = 5.44$, $df = 3$, $P = 0.14$). The three zones and control plots, however, differed significantly in the proportion of plant individuals belonging to non-forest species ($\chi^2 = 643.17$, $df = 3$, $P < 0.001$). In the core zones, 43% of the individuals were non-forest species (31% were trampling-tolerant, such as *Poa annua*, *Polygonum aviculare* and *Lolium perenne*, 3% were ruderals and 9% were ubiquitous; Figure 2B). In the intermediate zones, the proportion of non-forest individuals was 10% (0.1% trampling-tolerant individuals, 1% ruderals and 9% ubiquitous individuals). In periphery zones, almost all plants were forest species (no trampling-tolerant individuals, 0.4% ruderals and 1% ubiquitous individuals).

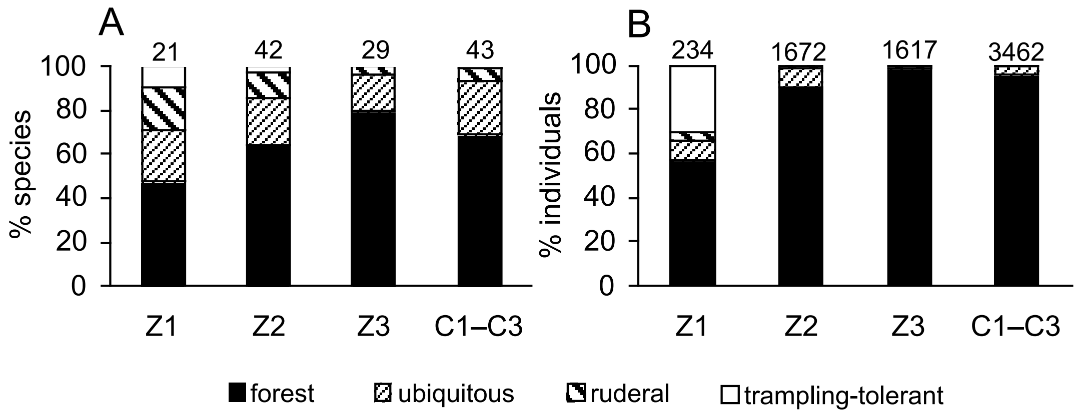

Fig. 2 Percentage of (A) plant species and (B) plant individuals belonging to different ecological groups in the core (Z1), intermediate (Z2) and periphery zones (Z3) of disturbed plots and in the corresponding control plots at nine fire places in northwestern Switzerland. In control plots, data from the three zones (C1–C3) were pooled. Figures on top of the bars indicate the number of species and individuals, respectively

Shrub Layer

Shrub layer characteristics along the transects in disturbed and control plots are illustrated in Figure 3. In disturbed plots all parameters showed a higher variability than in control plots. Picnicking and grilling reduced the height of the shrub layer (logistic regression, relative change: χ^2 = 22.28, *df* = 9,27, *P* = 0.01) and species density (χ^2 = 17.79, *df* = 9,27, *P* = 0.04). The number of shrub individuals/m^2 was marginally reduced by picnicking and grilling (χ^2 = 14.81, *df* = 9,27, *P* = 0.09). Light intensity did not affect shrub layer height, species density or number of shrub individuals (*P* > 0.50 for all parameters). However, there were interactions between the distance from the fire ring and light intensity on shrub layer height (χ^2 = 19.16, *df* = 9,27, *P* = 0.02), species density (χ^2 = 19.59, *df* = 9,27, *P* = 0.02) and number of shrub individuals/m^2 (χ^2 = 18.95, *df* = 9,27, *P* = 0.03). Thus, these parameters were differently affected by light intensity at different distances from the fire ring.

Picnicking and grilling significantly reduced the height of the shrub layer and the number of shrub individuals/m^2 up to a distance of 8 m from the fire ring (sign-tests: *P* < 0.04). Species density was marginally reduced up to 4 m from the fire ring (*P* = 0.07).

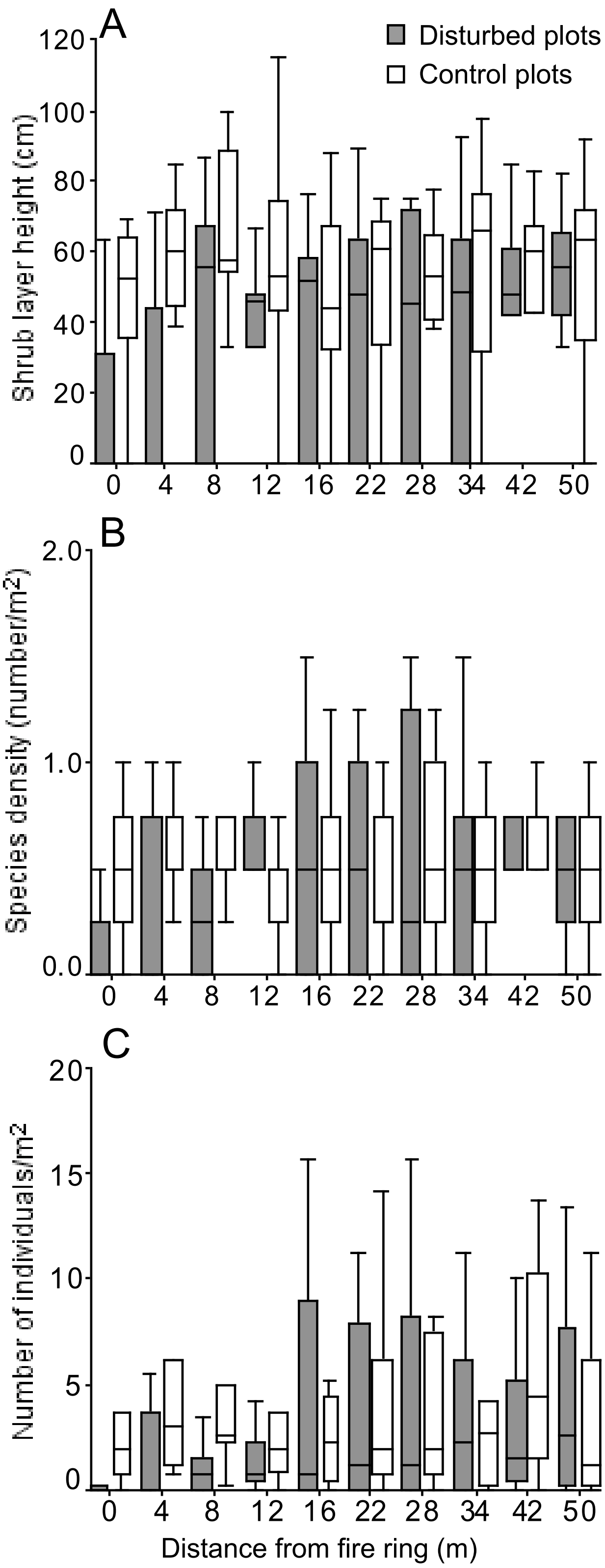

Fig. 3 Shrub layer characteristics in disturbed plots at increasing distances from the fire ring at nine fire places and at corresponding distances in nine control plots in northwestern Switzerland: (A) shrub layer height, (B) shrub species density, (C) number of shrub individuals/m^2. Boxplots show medians, 25% and 75% percentiles and ranges (minimum and maximum)

Young and Mature Trees

Diameter at breast height (dbh) of mature trees did not differ between disturbed and control plots (χ^2 = 9.94, *df* = 7, *P* = 0.19), confirming that disturbed and control plots had the same stand age. In total, 2367 young trees were recorded in disturbed plots and 3225 in the corresponding control plots. Picnicking and grilling caused significant changes in the age structure of young trees (Figure 4; χ^2 = 103.66, *df* = 9, *P* < 0.001). Even though there were 30% more trees with a very small diameter (0–0.5 cm) in disturbed than in control plots, the number of trees with a diameter ≤2.5 cm was reduced by 27% in disturbed plots. The group with a stem diameter of 1.1–1.5 cm was most severely impacted by recreational use: tree number was reduced by 45% in disturbed plots.

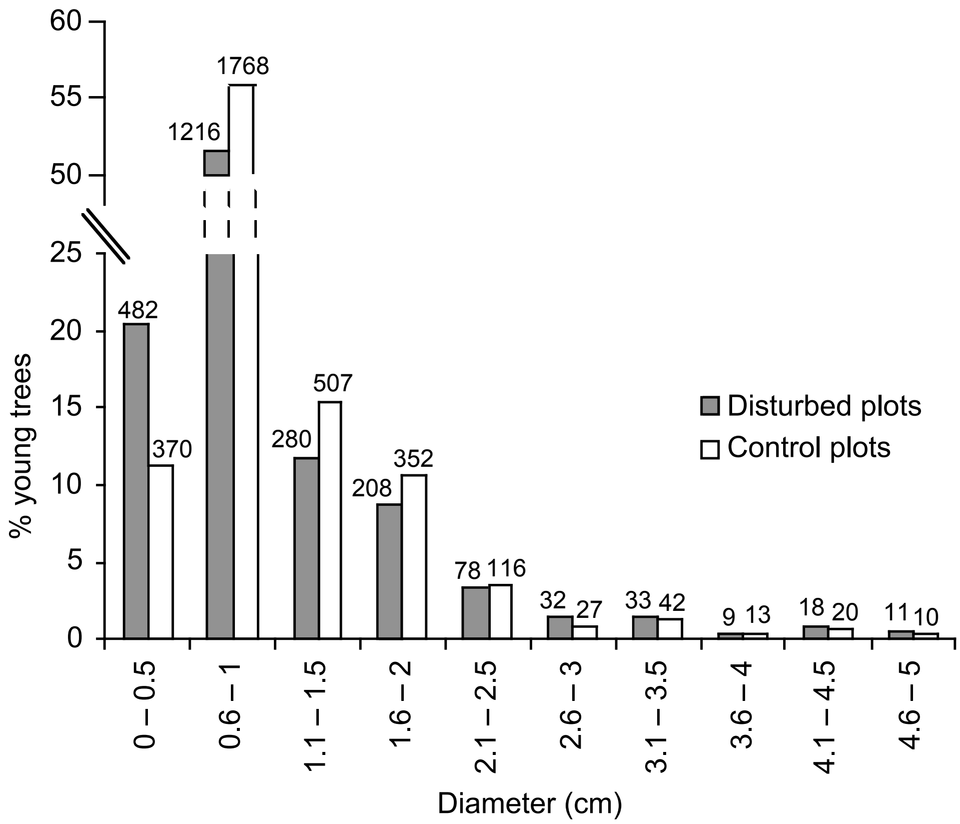

Fig. 4 Age structure of young trees recorded in disturbed and control plots at nine fire places in northwestern Switzerland. Percentages are shown for ten size classes. Numbers on top of bars indicate the number of trees

More mature trees were damaged in disturbed plots (39%) than in the controls (18%; χ^2 = 144.84, *df* = 1, *P* < 0.001). Young trees also tended to be more frequently damaged in disturbed (4.43%) than in control plots (3.70%; χ^2 = 2.91, *df* = 1, *P* = 0.09).

Woody debris

Total woody debris volume reached median values of 0.2 cm^3/m transect length (range: 0–25977 cm^3/m) in disturbed and 1.6 cm^3/m (range: 0–110447 cm^3/m) in control plots (Figure 5). This indicates an overall reduction of woody debris of 88% due to firewood collection. The relative change in woody debris volume varied significantly with size class (logistic regression: χ^2 = 11.05, *df* = 3,19, *P* = 0.01). Woody debris <0.6 cm was not impacted by picnicking and grilling (Figure 5A; *P* = 0.5; median of disturbed plots: 1.0 cm^3/m (range: 0–12 cm^3/m), control plots: 1.0 cm^3/m (0–17 cm^3/m)). In contrast, the amount of woody debris in the size class 0.6–2.5 cm was reduced by 61% in disturbed plots compared to control plots (Figure 5B; *P* < 0.001; disturbed plots: 20 cm^3/m (0–520 cm^3/m), control plots: 51 cm^3/m (0–524 cm^3/m)). Furthermore, larger woody debris of size 2.6–7.6 cm was severely affected by firewood collection (Figure 5C; *P* = 0.02; disturbed plots: 0 cm^3/m (0–4455 cm^3/m), control plots: 12 cm^3/m (0–5498 cm^3/m)). Woody debris >7.6 cm was not affected by picnicking and grilling (disturbed plots: 0 cm^3/m (0–25977 cm^3/m), control plots: 0 cm^3/m (0–110447 cm^3/m)).

The relative change in the amount of woody debris in disturbed plots varied marginally with distance from the fire ring (logistic regression: χ^2 = 14.72, *df* = 8,19, P = 0.06). Woody debris volume was significantly reduced up to a distance of 8–12 m (sign-tests: *P* < 0.02) and marginally reduced up to 12–16 m (*P* = 0.08) from the fire ring. The amount of woody debris in size class 0.6–2.5 cm was reduced by 92% in the section 0–4 m, by 44% in the section 4–8 m and by 75% and 73% in the sections 8–12 m and 12–16 m, respectively (Figure 5B). At further distances, the reduction leveled off at 30–40%. In size class 2.6–7.6 cm, median woody debris volume in disturbed plots was 0 cm^3/m in all five sections up to 16–22 m from the fire ring. In control plots, median woody debris volume was also 0 cm^3/m in the sections 0–4 m and 4–8 m. In the sections 8–12 m and 12–16 m, woody debris amounted to 127 cm^3/m and 142 cm^3/m, respectively, implying a reduction of 100% in the corresponding sections in disturbed plots.

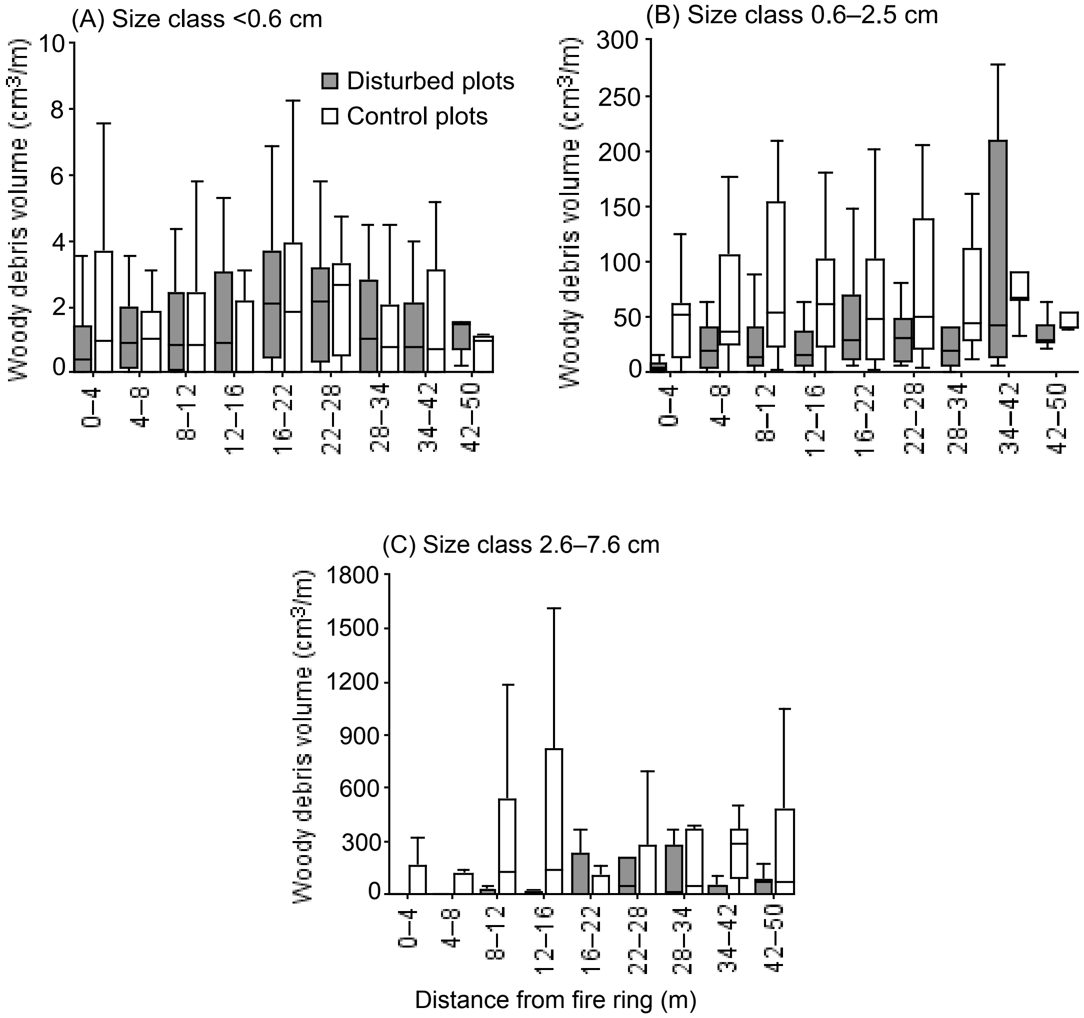

Fig. 5 Amount of woody debris in disturbed plots at increasing distances from the fire ring at nine fire places and at corresponding distances in nine control plots in northwestern Switzerland: (A) size class <0.6 cm, (B) size class 0.6–2.5 cm, (C) size class 2.6–7.6 cm. Boxplots show medians, 25% and 75% percentiles and ranges (minimum and maximum)

Discussion

Ground Vegetation and Soil Characteristics

The present study showed that the height of the ground vegetation, plant species density and the amount of leaf litter were reduced and soil compaction and soil pH were enhanced in disturbed plots compared to control plots. These effects are commonly observed in areas impacted by human trampling (e.g. Liddle 1997, Kutiel and Zhevelev 2001, Thurston and Reader 2001, Cole and Monz 2003, Roovers and others 2004). The ground vegetation of forests is particularly sensitive to trampling, being shade-tolerant with broad leaves and thin cell walls and therefore vulnerable to mechanical influences (Kuss 1986, Cole and Monz 2003, Cole and Monz 2004). Leaf litter can be broken up by trampling and either incorporated into the soil or blown away by the wind. This can lead to an increase or a decrease in organic matter, depending on which process prevails (Liddle 1997). In our study, the observed reduction in the amount of leaf litter was not reflected in any changes in SOM content. Possibly, the counteracting processes were neutralizing each other, or the loss of leaf litter had only occurred recently and was too small to result in changes in SOM content.

Fire place use led to an increase in non-forest plant species. A shift in species composition toward graminoids and other species resistant to trampling is frequently observed in areas with heavy recreational use (Jim 1987, Marion and Cole 1996, Andrés-Abellán and others 2005, Müller and others 2004). Trampling-tolerant plants are morphologically adapted to mechanical stress and produce seeds that can penetrate into deeper soil layers even under compacted soil conditions (Kuss 1986, Klug and others 2002). Disturbed conditions, trampling and more light in the open space around the fire rings most likely caused the observed increase in ruderals in the core zones (Godefroid and Koedam 2004). This shift in species composition is likely to remain even after regenerating disturbed sites, especially when the changes are discernible in the seed bank (Klug and others 2002, Amrein and others 2005).

Shrub Layer, Young and Mature Trees

Picnicking and grilling reduced the height and changed the age structure of shrubs and young trees. At the same time, there were more young trees with a very small diameter (0–0.5 cm), but less trees with a diameter ≤2.5 cm in disturbed plots. This means that although young trees were present, their growth was either suppressed or they were soon eradicated by trampling. This result is consistent with the findings of Bratton and others (1982) who showed that trampling reduced the number of trees by over 50% in the 1 cm and 2 cm diameter classes. In urban forests in Finland, an increase in path area led to a decrease in the number of saplings (Lehvävirta and Rita 2002). Similarly, in frequently visited areas in Swiss urban forests, 80% of young beech trees only reached a height of 30–50 cm, and there were no young trees of 2–3 m height (Rusterholz and others 2000). The changed soil characteristics in disturbed plots such as an increased level of compaction and shifts in nutrient composition might be factors limiting the growth of shrubs and young trees. In New England, mean annual height growth of scarlet oak was significantly reduced at recreation sites compared to control plots (Brown and others 1977). Mycorrhiza are indispensable for the growth and survival of trees. Consequently, the growth of trees could be inhibited because mycorrhiza are affected by human trampling. Waltert and others (2002) showed that at heavily trampled sites with a missing leaf litter layer, ectomycorrhiza formation of tree seedlings was lower than at control sites, thus making it harder for the seedlings to establish and grow.

Recreational use can also lead to a shift in the composition of shrub and tree species. We observed a reduction in shrub species density in disturbed plots, indicating that certain species could not withstand the trampling pressure. With increasing use, an enhanced proportion of saplings grow close to structures protecting them from trampling (e.g. trees, stones, fallen logs; Tonnesen and Ebersole 1997, Lehvävirta and others 2004). Species that can grow close to such structural elements will be the ones forming the future canopy.

Damages to mature trees caused by humans are frequently observed at picnic sites and campgrounds, but the extent varies greatly. Data from the USA show that the percentage of damaged trees ranges from 28% to 77% (Reid and Marion 2005). The 39% of trees damaged in our study lie within this range.

Wounding of trees makes them susceptible to pathogens, which may lead to the spread of diseases (Brown and others 1977, Grünwald and others 2002). Furthermore, trees scorched by fire receive more bark beetle attacks, and mechanical wounding can reduce diameter growth (Lombardero and others 2006). If these forests are used for timber production, as is the case in Switzerland, damages to trees have serious consequences for the forest owner, as poor quality wood has to be sold at a lower price (Baur 2003).

Apart from the ecological and economical consequences, the unnatural age structure of young trees, insufficient regeneration, reduced species density and unsightly damages to trees can lower the attractiveness of these picnic sites for forest visitors.

Woody debris

Total woody debris volume was reduced by 88% in disturbed plots compared to control plots, implying a massive reduction of woody debris due to firewood collection. The depletion of firewood in the suburban forests of our study was far larger than that found at montane and subalpine campsites in the USA, where the removal of woody debris averaged 40–50% (Bratton and others 1982, Hall and Farrell 2001). Possibly, the picnic sites in suburban forests are used more frequently, resulting in a higher reduction of woody debris. Furthermore, montane and subalpine areas have a shorter season for recreational activities than the forests at low altitude that we studied. Woody debris of size 0.6–7.6 cm were the most affected by fire building. This is consistent with the two studies conducted in the USA, in which size <0.6 cm was found to be less impacted than size 0.6–7.6 cm (Bratton and others 1982, Hall and Farrell 2001). Obviously, pieces <0.6 cm are too small to keep a fire going, while pieces bigger than 7.6 cm require a greater effort to be broken into smaller pieces to be burnt.

The reduction of woody debris reached a distance of 16 m from the fire ring. In comparison, the height and number of shrubs were only reduced up to a distance of 8 m. A radius of 16 m around each fire ring encompasses an area of 800 m^2. In most cases, this is far more than the area in which the ground vegetation is visually impacted. Hall and Farrell (2001) failed to detect a distance effect in the depletion of woody debris over a distance of 15 m and concluded that effects probably extended beyond this distance. While the situation in suburban deciduous forests might not be directly comparable to montane and subalpine campsites, it is possible that campsite users walk similar distances to gather wood for campfires, depending on the amount of wood available.

The constant removal of woody debris for recreational purposes has implications for the ecology of urban forests. Woody debris, and especially woody debris of oak trees, is a habitat for numerous specialized organisms (Albrecht 1991, Ammer 1991, Jonsell and others 2007). Woody debris collected for building fires is exclusively fine woody debris (diameter 5–10 cm; Kruys and Jonsson 1999) and very fine woody debris (diameter <5 cm; Küffer and Senn-Irlet 2005). Most studies on the biodiversity of dead wood focus on coarse woody debris (diameter ≥10 cm; e.g. Heilmann-Clausen and Christensen 2004, Jabin and others 2004). However, there is evidence that smaller pieces of dead wood harbor a multitude of species not found on larger pieces. In oak forests in southern Sweden, Nordén and others (2004b) recorded that 75% of ascomycetes had fruitbodies exclusively on fine woody debris, while basidiomycetes were distributed over all size classes. In Switzerland, 94.5% of woody debris pieces in managed forests belong to the category of very fine woody debris, which is an important refuge for fungal species even when larger pieces of wood would be available (Küffer and Senn-Irlet 2005). A number of saproxylic beetles also specialize in using the thinnest dead twigs (1–4 cm diameter; Jonsell and others 2007). Given the enormous reduction of fine and very fine woody debris within a radius of 16 m around each fire place, building fires is likely to have a direct influence on the species richness of saproxylic organisms in urban forests, especially when there are several fire places close to each other. In frequently visited forests, about 10% of the total forest area can be impacted by recreational use (Baur 2003).

Conclusions

Intensive use of fire places reduces the diversity of the sensitive ground vegetation on several levels. In addition, large amounts of woody debris are removed as firewood, leading to a habitat loss for numerous highly specialized organisms. Apart from the ecological consequences, frequently used sites become unattractive to forest visitors. Therefore, one aim of forest management must be to preserve recreational areas as attractive and diverse forests. Many visitors to natural recreation areas enjoy making fires (Christensen and Cole 2000) and firewood gathering is an integral part of visitors' experience. In urban forests around Basle, Switzerland, fire place users frequently complain about the shortage of firewood, indicating that in certain areas there is hardly any woody debris in the relevant size classes left (unpublished data). One possible measure is to deposit logging residues as firewood near picnic sites (Hasspacher 2007). A high amount of dead wood as part of an ecologically sound forest management is well accepted by the public (Hunziker 1997). This gives fire place users the possibility of gathering firewood from the surrounding area without depleting the naturally occurring dead wood. Piles of branches and twigs can also be used to restrict the movements of forest visitors to a defined area. This should help to maintain the high conservation value of oak-beech forests and at the same time ensure that these forests remain attractive recreation sites for the urban public.

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Appendix

Table A1 Relative change of ground vegetation and soil characteristics in the core, intermediate and periphery zones at nine fire places in northwestern Switzerland

	Z1/C1	Z2/C2	Z3/C3
Ground vegetation			
Species density (number/m^2)	-0.83 (-1.67– 0.00)	0.00 (-1.00– 3.00)	0.00 (-1.00–1.00)
Vegetation height (cm)	-0.98 (-1.07– -0.37)	-0.08 (-0.65– 1.25)	0.04 (-0.10–0.20)
Leaf litter (g/m^2)	-0.53 (-0.94– -0.17)	-0.12 (-0.37– 0.37)	0.04 (-0.37–0.95)
Soil characteristics			
Soil compaction (kg/cm^2)	0.23 (-0.04– 1.31)	0.06 (-0.13– 0.57)	-0.03 (-0.30–0.12)
Soil moisture (%)	-0.15 (-0.50– 0.45)	-0.21 (-0.28– 0.25)	-0.11 (-0.34–0.04)
pH	0.19 (-0.06– 0.93)	0.03 (-0.16– 0.14)	0.00 (-0.08–0.13)
SOM (%)	0.01 (-0.34– 0.63)	0.12 (-0.30– 2.18)	0.24 (-0.20–0.88)
Organic nitrogen (%)	-0.11 (-0.82– 0.30)	0.00 (-0.22– 0.63)	0.05 (-0.24–0.75)

Values represent medians of nine study sites (ranges in parentheses).

Table A2 Relative change of shrub layer characteristics (woody plant species, 30–150 cm height) at increasing distances from fire rings at nine fire places in northwestern Switzerland

Distance from fire ring (m)	Species density (number/m^2)	Number of individuals/m^2	Height (cm)
0	-1.00 (-6.00–0.50)	-0.71 (-5.33–0.14)	-0.53 (-3.25– 0.12)
4	-1.00 (-2.00–0.40)	-1.45 (-5.00–1.58)	-0.63 (-3.45– -0.09)
8	-0.50 (-2.00–2.00)	-0.97 (-4.00–0.42)	-0.44 (-3.11– 0.59)
12	0.00 (-2.00–6.00)	-0.38 (-1.86–3.00)	-0.38 (-1.09– 3.12)
16	0.00 (-1.00–1.60)	0.00 (-3.00–2.84)	-0.19 (-1.02– 0.38)
22	0.00 (-1.50–1.60)	-0.29 (-3.57–2.84)	-0.03 (-0.97– 2.76)
28	0.00 (-2.00–1.60)	-0.29 (-3.14–3.05)	-0.05 (-0.99– 3.44)
34	0.00 (-2.00–1.33)	0.00 (-1.05–0.91)	0.00 (-1.14– 0.36)
42	0.00 (-6.00–0.67)	-0.29 (-8.00–6.00)	-0.05 (-2.00– 3.97)
50	0.00 (-4.00–0.80)	0.12 (-16.00–3.26)	-0.01 (-0.36– 0.48)

Values represent medians of nine study sites (ranges in parentheses).

Table A3 Relative change of woody debris volume at increasing distances from fire rings and in different size classes at nine fire places in northwestern Switzerland

	Relative change of woody debris (cm^3/m)
Distance from fire ring (m)	
0–4	-0.15 (-8.45– 9.81)
4–8	-0.11 (-9.56–27.36)
8–12	-0.28 (-21.89–27.81)
12–16	-0.14 (-8.93–10.88)
16–22	0.00 (-2.24–46.58)
22–28	0.00 (-7.48–20.66)
28–34	0.00 (-26.72–15.74)
34–42	0.00 (-6.35– 2.93)
42–50	0.00 (-0.58– 1.29)
Size class (cm)	
<0.6	0.04 (-4.76– 7.39)
0.6–2.5	-0.43 (-17.80– 4.12)
2.6–7.6	-0.27 (-26.72–27.36)
>7.6	0.00 (-7.48–46.58)

Values represent medians of nine study sites (ranges in parentheses).

Chapter 3

Short-term versus long-term effects of human trampling on above-ground vegetation and soil enzyme activity in suburban beech forests

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Abstract

Understanding the effects of human trampling on ecosystem processes is essential for the management of recreational areas. Discussions on recreational impacts are generally based either on data from trampling experiments or on field survey data from sites subjected to long-term recreational use, but rarely on a combination of both. We examined whether results from a short-term trampling experiment reflect the impact of long-term trampling around frequently used fire places. We compared short- and long-term effects of human trampling on above-ground forest vegetation and soil physical, chemical and biological characteristics, including soil microbial biomass and activities of the enzymes dehydrogenase, β-glucosidase and phosphomonoesterase. We found both similarities and differences in short- and long-term trampling effects. Both short- and long-term trampling reduced plant cover, plant height and species density, though long-term effects were more pronounced than short-term effects. In both approaches, leaf litter biomass decreased with trampling intensity, whereas soil density increased with trampling intensity. Other soil characteristics such as soil moisture, soil pH, total soil organic matter content and total soil organic nitrogen content were not or only marginally affected by short- and long-term trampling. Furthermore, soil microbial biomass (C_{mic} and N_{mic}) and dehydrogenase activity were differently affected by short- and long-term trampling. In the short-term experiment, these soil characteristics decreased at low and medium, but not at high trampling frequencies. In contrast, the same soil characteristics decreased with increasing trampling intensity in the long-term field survey. The activity of β-glucosidase was only affected by short-term trampling. Phosphomonoesterase activity was most severely affected by long-term trampling, most probably as a result of the reduced plant cover. Our results imply that the restoration of degraded sites might be hampered by the low nutrient turnover resulting from the reduced litter layer and decreased enzyme activities, mitigating a successful re-establishment and growth of plants. Based on the different findings obtained in the two approaches we conclude that it is problematic to extrapolate short-term trampling effects to longer temporal scales.

Key words: experimental trampling; fire places; long-term effects; outdoor recreation; short-term effects; soil enzyme activities; urban forest.

INTRODUCTION

The impact of outdoor recreation on natural communities and habitats is of crucial interest to forest managers. In urban areas, forests are often the only freely accessible natural areas to spend some leisure time (Jacsman 1998, Niemelä 1999). Large numbers of forest visitors can lead to conflicts between recreation and nature conservation (Liddle 1997, Baur 2003). Previous observational and experimental studies have demonstrated effects of recreational activities on soil and vegetation of forest ecosystems (e.g. Cole 1995, Malmivaara et al. 2002, Waltert et al. 2002, Roovers et al. 2004). In particular, activities such as picnicking, barbecuing and camping can degrade large forest areas, and damages can spread to previously untouched areas (Jim 1987, Marion and Cole 1996, Kutiel and Zhevelev 2001, Amrein et al. 2005). Field surveys provide information on the extent of degradation, often at sites that have been in use for decades. Short-term trampling experiments showed that the extent of damage depends on the frequency of visitors and the kind of recreational activity, but also on the type of soil and vegetation and the season (summer or winter) of use (Cole 1987, Gallet and Roze 2001).

Human trampling leads to soil compaction, which increases bulk density and decreases porosity, resulting in a shortage of oxygen and a changed water regime in the soil (Kozlowski 1999). Microbial responses to such environmental stresses include changes in activity, growth and resource allocation (Schimel et al. 2007). An important function of soil microorganisms is the production of enzymes that catalyze the cycling of nutrients such as carbon, nitrogen and phosphorus (Burns and Dick 2002). Soil compaction due to logging and agricultural traffic reduces soil microbial biomass by 20–40% and enzyme activities up to 75%, resulting in reduced mineralization rates of carbon and nitrogen (Dick et al. 1988, Kaiser et al. 1991, Breland and Hansen 1996, Li et al. 2002, Tan and Chang 2007). Therefore, apart from the direct mechanical trampling damage, plants suffer from indirect effects such as a reduced availability of nutrients.

Understanding the effects of soil compaction caused by trampling on physical, chemical and biological soil characteristics and their interactions with plants is essential to assess the potential effectiveness of management actions aimed at restoring degenerated forest areas (Cole 2004). In spite of this, effects of recreation on soil microorganisms have rarely been looked at. Notable exceptions are two descriptive field studies by Zabinski and Gannon (1997) and Malmivaara-

Lämsä and Fritze (2003) who found shifts in the microbial community structure at intensively used camping sites and in urban forests. In a short-term trampling experiment in a pine forest in Spain, enzyme activities diminished with trampling intensity (Ros et al. 2004).

Short-term experiments are frequently used as a means to understand processes in natural systems. Experiments allow an assessment of the impact of different factors in a controlled way (Freckleton 2004). However, the time scale of ecological processes is usually longer than the duration of an experiment. While short-term experiments can provide reasonable estimates of long-term effects in some cases, results cannot always be extrapolated to longer temporal scales (Freckleton 2004, Briggs and Borer 2005, Olofsson 2006).

By directly comparing effects at different temporal scales, we studied whether a short-term trampling experiment provides good indications of long-term trampling effects on vegetation and soil enzyme activities in recreational forests. In experimental studies, trampling intensity increases with increasing number of passes, while at fire places frequently used over long periods, trampling intensity increases with decreasing distance to the fire ring. We therefore also determined the spatial dimension of visitor-induced disturbance at fire places. Even though trampling experiments have become a popular means of assessing potential effects of recreational activities, a direct comparison between field survey data and data from experimental trampling has hardly ever been attempted (for an exception see Marion and Cole 1996). We assessed the effects of human trampling on above-ground vegetation and soil characteristics, including microbial biomass and activities of the enzymes dehydrogenase, β-glucosidase and phosphomonoesterase. Dehydrogenase can be used as an indicator for general metabolic activity, while β-glucosidase and phosphomonoesterase are enzymes of the carbon and phosphorus cycles, respectively. To our knowledge, this is the first study comparing short-term and long-term trampling effects on soil microbial biomass and enzyme activities. The results provide basic knowledge concerning the influence of recreation on selected soil processes and thus contribute to the understanding of impacted forest ecosystem functioning.

METHODS

Study sites

The study was carried out in two beech (*Fagus sylvatica*) forests Allschwil (7°32´ E, 47°32´ N) and Sichtern (7°43´ E, 47°29´ N) in the vicinity of Basel, Switzerland, at an elevation of 350–430 m. Common tree species in both forests are *Fagus sylvatica*, *Carpinus betulus*, *Fraxinus excelsior*, and *Acer pseudoplatanus*. *Quercus* sp. is also abundant in Allschwil forest. Frequent species in the understorey include *Galium odoratum*, *Anemone nemorosa*, *Ranunculus ficaria*, *Hedera helix*, and *Carex sylvatica*. The soil type is a gleyic cambisol at Allschwil and a haplic luvisol at Sichtern (Driessen and Deckers 2001). Annual temperature averages 10.4 °C in Allschwil and 8.9 °C in Sichtern and annual precipitation 778 mm and 979 mm in the two forests (MeteoSwiss 2005*a*, *b*).

Short-term effects

We examined short-term effects of different intensities of human trampling experimentally in three undisturbed 25 x 25 m plots in both forests in spring 2005. The experimental design was based on standard trampling procedures (Cole and Bayfield 1993) and adapted to local conditions. Two replicate 2.5 x 3.5 m blocks were established in each experimental plot. Blocks consisted of four lanes, each 0.5 m wide and 2.5 m long. Trampling was conducted on a single day by a person weighing 60 kg and wearing hiking boots. Trampling frequencies were 100, 300 and 900 passes, randomly assigned to lanes. The fourth lane was used as a control. This design resulted in a sample size of N = 12 (6 at each site) for each trampling frequency.

We assessed above-ground vegetation characteristics in two 0.5 x 0.5 m subplots in each lane immediately before trampling. Total plant cover was visually estimated in % following Cole and Bayfield (1993), mean plant height was measured to the nearest cm (five measurements per subplot) and species density (number of plant species/0.25 m^2) was recorded. Leaf litter was collected from a quarter of the subplot. Soil density was measured as soil penetration resistance five times in each subplot using a handpenetrometer (Eijkelkamp Typ IB). Five soil samples were taken to a depth of 5 cm using a soil corer (100 cm^3), pooled and mixed. The samples were taken next to the subplots to avoid any disturbance other than experimental trampling. Samples were packed on ice during transport to the laboratory, where they were stored at –20 °C until analysis. Leaf litter was weighed after oven drying at 80 °C for 48 h.

Three days after the trampling, soil samples were taken next to the subplots again and soil penetration resistance was measured once more. Plant cover, height and species density of the surviving vegetation was recorded 2 weeks later and at the same time a second sample of leaf litter was taken.

Long-term effects

In both forests we chose three plots of 25 x 25 m containing a frequently visited fire place. The three plots in Allschwil were located within 600 m, those in Sichtern within 400 m of each other. Plots with fire places and plots with experimental trampling did not differ in species composition and age structure of trees. In Allschwil, 30% of the plot area was heavily impacted by trampling (range: 10–35%), i.e. bare ground was visible, in Sichtern 35% (15–65%). The fire places in Allschwil had been in use for 10–20 years, those in Sichtern for 30–35 years (local foresters, *personal communication*). The fire ring covered 0.13% (0.10–0.15%) of the plot area in Allschwil and 0.08% (0.05–0.13%) in Sichtern.

In order to examine the long-term impact and spatial dimension of human trampling, we collected data along three 20-m long transect lines in each plot at the same time as the trampling experiment was conducted. Each transect started at the edge of the fire ring and ended in the undisturbed forest. The angle between two transect lines was 45°. Subplots of 0.5 x 0.5 m were established at distances of 0.5, 1, 1.5, 2, 3, 4, 6, 8, 12, 16, and 20 m from the fire rings. Subplots situated in close proximity of fire rings are exposed to a high trampling intensity over long periods, while subplots at distances of 12–20 m from the fire rings are rarely trampled and therefore served as controls. Plant cover, height and species density of the above-ground vegetation, leaf litter and soil density were recorded and soil samples were taken in the same way as in the trampling experiment prior to treatment.

Soil characteristics

Soil moisture (%) was determined from the fresh weight to dry weight ratio. Soil pH was determined in distilled water (1:2.5 soil:water; Allen 1989). Total soil organic matter content (SOM) was assessed as loss-on-ignition of oven-dried soil at 700 °C for 23 h (Allen 1989). Total soil organic nitrogen content (N_t) was determined in a subset of 89 soil samples using the standard method of Kjeldahl (Bremner 1965). Regression analysis was used to calculate the N_t content from the SOM content of the remaining samples (R^2 = 0.85, N = 48, N_t = 0.14 + 0.03 x SOM, P < 0.001 for the trampling experiment and R^2 = 0.79, N = 41, N_t = 0.24 + 0.02 x SOM, P < 0.001 for the field survey; Gibson 2002). Because samples from subplots close to fire rings had an extremely high SOM content, these data were not considered in the regression analysis.

Soil microbial biomass and soil enzyme activities

The frozen soil samples were thawed at 4 °C before being sieved (< 2 mm) and stored at 4 °C prior to the analyses. Soil microbial biomass C (C_{mic}) and N (N_{mic}) were determined by chloroform-fumigation-extraction (Brookes et al. 1985, Vance et al. 1987). Fumigated (22 h at 25 °C) and unfumigated samples (10 g dry mass) were extracted with 40 ml 0.5 mol/L K_2SO_4 solution by 30 min horizontal shaking at 200 rev/min and filtered (Roth MN 615). Total organic C (TOC) in the extracts was determined by infrared spectrometry after combustion at 850 °C (DIMA-TOC 100, Dimatec, Essen, Germany). Total N was measured in the same sample by chemoluminescence (TN_b, Dimatec, Essen, Germany). C_{mic} and N_{mic} were calculated as the difference between extractable C and N in fumigated and unfumigated samples using the proportionality constants k_{EC} = 0.45 for C_{mic} (Joergensen and Mueller 1996*a*) and k_{EN} = 0.54 for N_{mic} (Joergensen and Mueller 1996*b*).

Dehydrogenase activity was determined following von Mersi and Schinner (1991). 1 g moist soil was mixed with 1.5 ml Tris buffer (1 mol/L, pH 7) and 2 ml INT solution (iodonitrotetrazolium chloride, 9.88 mmol/L) and incubated at 40 °C in the dark for 1 h. Blanks were prepared with autoclaved soils (121 °C for 20 min.). The soil suspensions were filtered (Roth MN 615) and the developed INF (iodonitrotetrazolium formazan) was measured spectrophotometrically at 464 nm after extraction with N,N-dimethylformamide and ethanol. Because INT is very sensitive to light, the whole procedure was carried out in a room with red light.

Activities of β-glucosidase (EC 3.2.1.21) and phosphomonoesterase (EC 3.1.3.2) were measured by using p-nitrophenyl-ester based assays (Tabatabai and Bremner 1969, Eivazi and Tabatabai 1988). 1 g moist soil was mixed with 0.25 ml toluene and 4 ml of modified universal buffer (MUB, pH 6 for β-glucosidase and pH 6.5 for phosphomonoesterase) and incubated at 37 °C for 1 h with either 1 ml PNG (p-nitrophenyl-β-glucoside, 25 mmol/L) for the β-glucosidase or 1 ml PNP (p-nitrophenyl phosphate, 15 mmol/L) for the phosphomonoesterase. After 1 h, 1 ml of $CaCl_2$ (0.5 mol/L) was added and reactions were terminated by adding either 8 ml of Tris buffer (0.1 mol/L, pH 12) to the β-glucosidase assay or 8 ml NaOH (0.5 mol/L) to the phosphomonoesterase assay. The soil suspensions were filtered (Roth MN 615) and the developed p-nitrophenol (pNP) was immediately measured spectrophotometrically at 400 nm. Blanks were prepared by adding PNG or PNP after incubation.

The repeatability of these methods was assessed by analyzing ten soil samples from each plot. Microbial biomass was determined three times. Average repeatability was 96.2% for TOC and 96.6% for total N. Enzyme activities were estimated four times. Repeatability was 88.8% for dehydrogenase, 95.0% for β-glucosidase and 92.7% for phosphomonoesterase. Thanks to the high repeatability, all measurements were performed once.

Data analysis

To avoid pseudoreplication, analyses of short-term effects were performed with mean values of the subplots gathered in each trampling lane or control lane. Vegetation characteristics, i.e. plant cover (PC), plant height (PH) and plant species density (PN) were analyzed as relative values after the recommendation of Bayfield (1979):

$$\mathrm{RPC, RPH, RPN} = \frac{\text{surviving cover/height/species density of trampled subplots}}{\text{initial cover/height/species density of trampled subplots}} \times \mathrm{cf} \times 100\%$$

where $\mathrm{cf} = \dfrac{\text{initial cover/height/species density of control subplots}}{\text{surviving cover/height/species density of control subplots}}$.

Soil characteristics including microbial biomass and enzyme activities were analyzed as differences between the values before and after trampling. Effects of experimental trampling on vegetation and soil characteristics were examined using a three-way analysis of variance (ANOVA) with factors forest, plot nested within forest, trampling intensity (number of passes) and interaction between forest and tramping intensity. Post hoc differences between the different trampling intensities were examined using Student's t test. If necessary, data were log- or arcsine square root-transformed to obtain normally distributed residuals and homogenous groups of variance.

To examine the impact of long-term human trampling on vegetation and soil characteristics, mean values of the three transects in each plot were calculated and analyzed using three-way analyses of variance (ANOVA) with factors forest, plot nested within forest, distance to the fire ring and interaction between forest and distance. Data that did not fit normal distributions were either log-, square root- or arcsine square root-transformed. Post hoc differences among subplots were examined using Student's t test.

In order to compare short-term and long-term trampling, each transect in the long-term study was split into the following sections to approximate the decreasing trampling frequencies used in the short-term experiment: 0.5–1 m (compared with 900 passes); 1.5–3 m (300 passes); 4–8 m (100 passes); 12–20 m (0 passes). Mean values of each parameter were calculated for each section and analyzed analogously to the short-term trampling data.

All results are reported as significant when $P < 0.05$. Statistical analyses were conducted using JMP version 6.0 (SAS 2005).

RESULTS

Short-term effects

Experimental trampling affected all vegetation characteristics examined (Table 1).

TABLE 1. Results of ANOVAs testing for differences in study site (forest), plot and experimental trampling intensity on vegetation and soil characteristics including soil microbial biomass and enzyme activities in two forests in the vicinity of Basel, Switzerland.

	Forest			Plot[Forest]			Trampling intensity		
	F	df	*P*	*F*	df	*P*	*F*	df	*P*
Vegetation characteristics									
Relative plant cover (%)	24.98	1, 10	**0.0005**	3.67	4, 10	**0.0434**	43.97	2, 10	**<0.0001**
Relative plant height (cm)	17.61	1, 10	**0.0018**	0.62	4, 10	0.66	12.35	2, 10	**0.0020**
Relative plant species density (number/0.25 m^2)	0.19	1, 10	0.67	1.42	4 10	0.30	6.21	2, 10	**0.0177**
Soil characteristics									
Leaf litter (g/m^2)	0.56	1, 14	0.47	1.42	4, 14	0.28	8.06	3, 14	**0.0023**
Soil density (kg/cm^2) †	58.76	1, 12	**<0.0001**	15.39	4, 12	**<0.0001**	8.99	3, 12	**0.0021**
Soil moisture (%)	1.54	1, 15	0.23	5.46	4, 15	**0.0065**	2.59	3, 15	0.09
Soil pH	5.78	1, 15	**0.0295**	3.75	4, 15	**0.0262**	0.08	3, 15	0.97
Total soil organic matter (%)	2.72	1, 15	0.12	3.05	4, 15	0.05	0.69	3, 15	0.57
Total soil organic nitrogen (%)	2.53	1, 15	0.13	1.30	4, 15	0.32	0.92	3, 15	0.46
Soil microbial biomass and enzyme activities									
C_{mic} (µg C/g soil)	11.77	1, 15	**0.0037**	3.71	4, 15	**0.0271**	2.16	3, 15	0.14
N_{mic} (µg N/g soil)	1.15	1, 15	0.30	2.61	4, 15	0.08	2.25	3, 15	0.12
Dehydrogenase (nmol INF·g^{-1}·h^{-1})	1.65	1, 15	0.22	2.57	4, 15	0.08	2.49	3, 15	0.10
β-glucosidase (µmol pNP·g^{-1}·h^{-1})	15.54	1, 15	**0.0013**	1.18	4, 15	0.36	3.98	3, 15	**0.0287**
Phosphomonoesterase (µmol pNP·g^{-1}·h^{-1})	14.56	1, 15	**0.0017**	0.86	4, 15	0.51	2.61	3, 15	0.09

Note: Values significant at $P < 0.05$ are indicated in boldface.
† df = 12 because the interaction between forest and trampling intensity was significant.

Plant cover and plant height, measured 2 weeks after trampling, had decreased with increasing trampling intensity (Fig. 1a, b). The overall reduction in plant height, however, was only due to a highly significant decrease in one forest (Sichtern, $F_{2,6} = 25.22$, $P = 0.0012$), whereas no trampling effect was found in the other forest (Allschwil, $P = 0.11$). Plant species density was also reduced by trampling (Table 1). Nine hundred passes had a more pronounced effect on plant species density than 300 or 100 passes (Post hoc test: $P < 0.05$; Fig. 1c).

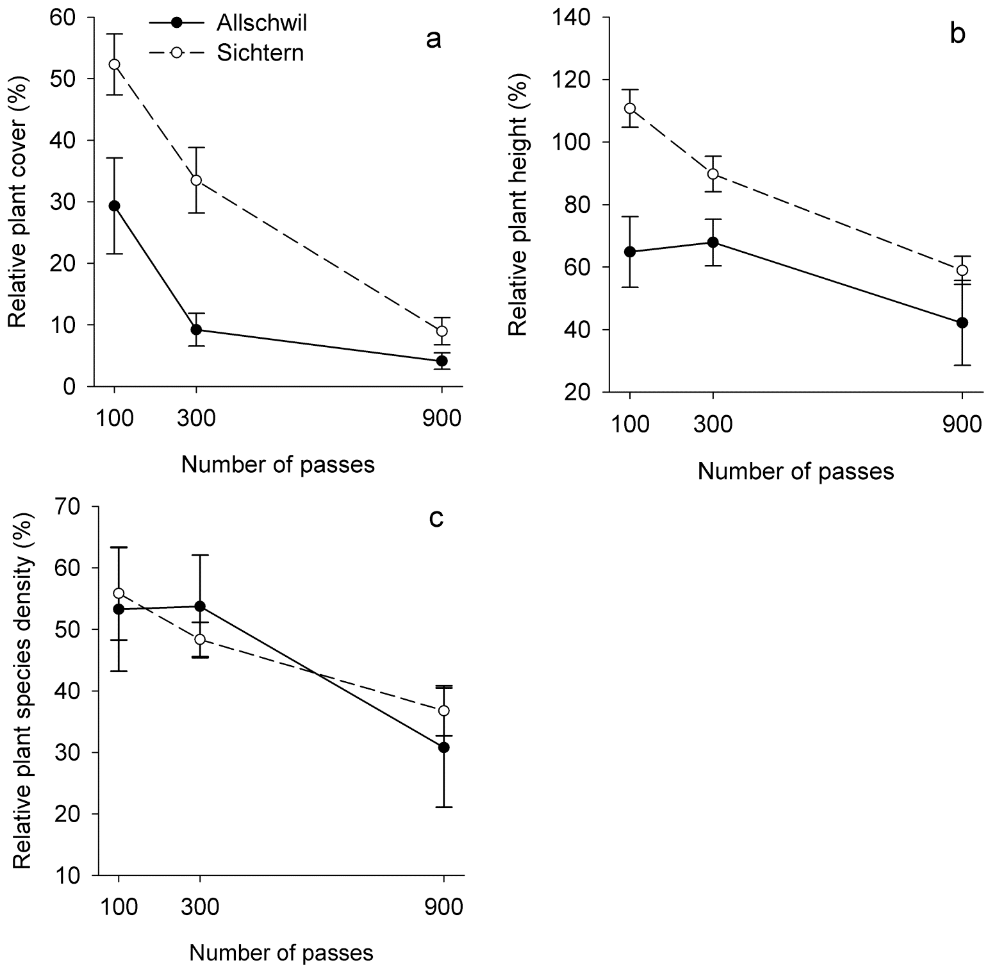

FIG. 1. Short-term effects of experimental human trampling on (a) plant cover, (b) plant height and (c) plant species density in the forests Allschwil and Sichtern in the vicinity of Basel, Switzerland. All values are means of relative values ± SE, in each case $N = 6$.

Leaf litter biomass 2 weeks after trampling decreased with increasing trampling intensity (from 659 g/m^2 in the control to 284 g/m^2 after 900 passes (data from Allschwil and Sichtern pooled); Table 1, Appendix A). In contrast, soil density, measured 3 days after trampling, increased with increasing trampling intensity (Table 1). The significant interaction between study site and trampling intensity ($F_{3,12} = 4.74$, $P = 0.021$) indicates that soil density was differently affected by trampling intensity in the two forests. Soil moisture in plots with 300 and 900 passes was reduced compared to that of control plots ($P < 0.05$). Overall, however, experimental trampling only tended to affect soil moisture (Table 1). Trampling intensity had no effect on soil pH, total soil organic matter content and total soil organic nitrogen (Table 1).

Overall, experimental trampling did not affect C_{mic} and N_{mic} (Table 1), although soil microbial biomass carbon content (C_{mic}) in plots with 100 passes was lower than in control plots ($P < 0.05$, Fig. 2a), and soil microbial biomass nitrogen content (N_{mic}) in plots with 100 and 300 passes was lower than in the control plots (in both cases $P < 0.05$, Fig. 2b). Surprisingly, the same C_{mic} and N_{mic} contents were found in plots with 900 passes and in control plots. Furthermore, experimental trampling did not affect the C_{mic}:N_{mic} ratio ($F_{3,13} = 0.68$, $P = 0.58$).

Overall, trampling intensity did not influence the activity of dehydrogenase measured 3 days after trampling (Table 1), although dehydrogenase activity was reduced in plots with 300 passes compared to control plots ($P < 0.05$, Fig. 2c). In contrast, β-glucosidase activity was significantly affected by experimental trampling (Table 1), mainly due to low β-glucosidase activity in plots with 300 passes ($P < 0.05$, Fig. 2d). Furthermore, trampling intensity tended to affect phosphomonoesterase activity (Table 1, Fig. 2e).

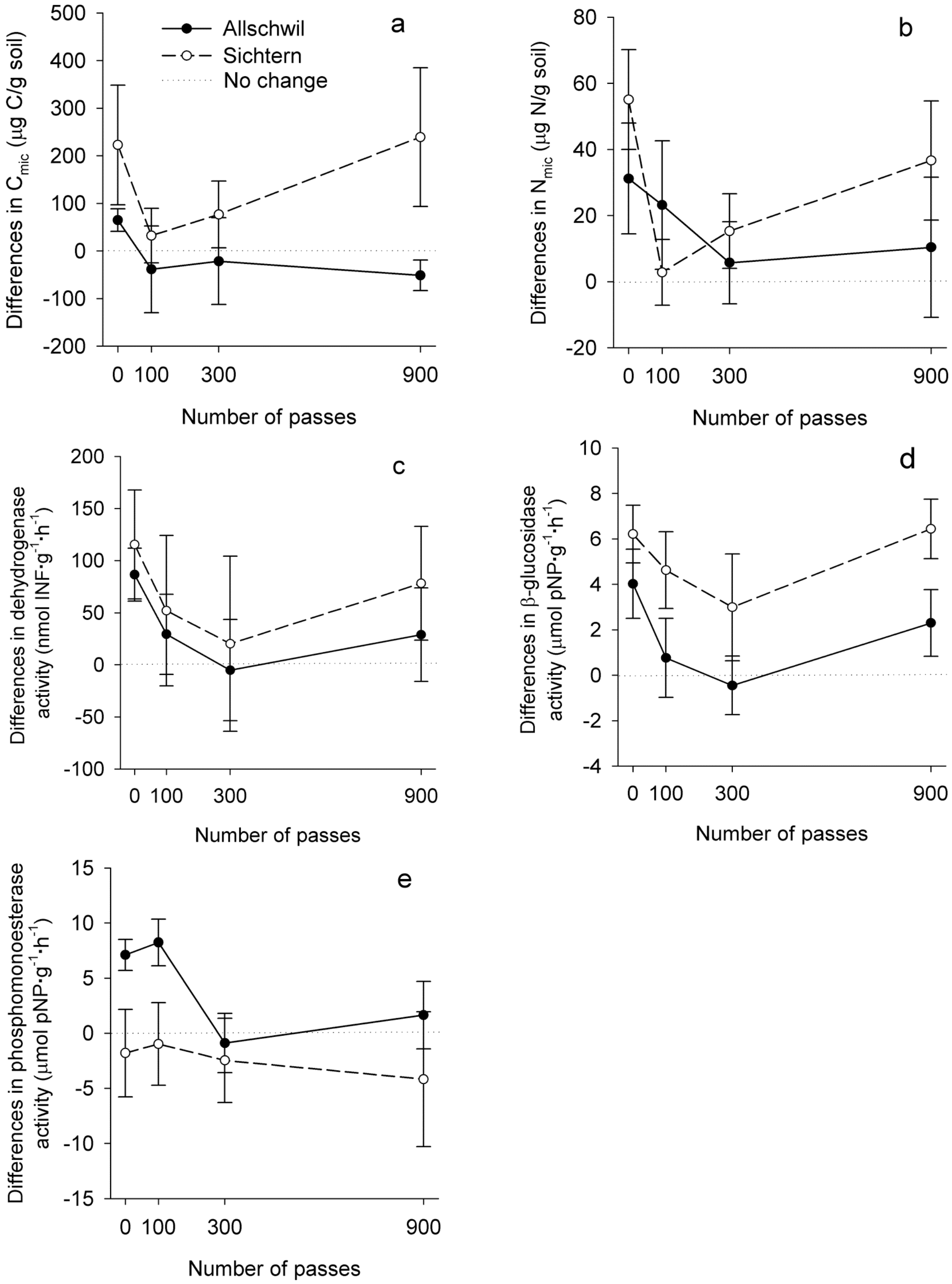

FIG. 2. Short-term effects of experimental human trampling on (a) soil microbial biomass C (C_{mic}), (b) soil microbial biomass N (N_{mic}), (c) dehydrogenase activity, (d) β-glucosidase activity and (e) phosphomonoesterase activity in the forests Allschwil and Sichtern in the vicinity of Basel, Switzerland. Means ± SE of the differences of soil microbial biomass and soil enzyme activities before and after trampling are illustrated, in each case $N = 6$.

Long-term effects

All recorded vegetation characteristics differed with distance to the fire rings (Table 2).

TABLE 2. Results of ANOVAs testing the effect of study site (forest), plot and distance to the fire rings on vegetation and soil characteristics including soil microbial biomass and enzyme activities at three fire places in each of the two forests Allschwil and Sichtern in the vicinity of Basel, Switzerland.

	Forest		Plot [Forest]		Distance to fire ring		Forest x distance	
	$F_{1, 40}$	*P*	$F_{4, 40}$	*P*	$F_{10, 40}$	*P*	$F_{10, 40}$	*P*
Vegetation characteristics								
Plant cover (%)	89.27	**<0.0001**	8.01	**<0.0001**	15.43	**<0.0001**	4.00	**0.0008**
Plant height (cm)	41.68	**<0.0001**	4.88	**0.0027**	20.99	**<0.0001**	1.93	0.07
Plant species density (number/0.25 m^2)	46.67	**<0.0001**	18.26	**<0.0001**	16.81	**<0.0001**	1.17	0.34
Soil characteristics								
Leaf litter (g/m^2)	0.03	0.86	7.38	**0.0002**	1.53	0.16	1.13	0.36
Soil density (kg/cm^2)	1180.28	**<0.0001**	16.76	**<0.0001**	9.48	**<0.0001**	1.46	0.19
Soil moisture (%)	0.02	0.89	13.88	**<0.0001**	0.64	0.77	2.20	**0.0378**
Soil pH	31.17	**<0.0001**	4.59	**0.0038**	13.63	**<0.0001**	1.58	0.15
Total soil organic matter (%)	146.43	**<0.0001**	6.62	**0.0003**	4.02	**0.0007**	1.49	0.18
Total soil organic nitrogen (%)	187.18	**<0.0001**	4.91	**0.0026**	1.83	0.09	1.57	0.15
Soil microbial biomass and enzyme activities								
C_{mic} (µg C/g soil)	158.71	**<0.0001**	1.68	0.17	2.56	**0.0169**	2.35	**0.0275**
N_{mic} (µg N/g soil)	249.42	**<0.0001**	3.63	**0.0130**	2.22	**0.0367**	1.74	0.11
Dehydrogenase (nmol INF·g^{-1}·h^{-1})	19.19	**<0.0001**	3.58	**0.0138**	3.87	**0.0010**	1.63	0.13
β-glucosidase (µmol pNP·g^{-1}·h^{-1})	144.81	**<0.0001**	4.38	**0.0050**	1.61	0.14	2.80	**0.0099**
Phosphomonoesterase (µmol pNP·g^{-1}·h^{-1})	37.99	**<0.0001**	17.75	**<0.0001**	11.86	**<0.0001**	2.21	**0.0371**

Note: Values significant at *P* <0.05 are indicated in boldface.

Plant cover decreased from 20% in Allschwil and 80% in Sichtern to almost 0% at the edge of the fire rings (Figs. 3a and 5). There was a significant interaction between study site and distance, indicating that plant cover was differently affected by long-term trampling in the two forests (Table 2). Plant height decreased within a circle of 8 m radius around the fire rings (Figs. 3b and 5). Plant species density decreased from 2.5–5 species per 0.25 m^2 to 0–1 species at the edge of the fire rings (Figs. 3c and 5).

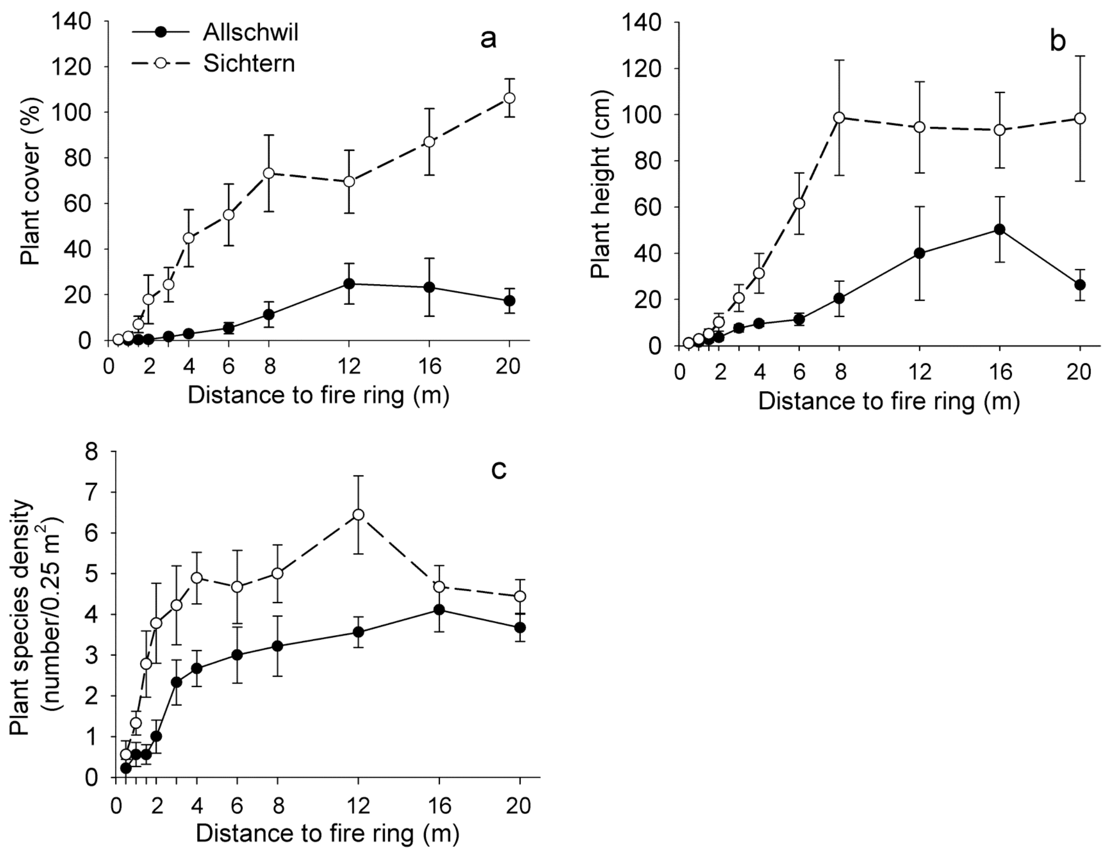

FIG. 3. Long-term effects of human trampling on (a) plant cover, (b) plant height, (c) plant species density along 20-m transect lines at three fire places in each of the two forests Allschwil and Sichtern in the vicinity of Basel, Switzerland. Means (± SE) of nine transect lines are shown.

Leaf litter biomass was not influenced by long-term trampling (Table 2; for details of soil characteristics see Appendix B). In both forests, soil density increased towards the fire rings (Table 2, Fig. 5). No distance effect was found on soil moisture (Table 2, Fig. 5). However, the significant interaction between study site and distance to the fire ring indicates that soil moisture was differently influenced by long-term trampling in the two forests. In Allschwil, soil moisture was enhanced within 3 m of the fire rings, whereas in Sichtern no distance effect was found. Soil pH was elevated close to the fire rings (Table 2, Fig. 5). Total soil organic matter (SOM) content showed a significant distance effect (Table 2). In the subplots nearest to the fire rings, SOM content was exceptionally high (Fig. 5). Total soil organic nitrogen content (N_t) was marginally affected by distance to the fire rings (Table 2, Fig. 5).

C_{mic} and N_{mic} showed significant distance effects (Table 2), with reduced values at a distance of 0.5 m to the fire rings (Figs. 4a, b and 5). The significant interaction between study site and distance for C_{mic} indicates that C_{mic} was differently influenced by long-term trampling in the two forests. The C_{mic}:N_{mic} ratio decreased within a radius of 6 m around the fire rings ($F_{10, 40}$ = 2.81, P = 0.0098), indicating a decrease in the proportion of fungi relative to bacteria. The C_{mic}:SOM ratio decreased over the last 1.5 m towards the fire rings ($F_{10, 40}$ = 2.94, P = 0.0074), indicating a declining availability of carbon for microorganisms with increasing proximity to the fire rings. Both effects were significant in Sichtern (C_{mic}:N_{mic}: $F_{10, 20}$ = 3.13, P = 0.0144; C_{mic}:SOM: $F_{10, 20}$ = 4.39, P = 0.0024), whereas in Allschwil, no distance effects on these ratios could be found (P > 0.45). Dehydrogenase activity decreased rapidly within 3 m around the fire rings (Table 2, Figs. 4c and 5). Overall β-glucosidase activity did not change with distance to the fire rings (Table 2). However, the significant interaction between study site and distance indicates that the distance effect was different in the two forests. There was a decrease in β-glucosidase activity in Sichtern over the last 1.5 m towards the fire rings (Fig. 4d), but no distance effect could be found in Allschwil. Phosphomonoesterase activity exhibited the strongest distance effects of the three enzymes, decreasing from a distance of 6 m towards the fire rings (Table 2, Figs. 4e and 5).

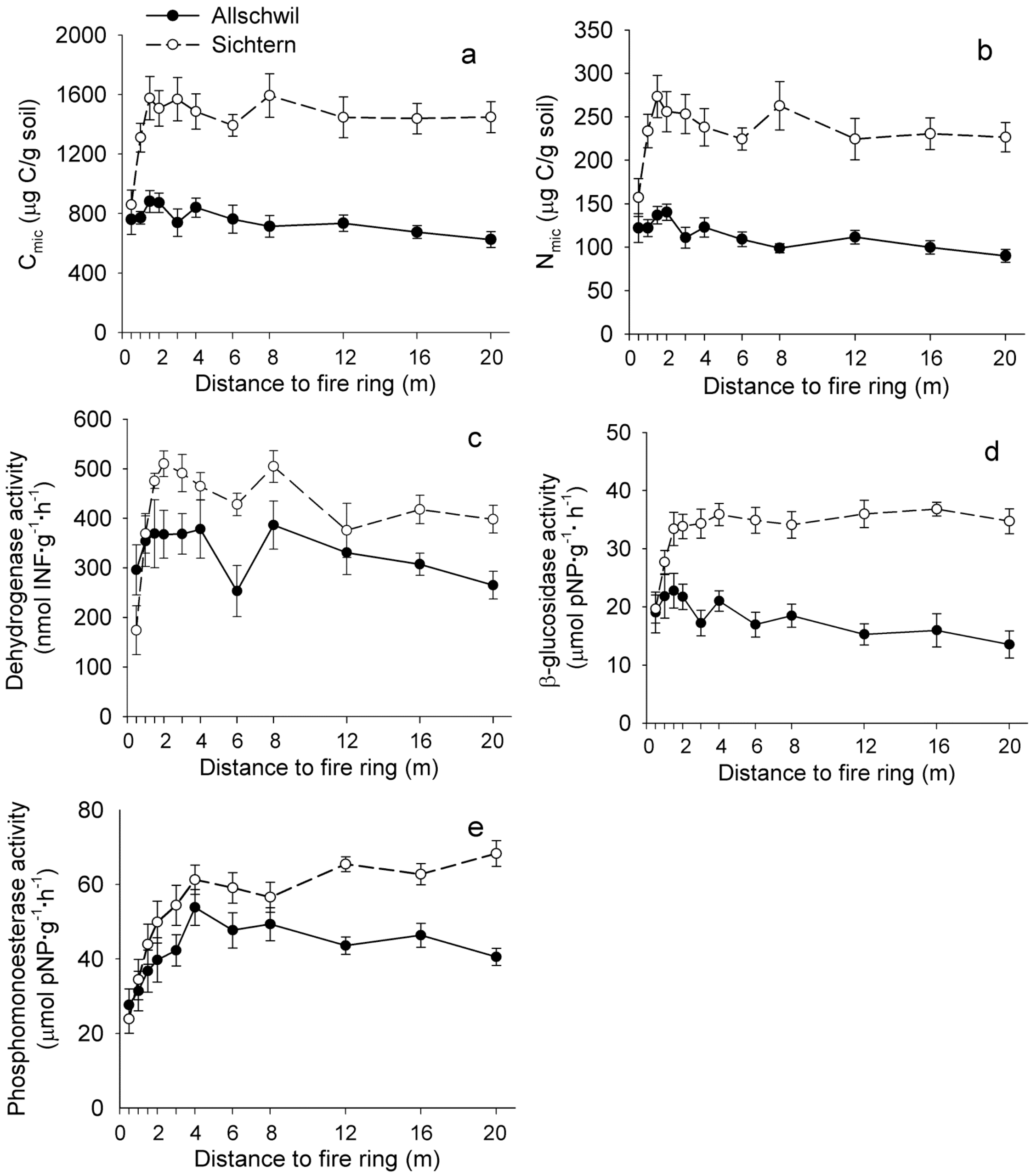

FIG. 4. Long-term effects of human trampling on (a) soil microbial biomass C (C_{mic}), (b) soil microbial biomass N (N_{mic}), (c) dehydrogenase activity, (d) β-glucosidase activity and (e) phosphomonoesterase activity along 20-m transect lines at three fire places in each of the two forests Allschwil and Sichtern in the vicinity of Basel, Switzerland. Means (± SE) of nine transect lines are shown.

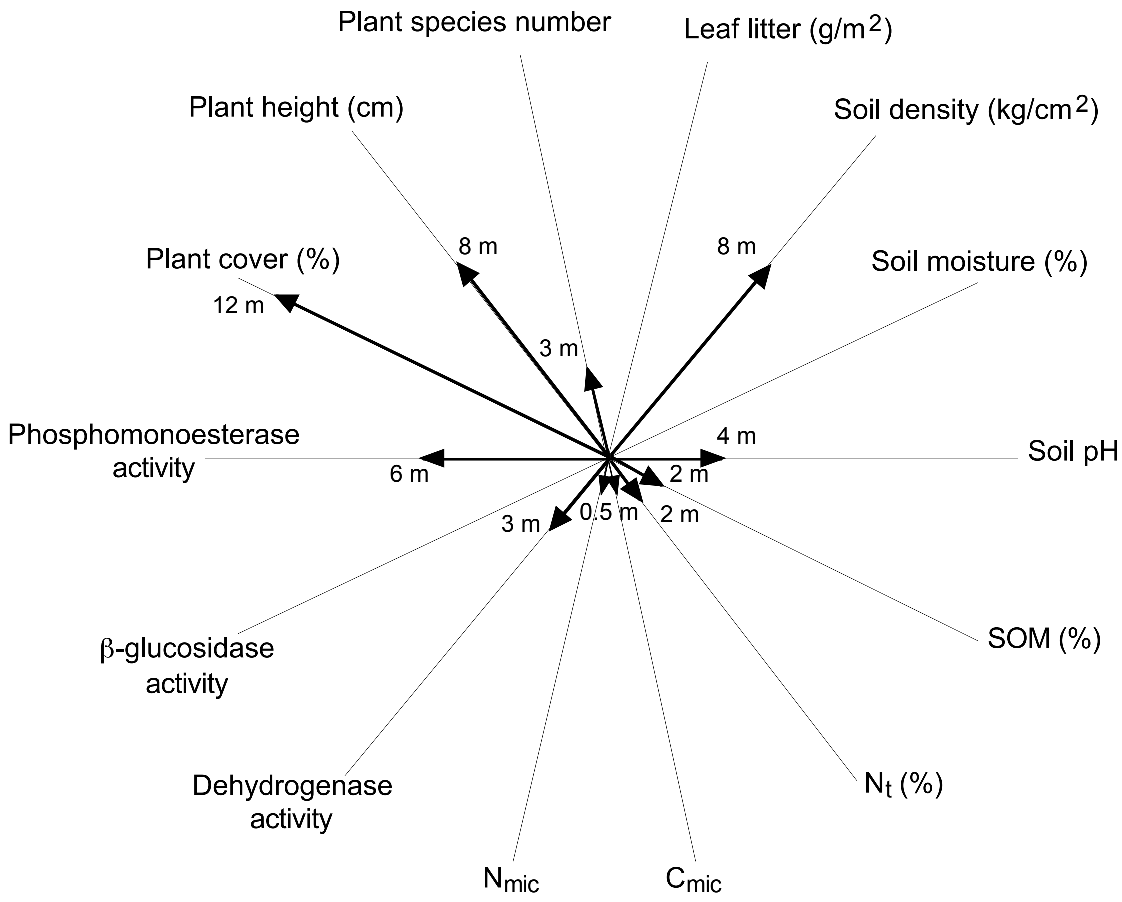

FIG. 5. Distances from fire rings (Post hoc tests: $P < 0.05$) over which vegetation and soil characteristics, including microbial biomass and enzyme activities exhibited effects due to long-term human trampling at three fire places in each of the two forests Allschwil and Sichtern in the vicinity of Basel, Switzerland.

Short- versus long-term trampling effects

The results of both the short-term trampling experiment and the survey of long-term trampling at fire places indicate similar changes in vegetation characteristics, leaf litter biomass and soil density. Plant cover, plant height and species density decreased with trampling intensity and decreasing distance to the fire rings (Table 3; Appendix A). Long-term trampling, however, had a more pronounced effect on the vegetation characteristics examined than short-term trampling (Appendix A). Similarly, leaf litter biomass decreased with trampling intensity and decreasing distance to fire rings, whereas soil density increased with trampling intensity and decreasing distance to fire rings (Table 3). Soil moisture and total soil organic nitrogen content were not influenced by short-term and long-term trampling. Interestingly, however, soil pH and soil organic matter content increased with decreasing distance to the fire ring, but no similar effect was found in the short-term trampling experiment.

Considering soil microbial activity, C_{mic}, N_{mic} and dehydrogenase activity did not differ between the samples from the short-term trampling experiment and those from the long-term trampling survey (Table 3). However, there were distinct differences in the activity of two enzymes: β-glucosidase activity decreased with increasing trampling intensity in the short-term trampling experiment, but was not affected by long-term trampling (Appendix A). In contrast, phosphomonoesterase activity decreased with decreasing distance to fire rings, but was not influenced by short-term trampling.

TABLE 3. Results of ANOVAs testing the effects of short- and long-term trampling on vegetation and soil characteristics including soil microbial biomass and enzyme activities in two forests in the vicinity of Basel, Switzerland.

	Short-term trampling		Long-term trampling	
	F	*P*	$F_{3, 15}$	*P*
Vegetation characteristics				
Plant cover (%)	43.97†	**<0.0001**	13.69	**0.0001**
Plant height (cm)	12.35†	**0.0020**	24.21	**<0.0001**
Plant species density (number/0.25 m^2)	6.21†	**0.0177**	21.02	**<0.0001**
Soil characteristics				
Leaf litter (g/m^2)	8.06‡	**0.0023**	4.45	**0.0200**
Soil density (kg/cm^2)	8.99§	**0.0021**	13.00	**0.0002**
Soil moisture (%)	2.59‖	0.09	0.35	0.80
Soil pH	0.08‖	0.97	17.21	**<0.0001**
Soil organic matter (%)	0.69‖	0.57	4.72	**0.0163**
Total soil organic nitrogen (%)	0.92‖	0.46	1.63	0.23
Soil microbial biomass and enzyme activities				
C_{mic} (μg C/g soil)	2.16‖	0.14	2.06	0.15
N_{mic} (μg N/g soil)	2.25‖	0.12	1.93	0.17
Dehydrogenase (nmol INF·g^{-1}·h^{-1})	2.49‖	0.10	3.16	0.06
β-glucosidase (μmol pNP·g^{-1}·h^{-1})	3.98‖	**0.0287**	0.99	0.42
Phosphomonoesterase (μmol pNP·g^{-1}·h^{-1})	2.61‖	0.09	13.54	**0.0002**

Note: Values significant at $P < 0.05$ are indicated in boldface.
† df = 2, 10
‡ df = 3, 14
§ df = 3, 12
‖ df = 3, 15

Discussion

This study showed that both short- and long-term trampling influenced vegetation characteristics and certain soil characteristics, including soil microbial biomass and enzyme activities. Some of these effects were similar in the experimental short-term trampling and in the survey of long-term trampling at fire places, but others were rather different.

Plant cover, height and species density were reduced by short- and long-term trampling. These effects are commonly observed in trampling experiments conducted in forest and grassland habitats (Cole 1995, Thurston and Reader 2001, Roovers et al. 2004) and in frequently visited recreational areas (Marion and Cole 1996, Amrein et al. 2005, Andres-Abellan et al. 2005). As the above-ground forest vegetation responds quickly to short-term trampling, the results from the experiment reflect some of the long-term damage to the ground vegetation. However, short-term trampling destroys the growing plants, whereas long-term trampling additionally leads to stunted growth in the surviving plants and alters species composition by favoring trampling-tolerant species (Jim 1987, Kutiel and Zhevelev 2001). In temperate forests, recovery after short-term trampling can be observed after 2 to 4 years (Kuss and Hall 1991). In contrast, repeated disturbance by long-term trampling substantially decreases the rate of recovery (Cole 1987).

Short-term and long-term trampling affected leaf litter in different ways. In the short-term experiment, low trampling intensity resulted in leaf litter being broken up and blown away by the wind, whereas at high intensity, leaf litter particles were incorporated into the soil. Long-term trampling in Sichtern forest resulted in a compacted leaf litter layer, except for 1 m around the fire ring, while in Allschwil forest, leaf litter is continuously decomposed due to high biological activity of the gleyic cambisol soil type (Walthert et al. 2004). Consequently, findings of the short-term experiment are not suitable to predict long-term trampling effects on leaf litter. An exception seems to be soil compaction measured immediately after experimental trampling. Soil density increased with both short- and long-term trampling intensity. After short-term trampling, however, soil compaction slowly decreases due to the activity of earthworms and other organisms. Continuous trampling, in contrast, hardly allows recovery of compacted soil.

Soil pH and soil organic matter content were not affected by short-term trampling, but increased with long-term trampling intensity, i.e. with decreasing distance to the fire rings. These soil characteristics were affected by the fire used for grilling. The increased soil pH in subplots closest to the fire rings can be explained by base cations released from dissolving ash (Boerner 2000), and the high soil organic matter content by the accumulation of charcoal around the fire rings. Charcoal degrades more slowly than non-charred woody materials (Hart et al. 2005). Furthermore, temperatures above 70 °C emitted from the fire kills fungi, protozoa and some bacteria, though some bacteria are more resistant to heat than fungi (Boerner 2000, Hart et al. 2005). This is reflected in the low C_{mic} and N_{mic} contents at 0.5 m distance to the fire rings. The significant distance effect of the C_{mic}:N_{mic} ratio indicates a shift in bacteria to fungi abundance close to the fire rings. Soil enzymes denature when temperature exceeds 70 °C. Dehydrogenase activity is often lower in plots burned by forest fires than in unburned plots, while β-glucosidase activity remains unaffected (Hernandez et al. 1997, Boerner et al. 2000). This is consistent with our finding that β-glucosidase activity did not exhibit any gradients at the fire places.

Soil compaction has been found to influence soil microorganisms by reducing pore space and soil aeration (Liddle 1997). In compacted forest soils after logging, C_{mic} was reduced by 38%, dehydrogenase activity by 75% and phosphatase activity by 41% in 10–20 cm depth (Dick et al. 1988). Wheel-induced compaction on agricultural land also reduced C_{mic} in the top soil layer (Kaiser et al. 1991, Santruckova et al. 1993). In maize cultures growing in experimentally compacted soil, enzyme activities changed with soil bulk density (Li et al. 2002). Soil compaction was one factor reducing C_{mic}, N_{mic} and enzyme activities at low and medium trampling frequencies in our experiment and in the highly compacted area around the fire rings.

The activity of β-glucosidase, one of the enzymes involved in the decomposition of leaf litter (Sinsabaugh et al. 1994), was only affected by short-term trampling. At low trampling frequencies, β-glucosidase activity was reduced compared to controls, and at high trampling frequencies, its activity increased again. Leaf litter was broken up and blown away by the wind at low trampling frequency. The missing litter in these plots most probably resulted in reduced β-glucosidase activity. At high trampling frequencies, on the contrary, leaf litter particles were incorporated into the soil, hereby enhancing enzyme activities. β-glucosidase activity is highest during early stages of decomposition (Sinsabaugh et al. 2002). The high C_{mic} and N_{mic} contents found in plots with high trampling frequency might be a result of rapid decomposition of leaf litter blent with soil and the subsequent uptake of nutrients by microorganisms. Especially bacteria can rapidly take up C substrates released by litter decomposition (Romani et al. 2006). A continuous reduction of leaf litter in plots with low and medium trampling frequencies would ultimately lead to a decrease in soil organic matter content. However, we assume that in the trampling experiment the removal of leaf litter had happened too recently to change soil organic matter content.

Plant-microbe interactions are essential for plant survival and productivity, and plants in turn directly influence the diversity and activity of soil microbial communities (Thompson and Bailey 2002). A decrease in plant biomass and plant species richness can lead to a decline of microbial biomass carbon content (C_{mic}) and mineralization rates (Spehn et al. 2000, Reynolds et al. 2003, Zak et al. 2003). As both short- and long-term trampling reduced plant cover, height and species density, this is a further factor reducing microbial biomass and enzyme activities. Phosphomonoesterase is not only produced by microorganisms, but is also exudated by plant roots (Dornbush 2007). Therefore, the observed decrease in phosphomonoesterase activity with increasing trampling intensity close to the fire rings is directly related to the loss of plants by trampling. This explains the pronounced effect phosphomonoesterase activity exhibited to long-term trampling.

Conclusions

We found both similarities and differences in the effects of short- and long-term trampling on vegetation, soil characteristics and soil microbial activity. Short-term trampling effects on above-ground forest vegetation reflected long-term responses to a certain extent, as both short- and long-term trampling reduced plant cover, height and species density. However, long-term trampling had a more pronounced effect on these vegetation characteristics than short-term trampling. Apart from soil density, which was enhanced by both short- and long-term trampling, soil characteristics were not affected by trampling. Short- and long-term trampling effects on C_{mic}, N_{mic} and dehydrogenase activity followed different patterns. Hence, we conclude that it is problematic to use the results of short-term trampling experiments to predict general long-term trampling effects. Experiments provide valuable information on the resistance and resiliance of different habitats and communities to trampling and help to understand certain processes of trampling on ecosystems. They can, however, not substitute comparative studies at sites impacted over long periods by recreational activities and control sites.

Our study shows that high trampling intensity reduces enzyme activities in the forest soil. This leads to low decomposition and mineralization rates and thus ultimately to less available nutrients for plant uptake (Breland and Hansen 1996, Tan and Chang 2007). These findings are highly relevant for forest managers aiming to restore disturbed sites. Experiments at subalpine campsites in the USA have shown that revegetation success on closed campsites is low and seed germination and seedling establishment are limited (Zabinski et al. 2002). Our results indicate that restoration of impacted sites in beech forests might be problematic due to low microbial activity and disturbed nutrient cycles. Therefore, further research should aim at developing means to enhance microbial activity on degraded sites.

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Appendix A: Vegetation and soil characteristics including soil microbial biomass and enzyme activities in plots treated with four trampling intensities (short-term trampling) and in four sections along 20-m transect lines at three fire places (long-term trampling) in each of the two forests Allschwil and Sichtern in the vicinity of Basel, Switzerland.

Plant cover (%)

Trampling intensity	Short-term trampling before	Short-term trampling after	Distance to fire ring (m)	Long-term trampling
Allschwil				
0	74.9 ± 7.9	71.8 ± 8.3	12–20	21.8 ± 8.4
100	58.5 ± 4.1	15.5 ± 2.9	4–8	6.5 ± 2.8
300	79.2 ± 7.0	7.5 ± 2.3	1.5–3	0.7 ± 0.9
900	63.6 ± 5.1	2.3 ± 0.7	0.5–1	0.1 ± 0.7
Sichtern				
0	82.9 ± 10.5	102.0 ± 9.6	12–20	87.6 ± 11.9
100	81.1 ± 9.3	52.2 ± 7.2	4–8	57.7 ± 10.9
300	80.3 ± 10.2	31.9 ± 5.3	1.5–3	16.4 ± 2.7
900	76.7 ± 9.3	8.9 ± 3.2	0.5–1	1.0 ± 0.6

Plant height (cm)

Trampling intensity	Short-term trampling before	Short-term trampling after	Distance to fire ring (m)	Long-term trampling
Allschwil				
0	14.6 ± 0.9	16.9 ± 1.4	12–20	38.9 ± 8.4
100	17.0 ± 2.0	10.8 ± 0.7	4–8	13.8 ± 2.8
300	15.5 ± 0.9	11.6 ± 1.3	1.5–3	4.6 ± 0.9
900	16.1 ± 1.1	7.4 ± 1.5	0.5–1	1.4 ± 0.7
Sichtern				
0	35.0 ± 3.8	36.9 ± 3.5	12–20	95.4 ± 11.9
100	31.5 ± 3.7	38.6 ± 5.3	4–8	63.9 ± 10.9
300	31.5 ± 3.1	31.4 ± 3.4	1.5–3	12.0 ± 2.7
900	29.5 ± 3.8	17.9 ± 3.6	0.5–1	1.9 ± 0.6

Plant species density (number/0.25 m^2)

Trampling intensity	Short-term trampling before	Short-term trampling after	Distance to fire ring (m)	Long-term trampling
Allschwil				
0	5.7 ± 0.6	5.3 ± 0.6	12–20	3.8 ± 0.2
100	6.0 ± 0.6	3.2 ± 0.5	4–8	3.0 ± 0.4
300	5.1 ± 0.5	2.6 ± 0.4	1.5–3	1.3 ± 0.3
900	5.3 ± 0.5	1.4 ± 0.3	0.5–1	0.4 ± 0.2
Sichtern				
0	5.8 ± 0.5	6.3 ± 0.6	12–20	5.2 ± 0.4
100	7.0 ± 0.8	4.2 ± 0.4	4–8	4.9 ± 0.4
300	6.8 ± 0.6	3.8 ± 0.4	1.5–3	3.6 ± 0.5
900	6.2 ± 0.6	2.4 ± 0.2	0.5–1	0.9 ± 0.2

Leaf litter (g/m^2)

Trampling intensity	Short-term trampling before	Short-term trampling after	Distance to fire ring (m)	Long-term trampling
Allschwil				
0	555.6 ± 86.0	577.7 ± 61.2	12–20	724.9 ± 61.9
100	475.2 ± 70.9	443.1 ± 71.6	4–8	653.1 ± 52.4
300	497.2 ± 61.7	363.6 ± 32.2	1.5–3	611.7 ± 67.7
900	578.6 ± 86.4	258.3 ± 65.9	0.5–1	368.0 ± 74.0
Sichtern				
0	690.4 ± 85.8	740.2 ± 83.7	12–20	589.6 ± 32.8
100	625.2 ± 87.5	545.6 ± 72.1	4–8	585.3 ± 50.0
300	793.0 ± 107.7	409.8 ± 56.1	1.5–3	617.6 ± 52.1
900	733.9 ± 118.6	308.9 ± 33.3	0.5–1	509.0 ± 73.1

Soil density (kg/cm^2)

Trampling intensity	Short-term trampling before	Short-term trampling after	Distance to fire ring (m)	Long-term trampling
Allschwil				
0	9.76 ± 0.54	11.63 ± 0.91	12–20	11.32 ± 0.64
100	9.73 ± 0.46	11.83 ± 0.91	4–8	14.22 ± 0.59
300	9.40 ± 0.31	11.96 ± 0.89	1.5–3	15.88 ± 0.58
900	9.45 ± 0.28	12.74 ± 1.00	0.5–1	18.96 ± 0.70
Sichtern				
0	39.11 ± 1.16	42.56 ± 1.15	12–20	36.77 ± 1.10
100	38.52 ± 1.47	44.79 ± 1.34	4–8	39.06 ± 1.55
300	38.37 ± 1.39	48.62 ± 1.01	1.5–3	43.71 ± 1.80
900	37.82 ± 0.99	49.00 ± 0.92	0.5–1	47.22 ± 1.14

Soil moisture (%)

Trampling intensity	Short-term trampling before	Short-term trampling after	Distance to fire ring (m)	Long-term trampling
Allschwil				
0	30.8 ± 1.2	31.0 ± 1.4	12–20	28.1 ± 0.4
100	30.3 ± 1.2	29.0 ± 1.1	4–8	29.1 ± 0.5
300	29.5 ± 1.0	28.0 ± 1.1	1.5–3	32.5 ± 0.9
900	31.1 ± 0.9	29.2 ± 1.1	0.5–1	33.0 ± 1.5
Sichtern				
0	31.2 ± 0.8	30.5 ± 0.9	12–20	31.5 ± 0.7
100	31.2 ± 1.0	29.3 ± 1.6	4–8	31.0 ± 1.0
300	32.6 ± 1.3	29.9 ± 1.2	1.5–3	29.5 ± 1.2
900	31.7 ± 1.0	29.8 ± 1.0	0.5–1	29.9 ± 1.0

Soil pH				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	5.38 ± 0.14	5.61 ± 0.16	12–20	5.25 ± 0.07
100	5.36 ± 0.12	5.59 ± 0.15	4–8	5.45 ± 0.15
300	5.28 ± 0.12	5.50 ± 0.15	1.5–3	6.54 ± 0.17
900	5.55 ± 0.11	5.70 ± 0.15	0.5–1	7.04 ± 0.21
Sichtern				
0	5.93 ± 0.16	5.99 ± 0.12	12–20	6.12 ± 0.08
100	5.91 ± 0.15	5.86 ± 0.18	4–8	6.19 ± 0.10
300	5.93 ± 0.16	5.95 ± 0.17	1.5–3	6.70 ± 0.13
900	5.98 ± 0.15	6.04 ± 0.10	0.5–1	7.36 ± 0.13

Total soil organic matter (%)				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	10.3 ± 0.5	10.7 ± 0.4	12–20	8.6 ± 0.4
100	10.1 ± 0.8	10.1 ± 0.5	4–8	12.5 ± 1.5
300	9.9 ± 0.5	9.6 ± 0.3	1.5–3	13.9 ± 1.2
900	10.4 ± 0.6	10.3 ± 0.4	0.5–1	16.3 ± 1.7
Sichtern				
0	20.2 ± 0.6	21.1 ± 0.9	12–20	21.1 ± 0.7
100	21.0 ± 0.5	21.3 ± 0.8	4–8	20.2 ± 0.6
300	21.1 ± 1.1	21.4 ± 1.1	1.5–3	21.6 ± 0.8
900	20.2 ± 0.7	21.1 ± 0.7	0.5–1	26.0 ± 1.6

Total soil organic nitrogen (%)				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	0.49 ± 0.02	0.48 ± 0.02	12–20	0.42 ± 0.01
100	0.47 ± 0.03	0.47 ± 0.02	4–8	0.49 ± 0.03
300	0.45 ± 0.02	0.45 ± 0.01	1.5–3	0.53 ± 0.02
900	0.48 ± 0.02	0.46 ± 0.02	0.5–1	0.52 ± 0.03
Sichtern				
0	0.79 ± 0.03	0.84 ± 0.02	12–20	0.69 ± 0.02
100	0.83 ± 0.02	0.81 ± 0.03	4–8	0.67 ± 0.02
300	0.81 ± 0.04	0.83 ± 0.04	1.5–3	0.69 ± 0.02
900	0.80 ± 0.03	0.80 ± 0.03	0.5–1	0.70 ± 0.04

C_{mic} (μg C/g soil)				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	619.7 ± 54.5	684.5 ± 43.5	12–20	680.4 ± 29.4
100	654.7 ± 49.1	616.1 ± 75.4	4–8	772.3 ± 44.5
300	593.5 ± 47.1	571.9 ± 67.7	1.5–3	831.0 ± 45.1
900	675.5 ± 54.2	624.3 ± 61.8	0.5–1	766.2 ± 52.7
Sichtern				
0	1193.7 ± 97.1	1416.5 ± 100.1	12–20	1444.3 ± 64.1
100	1286.6 ± 90.3	1318.9 ± 82.1	4–8	1490.4 ± 66.6
300	1338.2 ± 163.1	1414.7 ± 148.1	1.5–3	1550.5 ± 76.7
900	1198.6 ± 91.7	1437.7 ± 120.7	0.5–1	1084.8 ± 86.6

N_{mic} (μg N/g soil)				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	97.6 ± 18.4	124.7 ± 12.6	12–20	100.8 ± 4.6
100	90.5 ± 13.4	116.0 ± 18.3	4–8	110.1 ± 5.2
300	92.3 ± 11.1	99.1 ± 10.4	1.5–3	129.3 ± 6.4
900	117.2 ± 10.4	121.1 ± 14.7	0.5–1	122.1 ± 9.4
Sichtern				
0	168.7 ± 24.7	223.8 ± 21.4	12–20	227.2 ± 11.0
100	203.4 ± 14.9	206.2 ± 14.7	4–8	241.6 ± 12.4
300	217.5 ± 30.7	232.8 ± 27.4	1.5–3	260.9 ± 13.1
900	183.9 ± 17.9	220.6 ± 21.1	0.5–1	195.2 ± 16.9

Dehydrogenase activity (nmol INF·g^{-1}·h^{-1})				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	234.5 ± 37.1	321.0 ± 33.7	12–20	302.4 ± 19.3
100	293.5 ± 47.8	322.8 ± 41.7	4–8	339.1 ± 31.8
300	285.2 ± 44.2	280.0 ± 46.4	1.5–3	368.3 ± 30.0
900	277.0 ± 36.8	305.8 ± 47.4	0.5–1	324.6 ± 35.6
Sichtern				
0	318.2 ± 28.4	433.7 ± 27.5	12–20	397.1 ± 22.0
100	380.1 ± 19.9	432.0 ± 45.2	4–8	464.2 ± 16.4
300	393.3 ± 24.7	413.5 ± 52.5	1.5–3	492.1 ± 15.7
900	379.6 ± 26.4	457.8 ± 23.1	0.5–1	271.7 ± 38.8

β-glucosidase activity (μmol pNP·g^{-1}·h^{-1})				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	17.0 ± 1.5	21.0 ± 2.1	12–20	15.0 ± 1.3
100	19.3 ± 2.4	20.0 ± 1.7	4–8	18.8 ± 1.1
300	18.6 ± 2.4	18.2 ± 2.5	1.5–3	20.6 ± 1.5
900	19.3 ± 2.1	21.6 ± 2.7	0.5–1	20.4 ± 2.5
Sichtern				
0	28.9 ± 1.7	35.1 ± 1.3	12–20	35.8 ± 1.1
100	28.7 ± 0.8	33.3 ± 2.0	4–8	35.0 ± 1.2
300	30.2 ± 1.9	33.2 ± 2.7	1.5–3	33.9 ± 1.4
900	29.0 ± 0.7	35.5 ± 1.7	0.5–1	23.7 ± 1.8

Phosphomonoesterase activity (μmol pNP·g^{-1}·h^{-1})				
	Short-term trampling			Long-term trampling
Trampling intensity	before	after	Distance to fire ring (m)	
Allschwil				
0	38.8 ± 3.4	45.9 ± 3.4	12–20	43.6 ± 1.6
100	38.7 ± 3.6	46.9 ± 3.8	4–8	50.3 ± 2.6
300	41.2 ± 3.4	40.3 ± 3.8	1.5–3	39.6 ± 3.0
900	40.6 ± 3.5	42.2 ± 3.9	0.5–1	29.5 ± 3.4
Sichtern				
0	66.3 ± 1.9	64.5 ± 2.2	12–20	65.5 ± 1.6
100	66.5 ± 3.1	65.5 ± 1.8	4–8	59.0 ± 2.3
300	66.3 ± 3.5	63.8 ± 2.5	1.5–3	49.4 ± 3.1
900	70.2 ± 3.7	66.0 ± 2.3	0.5–1	29.2 ± 3.5

Note: Table entries are means ± SE. N = 12 for short-term trampling. N = 18 for long-term trampling, distance 0.5–1 m to fire ring and N = 27 for long-term trampling, distances 1.5–3, 4–8 and 12–20 m to fire ring.

Appendix B. Soil characteristics along 20-m transect lines at three fire places in each of the two forests Allschwil and Sichtern in the vicinity of Basel, Switzerland.

	Leaf litter (g/m^2)		Soil density (kg/cm^2)	
Distance from fire rings (m)	Allschwil	Sichtern	Allschwil	Sichtern
0.5	422.6 ± 129.3	409.8 ± 39.8	19.51 ± 1.12	47.22 ± 1.58
1	313.3 ± 76.2	608.2 ± 136.6	18.42 ± 0.85	47.22 ± 1.74
1.5	558.1 ± 85.8	583.6 ± 100.6	17.13 ± 1.42	46.00 ± 2.04
2	704.3 ± 157.7	506.4 ± 65.9	15.49 ± 0.46	46.47 ± 2.64
3	566.8 ± 95.7	762.7 ± 87.6	15.02 ± 0.84	38.67 ± 3.97
4	617.4 ± 110.2	608.6 ± 110.0	14.28 ± 0.84	38.67 ± 3.96
6	623.1 ± 79.0	653.0 ± 78.4	15.41 ± 1.03	40.95 ± 3.02
8	718.7 ± 87.3	494.1 ± 66.8	12.98 ± 1.13	37.57 ± 2.17
12	683.8 ± 104.1	632.2 ± 39.6	10.88 ± 0.99	38.32 ± 1.53
16	688.4 ± 118.7	516.2 ± 48.6	11.68 ± 1.42	36.58 ± 2.52
20	802.4 ± 106.6	620.3 ± 74.3	11.40 ± 0.99	35.40 ± 1.59

	Soil moisture (%)		Soil pH	
Distance from fire rings (m)	Allschwil	Sichtern	Allschwil	Sichtern
0.5	33.1 ± 2.7	31.0 ± 1.4	7.07 ± 0.30	7.54 ± 0.15
1	32.8 ± 1.7	28.7 ± 1.2	7.02 ± 0.30	7.17 ± 0.19
1.5	35.2 ± 1.8	29.4 ± 1.8	7.03 ± 0.28	6.99 ± 0.27
2	33.5 ± 1.1	28.6 ± 1.6	6.62 ± 0.29	6.59 ± 0.23
3	28.8 ± 1.1	30.5 ± 2.6	5.98 ± 0.25	6.52 ± 0.17
4	29.8 ± 0.9	31.2 ± 2.0	5.66 ± 0.27	6.23 ± 0.12
6	29.0 ± 0.8	31.0 ± 1.8	5.48 ± 0.31	6.13 ± 0.15
8	28.7 ± 1.1	30.9 ± 1.4	5.22 ± 0.18	6.20 ± 0.23
12	28.1 ± 0.8	31.1 ± 1.4	5.28 ± 0.13	6.03 ± 0.18
16	29.2 ± 0.6	31.8 ± 1.0	5.26 ± 0.12	6.11 ± 0.13
20	27.0 ± 0.5	31.6 ± 1.2	5.20 ± 0.11	6.21 ± 0.13

	Total soil organic matter (%)		Total soil organic nitrogen (%)	
Distance from fire rings (m)	Allschwil	Sichtern	Allschwil	Sichtern
0.5	18.0 ± 3.2	28.4 ± 2.2	0.54 ± 0.05	0.69 ± 0.06
1	14.6 ± 1.3	23.5 ± 1.9	0.50 ± 0.04	0.72 ± 0.04
1.5	17.0 ± 1.8	22.3 ± 1.6	0.57 ± 0.03	0.70 ± 0.04
2	14.3 ± 2.0	20.7 ± 1.1	0.54 ± 0.04	0.67 ± 0.27
3	10.5 ± 1.7	21.7 ± 1.5	0.47 ± 0.03	0.71 ± 0.03
4	15.1 ± 3.7	21.2 ± 0.9	0.56 ± 0.73	0.68 ± 0.02
6	12.7 ± 2.3	19.5 ± 0.9	0.48 ± 0.03	0.67 ± 0.03
8	9.6 ± 1.6	20.0 ± 1.5	0.43 ± 0.03	0.68 ± 0.04
12	8.4 ± 0.7	20.4 ± 1.4	0.43 ± 0.02	0.67 ± 0.03
16	9.6 ± 0.7	21.5 ± 1.2	0.45 ± 0.02	0.71 ± 0.03
20	7.8 ± 0.8	21.4 ± 1.0	0.39 ± 0.02	0.69 ± 0.02

Note: Table entries are means ± SE and N = 9 in all cases.

Chapter 4

Intensive recreational activities in suburban forests: quantifying the reduction in timber values

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Abstract

Central European forests are generally multifunctional: the same forest areas are frequently used for timber production as well as for many different recreational activities. In areas intensively used for recreation, damage to trees can often be observed. The present study investigates the reduction in oak and beech timber value due to visitor-related damage to the tree bark and the subsequent decline in wood quality in two suburban forests in northwestern Switzerland. In the two forests 9.4% and 23.0% of the total area contained trees damaged by recreational activities. The resulting reduction in timber value averaged 19 € and 53 € per hectare per year. Total recreation-induced costs, i.e. additional expenses and reductions in timber value exceeded 10% of the total expenditures of the two forest enterprises examined. The decrease in revenues due to recreation need to be considered in forest policy and decision-making.

Keywords: forest recreation; multifunctionality; timber quality; tree damage; spatial distribution of damage

1. Introduction

Forests traditionally used for wood production are increasingly being used for recreational purposes in Europe (Brun, 2002; Niemelä et al., 2005). Especially in urban areas, forests are often the only freely accessible natural areas to spend some leisure time (Jascman, 1998; Niemelä, 1999). Large numbers of forest visitors can lead to conflicts between recreation and wood production and recreation and nature conservation (Liddle, 1997; Baur, 2003; Niemelä et al., 2005). Recreational activities, in particular the use of fire places, can cause extensive damage to soil, ground vegetation, shrubs and trees (Marion and Cole, 1996; Reid and Marion, 2005). In heavily frequented forest areas, damage to trees caused by forest visitors is often observed. Damages include nails driven in, broken branches and trunk scars. The percentage of damaged trees ranges from 28–77% for campground areas in the USA (Reid and Marion, 2005) and from 18–39% in urban oak-beech forests in Switzerland (Hegetschweiler et al., submitted). Wounded bark makes trees susceptible to pathogens causing fungal infections and other diseases (Brown et al., 1977; Grünwald et al., 2002). Recreational use of forests does not necessarily affect tree growth (Brown et al., 1977). However, forest visitors perceive damaged trees as aesthetically displeasing and the number of injured trees has been found to be one of the most important factors influencing visitors' experience (Smith and Newsome, 2002).

Apart from ecological and aesthetical effects, recreational activities in forests can have substantial economical consequences for forest owners. The provision and maintenance of recreational infrastructure and additional security measures during logging operations and after windstorms are largely financed by the forest owners (Bartelheimer and Baier, 1991; Dupasquier, 1996; Bilecen and Kleiber, 2002). Information and education of forest visitors and the reinforcement of laws costs additional time and money. In Swiss forests, all these costs are estimated to amount to 30–330 € ha^{-1} a^{-1}, depending on the distance to cities (Dupasquier, 1996; Bilecen and Kleiber, 2002). This corresponds to 5–12% of the total annual expenditure of the forest enterprises. In Germany, recreation-induced costs average 22 € ha^{-1} a^{-1} and reach maximum values of 78 € ha^{-1} a^{-1} in urban forests (Bartelheimer and Baier, 1991). Furthermore, damage to trees can lead to a significant reduction in timber quality, forcing forest owners to take diminishing revenues into account (Bartelheimer and Baier, 1991; Dupasquier, 1996; Kleiber and Bilecen, 2003). For example, the reaction of iron from nails in the tree trunk with the tannic acid contained in oak wood causes a blue discolouration of the wood. Instead of being sold as high quality timber, the wood can only be used as firewood. Consequently, the owners of forests with intensive recreational activities have to take additional expenditures and profit losses into account.

In order to make evidence-based decisions, information on the financial consequences of recreation is needed. In this paper, we present two case studies, in which profit losses resulting from recreational damage to trees were assessed. In field surveys, we recorded damage to trees due to recreational activities over the entire area of an oak-hornbeam and a beech forest in northwestern Switzerland. Using these spatial damage patterns, we quantified the reduction in timber value as a result of intensive recreational use of forests.

2. Materials and methods

2.1. Study area

Field data for the present study were gathered in the oak-hornbeam forest of Allschwil (7°32´ E, 47°32´ N) and in the beech forest of Sichtern (7°43´ E, 47°29´ N) in northwestern Switzerland. The forest of Allschwil (230 ha) is situated in the immediate vicinity of the city of Basel. Approximately 50'000 individuals regularly visit its most popular areas for hiking, dog walking, jogging, mountain biking and horse riding, which results in more than 850'000 visits per year (Kleiber, 2006). Fourteen official picnic sites and approximately 60 visitor-created fire places allow picnicking and grilling (Hegetschweiler et al., 2007a). The forest is dominated by oak trees (*Quercus* sp.; 30%) and beech (*Fagus sylvatica*) and other deciduous trees (hornbeam (*Carpinus betulus*), ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*). The large proportion of oaks gives the forest a high economical and ecological value.

The Sichtern forest (140 ha) is part of a larger forest area situated 10 km south-east of Basel. The number of visitors and visits to the Sichtern forest is lower than to the forest of Allschwil. The main recreational activities include hiking, dog walking and biking (Kleiber, 2003). Six official picnic sites and about 20 visitor-created fire places attract numerous forest visitors. Sichtern forest is mainly composed of beech (60%) and relatively few oak trees (5%).

2.2. Recording of tree damage

Grids of 50 x 50 m plots were set up in both areas in spring 2002, resulting in a total of 920 plots in Allschwil forest and of 560 plots in Sichtern forest. In each plot, all oak and beech trees with a DBH (diameter at breast height) >10 cm were examined for damage and assigned to one of three classes: (1) undamaged trees with no visible signs of damage caused by recreational activities; (2) slightly damaged trees with few small scars on the bark but without visible fungal infections, leading to a moderate decline in wood quality, and (3) severely damaged trees with extensively damaged bark and visible fungal infections resulting in a severe reduction in wood quality. Damage due to windstorms, lightning or roe deer were recorded but not considered in the data analysis. Plots containing no oak or beech trees were not considered (Allschwil: 42 plots; Sichtern: 51 plots). Damage to trees also reduces the conservation value of the forest area. This aspect was not considered in the present study.

Based on the percentage of damaged trees – regardless of which damage class – each plot was assigned to one of four categories: (0) not impacted (no damaged trees); (1) slightly impacted (<40% trees with recreation-induced damage); (2) moderately impacted (41–90% trees with damage); and (3) severely impacted (>90% trees with damage).

2.3. Reduction of timber value: Development of the model

We developed a model to estimate the actual reduction in timber value due to recreation-induced damage. The reduction of timber value depends on (1) the frequency of a particular tree species (oak wood gives a higher revenue than beech wood) in a given forest area, (2) the mean annual increase in wood volume, (3) current prices for oak and beech timber of different quality, and (4) the frequencies of slightly and severely damaged trees of both species in this forest area. Recreation-induced damage to trees is not uniformly distributed over the entire forest area; damaged trees occur most frequently at picnic sites and around fire places. To account for the aggregated pattern of damage, the frequency of damaged stems was assessed for both tree species' on a small spatial scale (i.e. in each 50 x 50 m plot). The cumulative damage recorded in all plots gives an estimate for the entire forest area, which can also be expressed as mean damage per hectare forest area. The forests considered have been sustainably managed for more than a century (Baur, 1999; 2003). During this period, the mean timber harvest per year did not exceed the annual increase in wood volume. Our model is based on this scenario of sustainable wood harvesting.

Let o_i be the proportion of oak trees and b_i the proportion of beech trees in plot i:

$$o_i + b_i = 1. \quad (1)$$

o_{1i} denotes the proportion of undamaged oak trees in plot i, o_{2i} the proportion of slightly damaged oak trees, and o_{3i} the proportion of severely damaged oak trees in plot i:

$$o_i = o_{1i} + o_{2i} + o_{3i}. \quad (2)$$

Correspondingly, b_{1i}, b_{2i} and b_{3i} denote the proportions of undamaged, slightly damaged and severely damaged beech trees in plot i:

$$b_i = b_{1i} + b_{2i} + b_{3i}. \quad (3)$$

ΔV is the mean annual increase in wood volume per plot (expressed in m^3). The increase in wood volume depends on local conditions (soil characteristics, including moisture), climate and competition among trees, and varies between tree species. In mixed broad-leaved forests in Switzerland, actual measurements of annual increase in wood volume are available for stands or forests usually ranging in size from 5 to 200 ha. Thus, ΔV is specific for each forest, denoted by ΔV_f (f indicates different forests). Estimates of increase in wood volume for single tree species in mixed stands are not available. Furthermore, the current prices for oak timber of the three damage classes are po_1, po_2 and po_3, and those for beech timber of the three damage classes are pb_1, pb_2 and pb_3 (expressed in € per m^3).

If there is no damage to any tree $(o_{1i} + b_{1i} = 1)$ then the revenue (G_i) for oak and beech timber per year in plot i is

$$G_i = \Delta V\left[\left(o_{1i} \times po_1\right) + \left(b_{1i} \times pb_1\right)\right], \quad (4)$$

and for the entire forest the total potential revenue G_p per year is

$$G_p = \Delta V\left(\sum_{i=1}^{n} o_{1i} \times po_1 + \sum_{i=1}^{n} b_{1i} \times pb_1\right) \quad (5)$$

where n is the number of plots in the forest. In practice, however, the total revenue G is reduced because certain proportions of oak and beech trees are slightly or severely damaged. Thus, the revenue G_i per year in plot i is reduced by the proportions of slightly and severely damaged oak and beech trees in this plot:

$$G_i = \Delta V\left[\left(o_{1i} \times po_1\right) + \left(o_{2i} \times po_2\right) + \left(o_{3i} \times po_3\right) + \left(b_{1i} \times pb_1\right) + \left(b_{2i} \times pb_2\right) + \left(b_{3i} \times pb_3\right)\right]. \quad (6)$$

For the entire forest, the total actual revenue G_a per year is

$$G_a = \Delta V_f\left[\sum_{i=1}^{n}\left(o_{1i} \times po_1\right) + \sum_{i=1}^{n}\left(o_{2i} \times po_2\right) + \sum_{i=1}^{n}\left(o_{3i} \times po_3\right) + \sum_{i=1}^{n}\left(b_{1i} + pb_1\right) + \sum_{i=1}^{n}\left(b_{2i} \times pb_2\right) + \sum_{i=1}^{n}\left(b_{3i} \times pb_3\right)\right]$$

(7)

where n is the number of plots in the forest. The forest-specific reduction in timber value (R) due to recreational activities is

$$R = G_p - G_a. \qquad (8)$$

Depending on market, timber value is varying (Table 1). Therefore, we used minimum, median and maximum prices for oak and beech timber to estimate the recreation-related reduction in timber value in both forests.

Table 1
Prices (median values and ranges) for standard quality (undamaged) and differently damaged beech and oak timber (€ m^{-3}) based on local market prices in Switzerland in November 2007 (*local foresters, personal communication*).

Timber quality	Beech timber € m^{-3}	Oak timber € m^{-3}
Standard quality (undamaged; class 1)	123 (90–150)	500 (300–721)
Slightly damaged (class 2)	62 (36–90)	125 (60–210)
Severely damaged (class 3)	34 (24–48)	29 (24–36)

See materials and methods for definitions of damage classes.

3. Results

3.1. Extent and spatial pattern of recreation-induced tree damage

In Allschwil forest, 6.3 ha (2.9%) of the 220 ha forest area were heavily impacted by recreational use, 20.5 ha (9.3%) moderately and another 23.8 ha (10.8%) slightly impacted by recreational activities (Fig. 1). Thus, 23.0% of the total forest area contained trees with recreation-induced damage. In Sichtern forest, 9.4% of the total area contained trees damaged by recreational use: 1.5 ha (1.2%) of the 141 ha area were heavily impacted, 3.0 ha (2.4%) moderately and further 8.0 ha (5.7%) slightly impacted (Fig. 2).

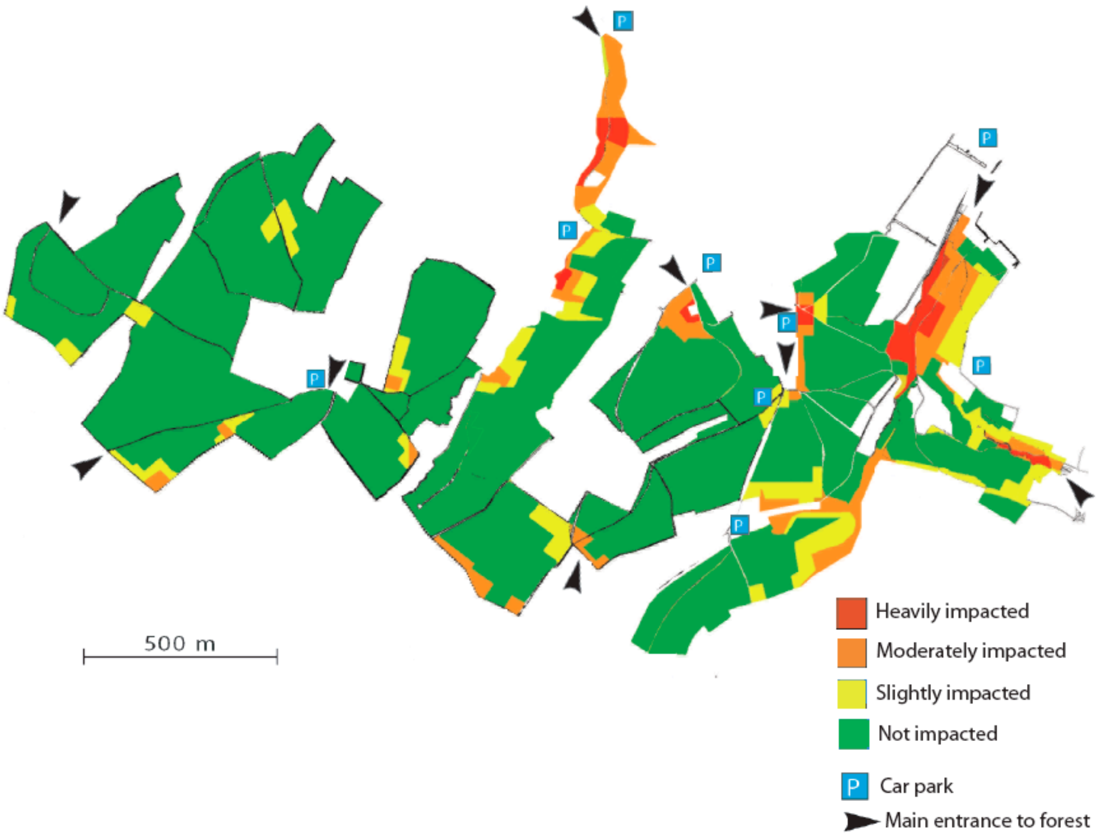

Fig. 1. Spatial distribution of recreation-induced damage to trees in Allschwil forest near Basel in northwestern Switzerland.

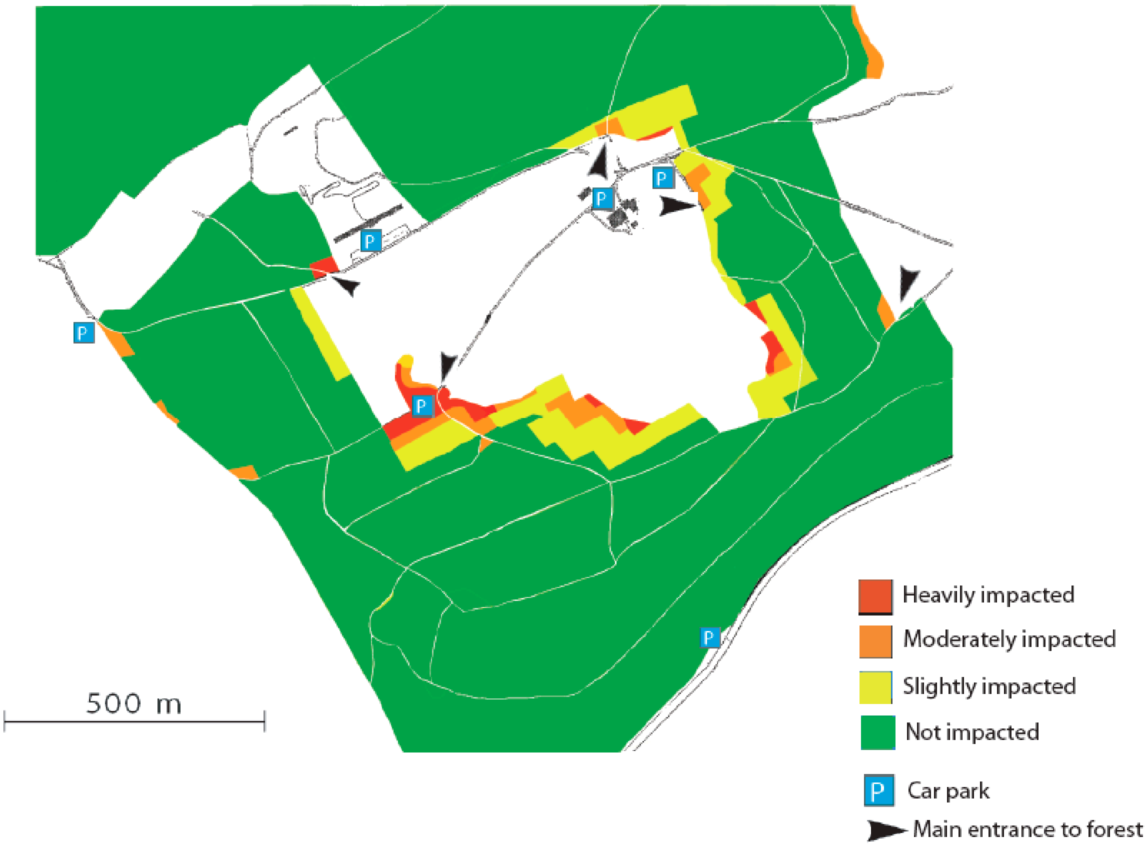

Fig. 2. Spatial distribution of recreation-induced damage to trees in Sichtern forest near Basel in northwestern Switzerland.

Considering the heavily impacted areas, which in most cases contained picnic sites and fire places and were situated near the forest edge, the two forests were similar in the frequency of damaged trees (oak: Allschwil: 83%, Sichtern: 95%; beech: Allschwil: 92%, Sichtern: 93%). In moderately impacted areas, however, the two forests slightly differed in frequency of damaged trees (oak: Allschwil: 54%, Sichtern: 73%; beech: Allschwil: 69%, Sichtern: 74%). The corresponding values for slightly impacted forest areas were: oak: Allschwil: 3.6%, Sichtern: 0%; beech: Allschwil 6.4%, Sichtern: 7.0%.

3.2. Reduction in timber value

Estimates of the reduction of timber value caused by recreational activities over the entire area of Allschwil forest ranged from 8’428 to 16’095 € per year, considering minimum and maximum market prices (median: 11'678 € per year). The corresponding timber value reduction in Sichtern forest ranged from 2'111 to 3'752 € per year (median: 2'741 € per year). The average reduction in timber value was 53 € per hectare per year in Allschwil forest (range: 38–73 € per year) and 19 € per year in Sichtern forest (range: 15–27 € per year). Considering only the heavily impacted areas, which are of major concern to forest managers, the annual reduction in timber value was similar in both forests (Table 2). The high intensity of recreational activities in these areas reduces the timber value by 500 € per hectare and year in Allschwil forest (range: 359–696 €) and by 554 € per hectare and year in Sichtern forest (range: 421–775 €). Even in moderately impacted areas the recreation-induced annual reduction in timber value is still considerable (Table 2).

Table 2
Reduction of timber value (in € ha^{-1} a^{-1}) in areas differently impacted by recreational activities in two suburban forests situated in northwestern Switzerland (median values and ranges are shown).

Extent of damage	Allschwil forest € ha^{-1} a^{-1}	Sichtern forest € ha^{-1} a^{-1}
Slightly impacted areas	19 (17–20)	39 (33–47)
Moderately impacted areas	394 (281–548)	409 (310–566)
Heavily impacted areas	500 (359–696)	554 (421–775)

4. Discussion

Central European forests are, in general, multifunctional, fulfilling ecological, economical and social services (Brun, 2002; Niemelä et al., 2005). Many European countries have a legal basis for multifunctionality and sustainable management, and several policies encourage public access to forests. Important forest functions or services are protected and measures exist to support increased production of non-market benefits from forests (UNECE, 2005). Similarly, in Switzerland, legislation requires multifunctionality and sustainable management (Federal Forest Law, 1991). Conflicts arise when the same forest areas are used simultaneously for recreation and timber production. The present study shows that reductions in timber value due to visitor-related damage to trees range from 19 to 53 € per hectare and year in the two forests examined.

In Germany, profit losses due to damage by visitors, the renouncement of hunting and lower wood production when former wood production areas are lost to picnic sites averaged 2.20 € ha^{-1} a^{-1} in urban forests, holiday areas and other forests (Bartelheimer and Baier, 1991). In Bavarian forests, management adaptations such as renouncing clearcuts, using less profitable tree species to adjust to visitor preferences and limiting mechanization are estimated to cost 1.13 € ha^{-1} a^{-1} (Ammer and Pröbstl, 1991). Using accounting data and information from local foresters, Dupasquier (1996) calculated profit losses to range from 0.36 to 10.40 € ha^{-1} a^{-1} in Western Switzerland, depending on the forest. The profit loss is assumed to result from a reduced natural regeneration rate due to human trampling, damage to trees, the loss of timber production areas due to construction of recreational infrastructure and management adaptations in frequently visited areas (Dupasquier, 1996). The reductions in timber value estimated in the present study are higher than those of the other studies mentioned. However, a direct comparison is not possible, because the other studies were not conducted exclusively in typical suburban recreation forests and the resulting estimates are, to a large extent, based on factors other than tree damage. Furthermore, the other investigations included large forests, in which recreation plays a minor role.

Total costs caused by recreation are composed of the additional expenditures of the forest owner and profit losses. Kleiber and Bilecen (2003) estimated expenditures due to recreation including labour costs, material costs and insurance costs to amount to 141 € ha^{-1} a^{-1} in Allschwil forest and 73 € ha^{-1} a^{-1} in Sichtern forest. Additionally, taking into account the reductions in timber value, total costs add up to 194 € ha^{-1} a^{-1} in Allschwil forest and 92 € ha^{-1} a^{-1} in Sichtern forest.

Considering the difficult economical situation of most forest enterprises since 1990, when timber prices started to decline (Hyttinen et al., 1997), the reduction in timber value can become a significant financial burden. In Allschwil forest, the proceeds from the sale of wood amounted to 75'089 € in 2006 (*local forester, personal communication*). This means that the annual reduction in timber value of 11'678 € corresponds to 16% of the proceeds. Total expenditures of the forest enterprise in Allschwil averaged 279'251 € per year between 1996 and 2000 (Kleiber and Bilecen, 2003). Therefore, the timber value reduction of 11'678 € represents 4% of the total expenditures and the total recreation-induced costs of 40'293 € per year account for 14% of the total expenditures. In Sichtern forest, total expenditures of the forest enterprise averaged 130'130 € per year over the same five year period (Kleiber and Bilecen, 2003). Accordingly, the reduction in timber value (2'741 € per year) represents 2% of the total expenditures, and total costs caused by recreation (15'976 € per year) account for 12% of the total expenditures. The situation is similar in other parts of Switzerland. In a nation-wide survey conducted in 2005, many forest managers in large urban areas assumed that costs related to recreation exceeded 10% of the total expenditures of the forest enterprises (Hegetschweiler et al., 2007b). Not surprisingly, 63% of the forestry experts asked for additional financial support for tasks concerning recreation.

In order to evaluate these costs, it is necessary to consider the benefits that the public draws from forest recreation. For example, the consumer surplus of the Allschwil forest was assessed to be 5'446 € ha^{-1} a^{-1} (Kleiber, 2006), far more than the total costs in the two forests examined in this study. The consumer surplus of the urban forests of Zurich was estimated to amount to 8'018 € ha^{-1} a^{-1} (Bernath et al., 2006). Similarly, urban forests in Joensuu in eastern Finland reached a consumer surplus of 8'683 € ha^{-1} a^{-1}, 7 to 12 times more than the total provision costs for recreation services in that area (Tyrväinen, 2001). Elsasser (1996) even estimated the consumer surplus of the forests of Hamburg to amount to

15'978–23'967 € ha^{-1} a^{-1}. These studies show that the monetary benefits of forest recreation by far exceed the costs.

5. Conclusions

The concept of multifunctional forestry explicitly demands possibilities for forest recreation in accordance with wood production. Considering the high benefit the public draws from forest recreation, it is imperative to maintain these possibilities. However, recreation in urban forests is a major expense factor and the financial burden on forest enterprises already in a difficult economical situation is high, especially in highly frequented forests such as the Allschwil forest. This cost factor needs to be considered when making forest policies and management plans.

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Chapter 5

Fire place preferences of forest visitors in northwestern Switzerland: Implications for the management of picnic sites

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Fire place preferences of forest visitors in northwestern Switzerland: Implications for the management of picnic sites

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Abstract

Some recreational activities in urban forests can cause extensive damage to soil and vegetation. In Switzerland, forest visitors frequently build fires outside picnic sites for barbecuing. This indicates that the existing picnic sites are either not attractive enough for these visitors, or that there are not enough sites for all the visitors during peak days. We used an on-site survey to assess the requirements of picnickers in two forest areas in the vicinity of Basle. Results showed that the existing picnic sites do not meet the requirements of some visitor groups, causing the respective visitors to make their own fires in locations that suit them better. There was a preference for sites near streams, away from forest roads and close to open spaces. Furthermore, while some visitors highly appreciated the well-equipped official sites, others preferred more natural infrastructure with pieces of stones forming a fire ring rather than concrete rims, and logs to sit on instead of benches. Picnic sites that are closer to the requirements of visitors who normally steer away from official sites might reduce the number of self-made fire rings. The study shows that understanding visitor behaviour is a prerequisite for the implementation of measures to reduce ecological impacts.

Keywords: Day use; Picnicking; Recreational infrastructure; Survey; Urban forest; Visitor monitoring

Introduction

Outdoor recreation in forests has become an important part of many people's lives, especially in urban areas, where forests are often the only freely accessible natural areas to spend some leisure time (Jacsman, 1998). Large numbers of forest visitors can lead to conflicts between recreation and nature conservation and between recreation and wood production (Liddle, 1997; Baur, 2003). Ecological studies report effects of wear on vegetation (e.g., Cole, 1995; Malmivaara et al., 2002; Roovers et al., 2004), various soil parameters (Lutz, 1945; Liddle, 1997), the soil seed bank (Amrein et al., 2005) and soil microorganisms (Zabinski and Gannon, 1997; Malmivaara-Lämsä and Fritze, 2003). Other consequences of the intense recreational use of forests are social conflicts between different user groups (Ramthun, 1995; Heer et al., 2003) and the perception of crowding (West, 1982; Arnberger and Haider, 2005). Residents in the neighbourhood might also be negatively affected by overcrowding and the subsequent noise and pollution (Perez-Verdin et al., 2004).

Evidence from ecological studies is giving rise to a growing concern about the environmental impact of leisure activities on the forest. Traditionally, sensitive environments have been managed by controlling access to natural areas or by trying to ban recreation in these

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areas altogether (Reynolds and Elson, 1996). This form of management was largely based on the concept of carrying capacity. This concept aims to define a maximum level of recreational use that can be sustained without unacceptable or irreversible damage to the site (Curry, 1994). These originally biological models did not transfer well into ecosystems being managed for recreation, leading to the development of several visitor management frameworks, e.g., the Limits of Acceptable Change (LAC) planning system (Stankey et al., 1985; McCool, 1996; Moore et al., 2003). During recent years, more effort has been made to incorporate usage trends and visitor demand into recreational planning (Cope et al., 2000). Examples include incorporating mountain bike user preferences into trail design (Symmonds et al., 2000) and using visitor information to increase recreationists' awareness of the environmental fragility of natural areas (Hughes and Saunders, 2005). Nevertheless, surveying of visitor opinions for the purpose of developing measures to minimize environmental impacts remains an exception (Cope et al., 2000).

In the following, we present a study from a suburban forest area in northwestern Switzerland, in which impact assessments and visitor monitoring have been conducted since 1997 (Baur, 1999, 2003; Rusterholz et al., 2000; Kleiber, 2001; Waltert et al., 2002; Rusterholz and Baur, 2003; Amrein et al., 2005). This approach enabled us to explain damages caused by picnicking and grilling by visitor needs that were not satisfied, rather than by visitor levels alone. The results from the investigation will be used to implement measures to minimize ecological damage.

Grilling sausages in the forest is a traditional pastime in Switzerland. Legislation allows free access to forested areas (Civil Code, Art. 699, 1907) as well as the lighting of fires outside official picnic sites (Federal Forest Law, 1991). Barbecue pits at picnic sites are characterized by a concrete rim, while self-made fire rings usually have a ring of pieces of stones to prevent the fire from expanding beyond control. In urban forests, the constant use of picnic sites and especially the creation of fire rings in previously untouched areas allow damages to spread uncontrollably throughout the forest (Bratton et al., 1982; Jim, 1987; Kutiel and Zhevelev, 2001; Baur, 2003; Reid and Marion, 2005; Rusterholz, 2005). Therefore, it is important to find out why forest visitors make fires outside picnic sites and what their preferences are concerning places suitable for grilling. The aim of the study was to provide a basis for designing fire places that really meet the requirements of their users. We used on-site surveys to assess the preferences of people in two forests in the vicinity of Basle in northwestern Switzerland. We also asked residents in a suburban area about their preferences concerning picnicking and other recreational activities in an isolated grove in the neighbourhood. The implementation of the results should reduce the establishment of new "wild" fire rings.

Material and methods

Forest visitor survey

Allschwil forest (7°32′E, 47°32′N) is a relatively small, suburban forest (about 230 ha) in the proximity of the city of Basle (Fig. 1). The forest can easily be reached by public transport and there are several car parks. Counts revealed that up to 200,000 people visit the most popular areas within one year (Baur, 1999). Querco-Carpinetum-stands and a high diversity of vascular plants and invertebrates make this forest ecologically valuable (Baur, 1999). As a consequence, the whole forest was declared a nature conservation area in 2003 (Ordinance on the Nature Reserve "Allschwil Forest", 2003). Since then, building fires in places other than barbecue pits is prohibited. Maps at the forest entrances show visitors where the official picnic sites are located. Signs also inform visitors about special regulations in the forest, including the prohibition of fires outside designated picnic areas. However, many "wild" fire places have been established for several years. Visitors continue to use them, in spite of repeated attempts by the forestry service to remove the fire rings.

The Schönmatt-Plateau (7°40′E, 47°30′N) is a large forested area (about 1570 ha) situated between Liestal, Pratteln and Arlesheim about 10 km southeast of Basle. Reaching the forest edge by public transport requires a short walk from the train stations. There are some parking spaces at the edge of the forest. However, to reach the more remote areas, it takes a 1–2 h walk. The number of visitors to the Schönmatt-Plateau is lower than to the Allschwil forest.

We interviewed 214 groups of people (149 in Allschwil forest and 65 on the Schönmatt-Plateau) that had made a fire in the forest. One hundred and thirteen interviews (53%) were conducted at official picnic sites with barbecue pits and 101 interviews (47%) at fire rings outside picnic sites. Interviews were conducted on all seven days of the week between 10:00 and 19.30 h in June, July and August 2004. Most people, however, grilled on Sundays. Equal numbers of men and women were interviewed. If possible, adults were questioned, only 19% were children or adolescents ($<$23 years). In Allschwil forest, eight groups (5%) could not be interviewed, either because they refused to participate or because of language difficulties. On the Schönmatt-Plateau, two groups (3%) could not be interviewed for the same reasons.

The questionnaire consisted of 15 questions, of which twelve had closed response formats. The questionnaire is available at 〈http://www.conservation.unibas.ch/research/recreation/index.html〉 (last accessed 1 March 2007).

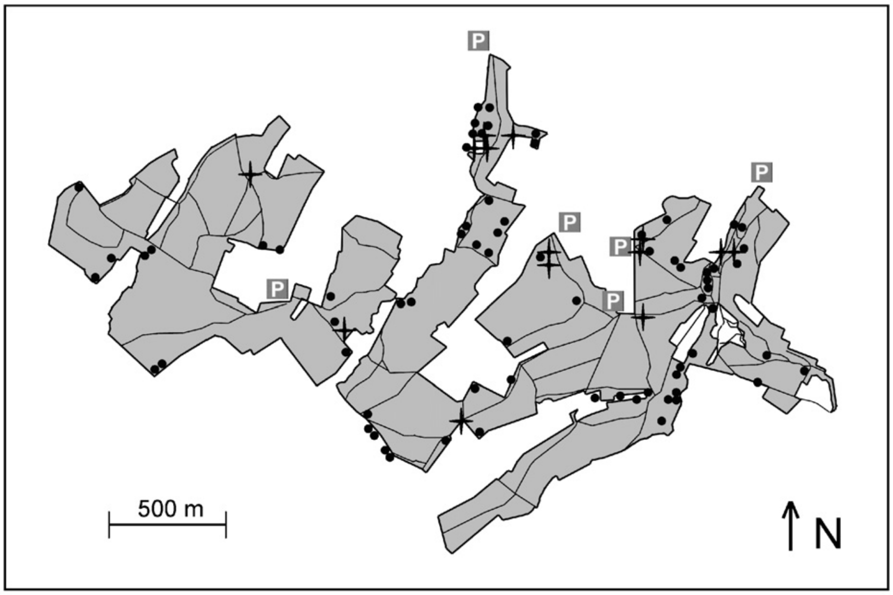

Fig. 1. Map of Allschwil forest with 14 official picnic sites with barbecue pits (stars) and 71 self-made ("wild") fire rings (dots) recorded in summer 2004. P indicates car parks.

The first part of the questionnaire dealt with the frequency and duration of picnicking and aimed at assessing the demand of picnic sites. Several questions focused on the recreationists' preferences and requirements concerning location and infrastructure of picnic sites. This part included a show card with a series of computer-generated images (Adobe Photoshop 7.0) on which the interviewees were asked to voice their opinion (Figs. 2a–f). The usage of these manipulated photographs made it possible to control variables such as background, vegetation type, light conditions, etc. (Karjalainen and Tyrväinen, 2002). Fig. 2a shows a picnic site with a concrete barbecue pit and plenty of infrastructure. Fig. 2b shows a fire ring made of stones at a picnic site with benches, a table and a rubbish bin. This is obviously an official site, in spite of the missing barbecue pit. Fig. 2c shows the present situation in the study area: a concrete barbecue pit with some benches. Fig. 2d shows a fire ring made of pieces of stones in a cleared open space. This is what "wild" fire places look like after they have been used for a few years. Fig. 2e shows a concrete barbecue pit in an undisturbed forest area. The purpose of this picture was to see whether there is a want for official picnic sites in undisturbed forest areas. Fig. 2f shows the classical "wild" fire place: a fire ring made of stones in an undisturbed forest patch. Lastly, the respondents were asked a few questions on travelling to and from the forest, and some questions on socio-demographic variables like age and gender were added.

We also characterized all fire places found in the two forest areas and examined their surrounding environment.

Resident survey

Residents living in the neighbourhood of Fuchshag forest (7°34′E, 47°32′N), a small, isolated forest patch (about 0.7 ha) in a suburban area about 2 km south of the centre of Basle, complained about recreational activities in this grove. Especially the building of fires in spite of no barbecue pits being provided, highlighted the need for management actions to improve the situation. Among other things, the installation of a proper picnic site was discussed. We prepared a self-administered questionnaire to enable the residents to voice their opinion on the ideas discussed by the authorities. The questionnaires were delivered to the residents personally and picked up again a few days later. This method ensures a high response rate (Smith and Krannich, 2000; Kaczensky et al., 2004). In all, 139 households out of 167 were reached this way. Out of these, 115 returned a completed questionnaire, resulting in a response rate of 83%. The first part of the questionnaire dealt with recreational activities in the grove in general. The second part focussed on the discussed management actions, especially on the installation of a picnic site. A set of socio-demographic variables enabled us to make a profile of people who were in favour of a picnic site in Fuchshag forest and people who were not. The questionnaire is available at 〈http://www.conservation.unibas.ch/research/recreation/index.html〉 (last accessed 1 March 2007). The resident survey gave us some indication of the users of fire places versus people who do not make use of fire places in the forest, and therefore complemented the forest visitor survey which concentrated on users of fire places alone.

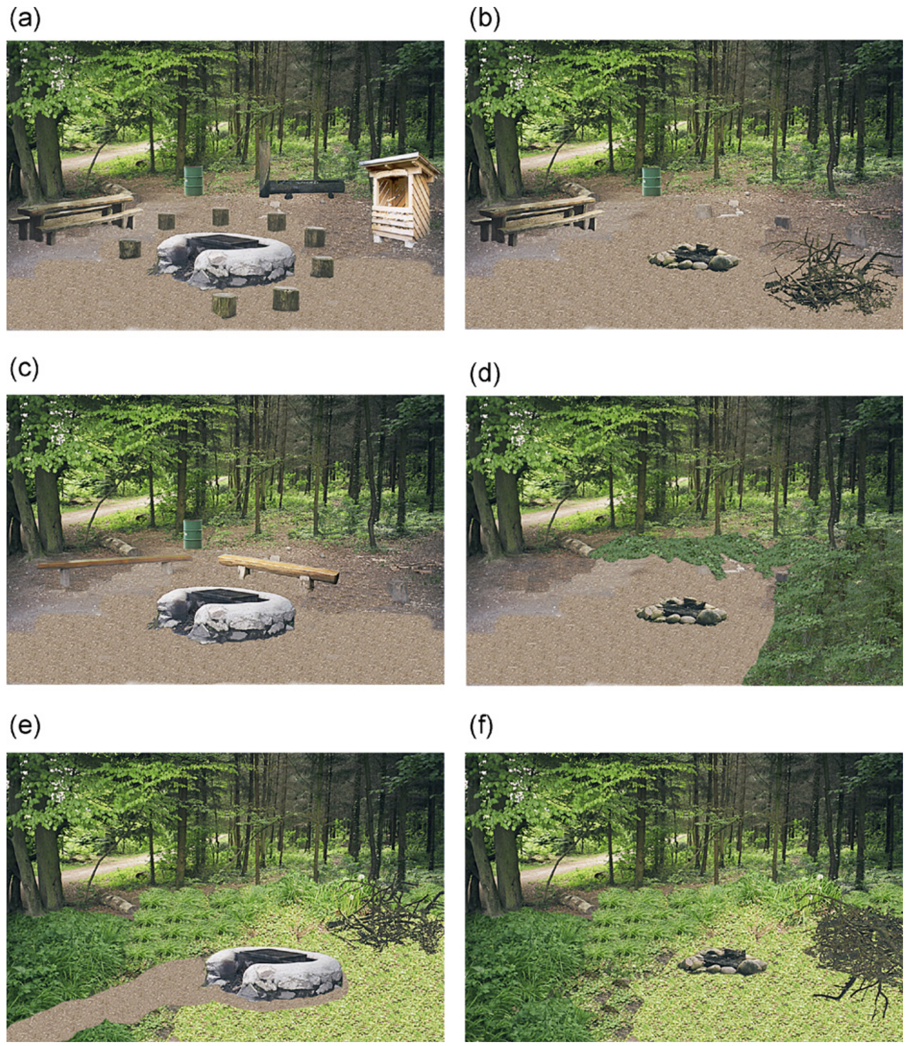

Fig. 2. (a)–(f) Set of computer-generated images – each image depicts either a barbecue pit or a fire ring with varying amounts of infrastructure and different surroundings.

The data were analysed using nonparametric statistical tests (Siegel and Castellan, 1987). For all statistical analyses SPSS was used (SPSS 11.0, 2002).

Results

Forest visitor survey

Visitors using official picnic sites with concrete barbecue pits differed in their means of travel to the forest from visitors using "wild" fire rings ($\chi^2 = 7.85$, $df = 1$, $p = 0.005$). The former almost always travelled to the forest edge by car, whereas the latter used public transport or bicycles more frequently. There was a trend for users of "wild" fire rings to take longer travelling time into account ($\chi^2 = 5.71$, $df = 2$, $p = 0.058$). Most visitors used fire places 1–4 times a year. Sixteen percent of visitors at "wild" fire places were very frequent users and made a fire in the forest at least once a week. Big groups of more than 20 people nearly always used official sites, as did school classes in Allschwil forest. In contrast, most school classes on the Schönmatt-Plateau were found at self-made fire rings. Families preferred fire rings away from picnic sites in Allschwil forest and official sites on the Schönmatt-Plateau. The same number of children (4 children on average) was counted at both types of fire places. There were no differences in the duration of usage neither between the type of fire place used nor between the two forests.

When asked about their preferences concerning the surroundings and the accessibility of picnic sites, several respondents referred to open space as important. A number of people wanted the picnic site to be at the forest edge (Fig. 3). An open forest structure was preferred to a closed forest structure. Sites near streams were also favoured, especially by users preferring "wild" fire rings. For users preferring official picnic sites with

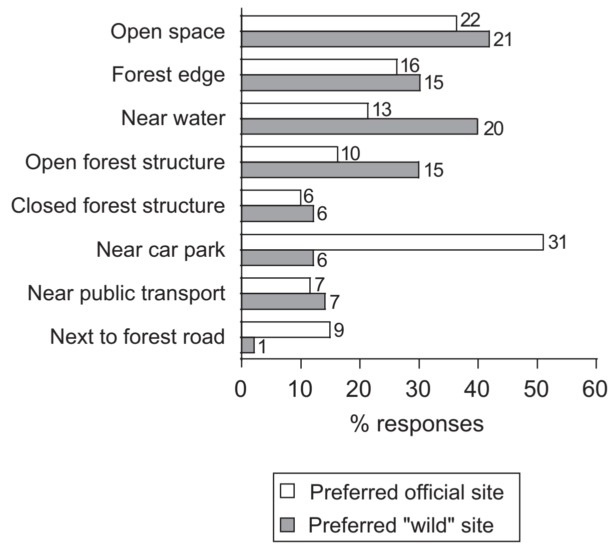

Fig. 3. Preferences of forest visitors preferring either official picnic sites or "wild" fire rings concerning the surroundings and the accessibility of picnic sites in Allschwil forest and on the Schönmatt-Plateau in northwestern Switzerland. Data of the two forests were combined. Numbers next to bars indicate sample sizes, multiple responses were possible.

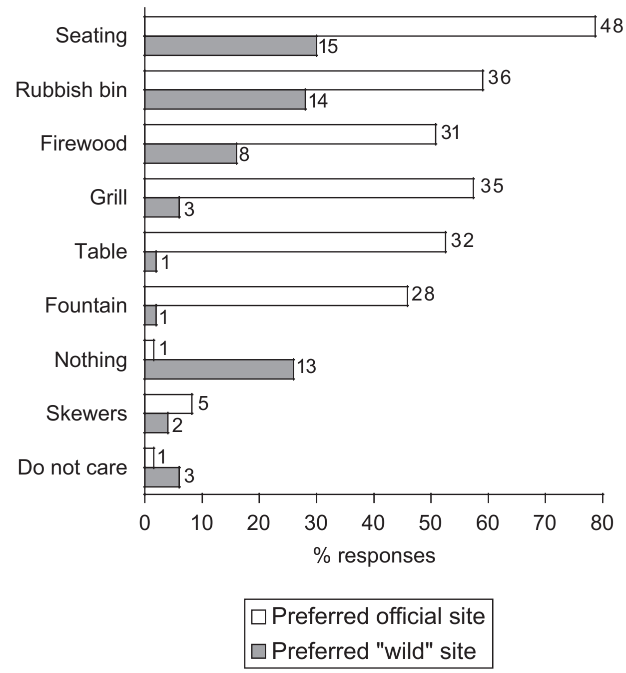

Fig. 4. Preferences of forest visitors favouring either official picnic sites or "wild" fire rings concerning the infrastructure of picnic sites in Allschwil forest and on the Schönmatt-Plateau in northwestern Switzerland. Data of the two forests were combined. Numbers next to bars indicate sample sizes, multiple responses were possible.

barbecue pits, the proximity to a car park was much more important than the proximity to public transport, whereas for users preferring "wild" sites, the proximity to car parks and public transport was of equally low importance. Sites at the edge of a forest road were extremely unpopular, especially with users preferring "wild" fire rings. Preferences concerning surroundings and accessibility differ between users favouring official sites and users favouring "wild" fire rings ($\chi^2 = 23.55$, df = 7, $p = 0.001$). There were no differences in these preferences between the two forests ($\chi^2 = 6.03$, df = 7, $p = 0.54$).

Regarding the infrastructure of picnic sites, some kind of seating ranked first, followed by rubbish bins (Fig. 4). Users preferring "wild" fire rings wanted less infrastructure than users preferring official sites. Several of the visitors preferring "wild" sites would have been satisfied without any infrastructure at all. The differences in preferences concerning infrastructure between users favouring official picnic sites and users favouring "wild" fire rings were highly significant ($\chi^2 = 66.77$, df = 8, $p < 0.001$). There were no differences in preferences concerning infrastructure between the two forests ($\chi^2 = 7.04$, df = 8, $p = 0.53$).

When asked which of the six pictures on the show card represented their favourite fire place, Fig. 2a was chosen most frequently, followed by Fig. 2b (Fig. 5a). On the other hand, Figs. 2f and a were the two most unpopular pictures (Fig. 5b). Fig. 2a was mainly chosen by people preferring to use barbecue pits. Fig. 2b was chosen by some visitors preferring official sites but more often by visitors preferring to use "wild" fire rings, whereas Figs. 2d and f were favoured almost exclusively by respondents preferring to grill outside official sites. Fig. 2e was an option neither for visitors preferring official sites nor for visitors preferring "wild" sites.

A comparison of visitors' preferences with the type of fire place they were interviewed at, showed that most visitors were using a site that met their requirements (Table 1). Visitors interviewed at official sites were mostly satisfied with the barbecue pit they were using, only a minority – 20% on the Schönmatt-Plateau and 14% in Allschwil forest – would have preferred a "wild" fire ring. Visitors interviewed at "wild" sites showed the same pattern. In Allschwil forest, 74% of users of "wild" fire rings wished to have a fire ring made of stones. On the Schönmatt-Plateau, no one would have preferred a concrete barbecue pit instead of the ring of stones that they were using. Preferences varied between the type of fire place used ($\chi^2 = 45.85$, df = 1, $p < 0.001$) as well as between the two areas ($\chi^2 = 3.89$, df = 1, $p = 0.049$). On the Schönmatt-Plateau more respondents preferred a ring of stones than in Allschwil forest.

One reason for creating new fire rings might be an insufficient number of official sites. In order to assess this, we asked whether people had decided beforehand or spontaneously which site they were going to use. We also asked whether or not they had been able to use their

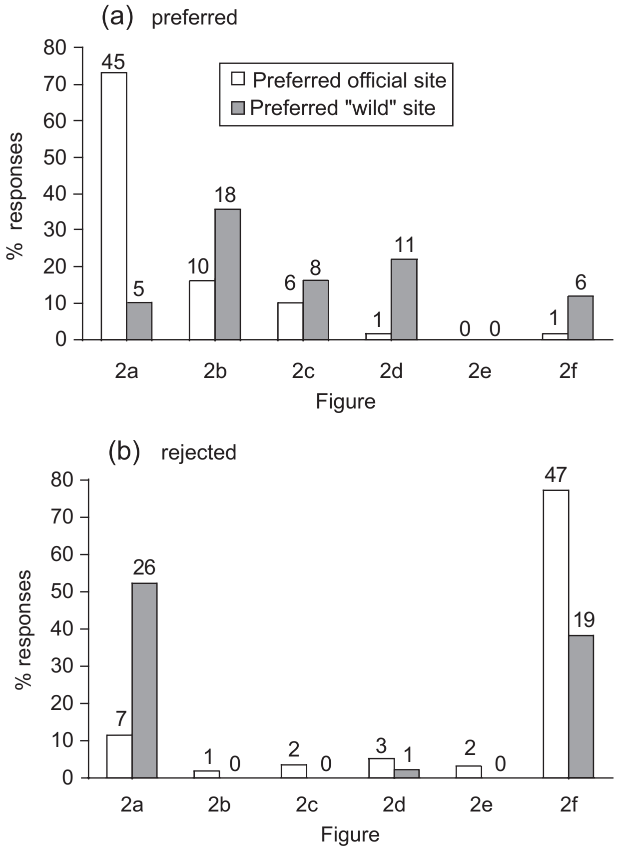

Fig. 5. Frequency distribution (in %) of particular types of picnic sites preferred (a) or rejected (b) by forest visitors preferring either official picnic sites or "wild" fire rings in Allschwil forest and on the Schönmatt-Plateau in northwestern Switzerland. Data of the two forests were combined. Numbers on top of bars indicate sample sizes.

Table 1. Preferences of forest visitors interviewed at official and "wild" picnic sites concerning the type of fire place in Allschwil forest and on the Schönmatt-Plateau in northwestern Switzerland

	Allschwil forest	Schönmatt-Plateau
Interviewed at official site		
Preferred barbecue pit	42 (86)	8 (80)
Preferred "wild" fire ring	7 (14)	2 (20)
Interviewed at "wild" site		
Preferred barbecue pit	10 (26)	0 (0)
Preferred "wild" fire ring	28 (74)	12 (100)

The number of answers (in parentheses the percentage) is shown.

chosen site and whether they knew other sites in the forest. The results showed that most visitors had envisaged a certain place, but more users of "wild" fire rings had spontaneously chosen their site than users of official picnic sites ($\chi^2 = 4.15$, df $= 1$, $p = 0.042$). In Allschwil forest, more spontaneous decisions were made than on the Schönmatt-Plateau ($\chi^2 = 9.32$, df $= 1$, $p = 0.002$). Seventy-nine percent of the respondents were able to make use of their chosen site. There were no differences in this between the two forests ($\chi^2 = 0.005$, df $= 1$, $p = 0.9$). In both forests more users of "wild" fire rings said that the site they were using was not their first choice ($\chi^2 = 6.47$, df $= 1$, $p = 0.011$). However, 56% of these "displaced" visitors would have preferred another "wild" site, not an official one. The occurrence of crowding, forcing visitors to settle at a fire place of their second or third choice differed between weekdays (11% of weekday respondents), Saturdays (15%) and Sundays and public holidays (31%). The number of "wild" sites occupied was usually similar to the number of official sites occupied: on weekdays on average 1.2 (SE 0.33) official sites and 0.9 (SE 0.23) "wild" sites were occupied, on Saturdays 3.5 (SE 1.06) official sites and 3.5 (SE 0.85) "wild" sites and on Sundays and public holidays 4.6 (SE 0.58) official sites and 6.1 (SE 1.35) "wild" sites. Visitors were well informed about alternative picnic sites in the forest area. Seventy-seven percent of the respondents knew other fire places they could use – 73% at official sites and 82% at "wild" sites. Only one of the groups preferring an official site but using a "wild" fire ring – a family with 2 adults and 3 children – did not know any other fire places. Awareness of the prohibition of building fires outside official picnic sites in Allschwil forest did not differ between users of official sites and users of "wild" sites ($\chi^2 = 0.031$, df $= 1$, $p = 0.86$). Forty-six percent of visitors using official sites and 44% of visitors using "wild" fire rings were aware of this regulation.

A comparison of the number of "wild" fire rings in Allschwil forest in the years 2004 and 2006 showed that over the course of 2 years, 16 sites had been abandoned and 11 new sites created. In June 2006, 12 "wild" fire rings were removed by the forestry service. However, new fire rings were created at 9 of these sites during the following weeks.

Resident survey

Forty-four percent of the questioned residents felt disturbed by at least one of the observed activities in the grove. Activities that disturbed people most were dog-walking (60%) and making "wild" fires (34%). Especially rubbish left lying around (78%) and damage to nature (68%) annoyed the residents. Seventy-three percent of the respondents were against the installation of an official picnic site, fearing that a picnic site would attract even more recreationists (42%), leading to more noise and littering (42% and 66%, respectively). The activity of making fires was observed by 40% of the residents, but only 3% participated in it themselves.

Residents objecting to a picnic site were mainly residents who felt disturbed by the activities in the grove ($\chi^2 = 6.93$, df = 1, $p = 0.008$) and who tended to avoid spending leisure time in the grove ($\chi^2 = 3.18$, df = 1, $p = 0.075$). On average, they were older (Mann–Whitney U test: $z = 2.95$, $p = 0.003$) and had lived in the area longer ($z = 2.70$, $p = 0.007$). Eighty-nine percent lived in a detached house and 85% had no children living in the same household. By contrast, residents in favour of the installation of a picnic site felt less disturbed by recreational activities in the grove and made use of the grove to go for walks, some also to go biking, play with children and make fires. They were younger on average, had lived in the area for a shorter time and 27% of them lived in an apartment. Forty-one percent of them had children living in the same household.

When asked about their preferences concerning infrastructure of picnic sites in general, 81% of the respondents underlined the need for a rubbish bin. Fifty-eight percent wanted logs to sit on. These were the two most important items. The percentage of respondents requiring a concrete rim (37%) was almost equal to the percentage requiring a ring of stones (41%).

Discussion

Our survey revealed that "wild" fire rings are used by different visitor groups than official picnic sites. On the Schönmatt-Plateau, where creating and using "wild" fire rings is allowed, school classes used self-made fire rings more often. Children usually enjoy helping to gather stones and wood and construct a fire place, and "wild" fire rings offer more possibilities to do so. However, we found no indication that "wild" fire rings are used more frequently with children than official sites.

Concerning surroundings and location of picnic sites, forest visitors frequently favoured sites by a stream, where children could play and drinks could be cooled, slightly away from the forest road and at the forest edge, with enough open space to accommodate everyone comfortably. As a consequence, in Allschwil forest most "wild" fire rings are created close to streams and along forest edges, while official picnic sites are frequently in homogeneous forest, away from the streams and adjacent to forest roads. The latter makes the upkeep by the municipal workers easier (personal observation).

Most picnickers preferred an open forest structure. Other studies also indicate that the ideal forest for recreation is not a primeval, but a managed forest, and that dense areas are appreciated for their scenic beauty, but moderately open settings are preferred for recreation (Ammer and Pröbstl, 1991; Bjerke et al., 2006).

Both surveys showed that the two most important elements of a picnic site were seating and rubbish bins. In the resident survey, where seating was defined more detailed as benches or logs, logs were preferred, reflecting the wish for the infrastructure to be as natural as possible. Existing picnic sites, where seating is generally provided in the form of stone or wooden benches, do not conform to this wish. Residents termed a rubbish bin even more important than seating. They are left with all the rubbish after other forest visitors have gone home and may therefore perceive littering as a greater problem. This is also reflected by the result that littering is what disturbs residents most about the recreational activities in the forest. Littering is indeed a concomitant phenomenon wherever recreationists are present, and studies have shown that the provision of rubbish bins may or may not reduce the amount of littering (Liu and Sibley, 2004; Santos et al., 2005).

Users preferring "wild" fire rings showed different preferences concerning the computer-generated images on the show card than users preferring official picnic sites. Fig. 2a was the most controversial picture. Most respondents preferring official sites want to have as much infrastructure as possible, as it is offered in Fig. 2a. Respondents preferring "wild" sites however, liked this fire place least. Several respondents said that Fig. 2a was almost like a kitchen and using that fire place would be like barbecuing in their own garden. Fig. 2b was much less controversial. This picture was preferred by a lot of respondents preferring "wild" sites, in spite of its official character with benches and a rubbish bin. This indicates that visitors using "wild" sites might be willing to use official sites, if these were more natural. Fig. 2e was neither preferred nor rejected. It seems that this unrealistic setting was barely perceived by the visitors. This shows that visitors preferring natural surroundings do not want a concrete barbecue pit, and visitors who use concrete barbecue pits do not want to grill in completely undisturbed forest areas. Likewise, making a fire in a green forest patch like in Fig. 2f was not an option for most recreationists. They preferred more developed sites. Similarly, most visitors also prefer hiking on established trails and camping on existing campsites (Marion, 1996). This is a positive sign where damage to the forest caused by grilling is concerned.

People questioned at "wild" fire rings said more frequently than people at official picnic sites that the site they were using was not their first choice. This means that at least some of the fires built outside official sites might be explained by an insufficient number of picnic sites. During public holidays and Sundays there are more visitors in the forest than the official sites can accommodate (personal observation). In Switzerland, once a site is occupied, no other group will use the same site. People who do not know each other never share fire places. However, there are several indications that "wild" fire places cannot be attributed to an insufficient number of picnic sites alone. Often, "wild" fire rings were occupied even though an official site nearby would have been free (personal observation). Of the visitors at "wild" fire rings that would have preferred another site, about half would have preferred a different "wild" site. Table 1 shows that visitors had mainly chosen a fire place that corresponded with their preferences, and that most visitors using "wild" fire places were doing so because these were the sites that satisfied their needs. The relatively low number of abandoned and newly created sites and the unsuccessful removal of "wild" fire rings indicate that most "wild" fire places are regarded as established sites by forest visitors.

Conclusions

The results of the forest visitor survey provide basic knowledge about the reasons for the creation and usage of "wild" fire rings. The official picnic sites fulfil the requirements only of a part of picnickers: large groups, people who need a car park nearby because they bring a lot of food, drinks and equipment with them, and visitors who prefer the comfort of benches and tables and a concrete barbecue pit with a grill. But some visitors prefer more natural settings: no concrete, some logs to sit on, possibilities for children to participate in constructing the fire place. These visitors satisfy their needs by making their own fire in a place they find suitable, because the official sites do not fulfil their requirements. This behaviour leads to uncontrolled trampling damage in previously untouched forest areas. The situation in Allschwil forest shows that prohibiting the lighting of fires outside official picnic sites – a measure that was taken out of ecological necessity – does not have much effect, as even visitors who knew about this regulation continued to use "wild" fire rings.

Based on the results of this study, we suggest a new construction of picnic sites. We recommend providing some picnic sites that resemble "wild" sites and fulfil the requirements of visitors that have steered away from official sites up to now – sites near a stream at the forest edge, away from the forest road, with fire rings without concrete and just some logs to sit on. These measures can reduce the number of self-made fire rings being created in the respective forest area. In order to ensure the effective implementation, these measures need to be integrated into a forest management plan. This approach has already proved to be successful in Allschwil forest. Our study shows that understanding the reasons for certain behaviour patterns can be a way of dealing with impacts due to recreation in urban forests.

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Chapter 6

Manche feuern lieber wild. Können benutzergerechte Feuerstellen das Entstehen "wilder" Feuerstellen reduzieren?

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Wald und Holz 2/08: 45–47

Können benutzergerechte Feuerstellen das Entstehen «wilder» Feuerstellen reduzieren?

Manche feuern lieber wild

So genannte «wilde» Feuerstellen führen in stadtnahen Wäldern zu einer Verdichtung des Bodens und verhindern die natürliche Verjüngung. In Baselland wurde untersucht, weshalb Besucher diese Feuerstellen anlegen. Anhand der erfragten Vorlieben von Feuerstellenbenutzern wurden vom Forstdienst neue, naturnahe Feuerstellen angelegt. Diese Massnahme kann das weitere Entstehen von «wilden» Feuerstellen eindämmen.

Abbildung 1: Eine häufig benutzte «wilde» Feuerstelle. Die Kraut- und Strauchschicht um die Feuerstelle ist stark reduziert.

Für die städtische Bevölkerung bilden Wälder in Siedlungsnähe wichtige Erholungsgebiete. Wälder in grossen Agglomerationen werden während des Sommerhalbjahres vor allem zum Spazieren,

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Joggen und Picknicken oder Grillieren aufgesucht (*Hegetschweiler* et al. 2007a). Dabei werden häufig nicht die offiziellen, vom Forstdienst zur Verfügung gestellten Feuerstellen benutzt. Vielmehr werden auf bisher ungestörten Waldflächen eigene Feuerstellen, umgrenzt von wenigen losen Steinen, errichtet.

Durch die Tritteinwirkung der Waldbesucher wird der Boden um die Feuerstellen verdichtet und die Bodenvegetation geschädigt, so dass weder Pflanzen der Krautschicht noch junge Bäume und Sträucher nachwachsen können. Die Pflanzenvielfalt nimmt ab, und die typischen Waldpflanzen werden durch wenige trittresistente Arten ersetzt (*Baur* 1999, *Baur* 2003). In Waldgebieten mit einer hohen Dichte an «wilden» Feuerstellen breiten sich diese Schäden flächendeckend aus, da «übernutzte» Feuerstellen weniger attraktiv sind und zum Erstellen neuer Feuerstellen verleiten (**Abb. 1**).

Bei einem nachhaltigen Management von Erholungswäldern sollten die negativen Auswirkungen von «wilden» Feuerstellen reduziert oder sogar verhindert

Abbildung 2: Naturnah gestaltete Versuchsfeuerstelle im Allschwiler Wald. Die Ausstattung entspricht den Vorlieben der Waldbesucher.

werden. Eine Möglichkeit besteht darin, mit geeigneter Besucherlenkung die Anzahl «wilder» Feuerstellen einzudämmen. Um dieses Ziel zu erreichen, ist es wichtig zu wissen, warum «wilde» Feuerstellen entstehen und welche Vorlieben die Waldbesucher in Bezug auf Feuerstellen haben. Im ersten Teil dieser Arbeit wird eine Studie vorgestellt, welche die Beweggründe der Waldbesucher für das Erstellen von «wilden» Feuerstellen erfasste. Anhand der erfragten Vorlieben wurden vom Forstdienst neue, besuchergerechte Feuerstellen eingerichtet. Im zweiten Teil wird gezeigt, in welchem Ausmass diese neuen, naturnah gestalteten Feuerstellen von den Waldbesuchern akzeptiert wurden.

Warum «wilde» Feuerstellen?

Im Sommer 2004 wurde im Allschwiler Wald und auf dem Schönmattplateau zwischen Pratteln, Arlesheim und Liestal (beides Kanton BL) eine Umfrage bei Benutzern von festen (offiziellen) und «wilden»

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Feuerstellen durchgeführt (*Hegetschweiler* et al. 2007b). 214 Personen wurden nach einem vorgegebenen Protokoll über ihre Vorlieben bezüglich Feuerstellen befragt.

Benutzer von festen Feuerstellen zeigten sich mehrheitlich mit dem Angebot zufrieden. Sie schätzten die gut ausgebauten Grillplätze, zu denen immer eine Feuerstelle mit gemauerter Umrandung und Sitzbänke, manchmal auch ein Tisch und ein Brunnen gehören. Benutzer von «wilden» Feuerstellen gaben hingegen ganz andere Bedürfnisse an. Sie bevorzugten naturnah gestaltete Feuerstellen ohne gemauerte Umrandung. Mehrfach wurde der Wunsch nach liegenden Baumstämmen zum Sitzen geäussert. Die vorhandenen festen Feuerstellen können aber diese Bedürfnisse nicht erfüllen. Die Umfrage zeigte, dass das Errichten von «wilden» Feuerstellen nur teilweise auf ein zu kleines Angebot an festen Feuerstellen zurückzuführen ist. Vielmehr entsprechen die festen Feuerstellen nur den Bedürfnissen eines Teils der Waldbesucher. Besucher, die eine naturnahe Ausstattung bevorzugen, weichen auf bereits existierende «wilde» Feuerstellen aus oder errichten eine eigene.

Neue naturnahe Feuerstellen

Auf den Ergebnissen dieser Umfrage aufbauend, wurden im Sommer 2006 im Allschwiler Wald vier Versuchsfeuerstellen gebaut (**Abb. 2**). Die Feuerstellen wurden mit einem Ring aus grossen, losen Steinen und Baumstämmen zum Sitzen sowie einer Mülltonne ausgestattet. In der Nähe wurde Astmaterial von Holzschlägen deponiert, um Waldbesuchern das Holzsuchen zu ermöglichen. Alle vier Versuchsfeuerstellen lagen in der Nähe von häufig benutzten festen oder schon bestehenden «wilden» Feuerstellen.

Im Verlaufe des Sommers wurden 200 Personen an festen (88), «wilden» (77) und an den neuen, naturnahen Feuerstellen (35) über die Gründe für die Wahl der jeweils besuchten Feuerstelle befragt. Durch Vorlegen von Fotos mit verschiedenen Varianten wurden die Picknicker zudem gefragt, wie ihre ideale Feuerstelle ausgestattet sein sollte (**Abb. 3**).

Von den sechs gezeigten Feuerstellen-Varianten wurden a und f am häufigsten gewählt (**Abb. 4**). Interessanterweise wählten die meisten Benutzer von festen Feuerstellen (43%) Bild a, während 46% der Benutzer von «wilden» Feuerstellen und 51% der Benutzer von Versuchsfeuerstellen Bild f bevorzugten. Die Waldbesucher wählten also grösstenteils eine Feuerstellen-Variante, welche derjenigen Feuerstelle am ähnlichsten war, die sie gerade benutzten. Benutzer von «wilden» Feuerstellen zeigten dabei ähnliche Präferenzen wie Benutzer von Versuchsfeuerstellen. Die Ausstattung der neuen Versuchsfeuerstellen scheint also tatsächlich die Bedürfnisse der Besucher von «wilden» Feuerstellen abzudecken. Feuerstellen-Varianten, bei denen Einrichtungen von festen und «wilden» Feuerstellen gemischt vorkamen, stiessen bei den Besuchern auf geringes Interesse.

Das Einrichten der neuen, naturnahen Versuchsfeuerstellen wurde von 81% der befragten Picknicker positiv bewertet. Als Gründe gaben 36% der Personen an, die Ausstattung gefalle ihnen gut, 26% begrüssten das erhöhte Angebot an offiziel-

Abbildungen 3a–f (von links nach rechts): Fotos mit verschiedenen Feuerstellen-Varianten zur Ermittlung der Besuchervorlieben. Diese Bilder wurden den Besuchern zur Auswahl vorgelegt. Auf jedem Bild sind die einzelnen Elemente unterschiedlich zusammengesetzt.

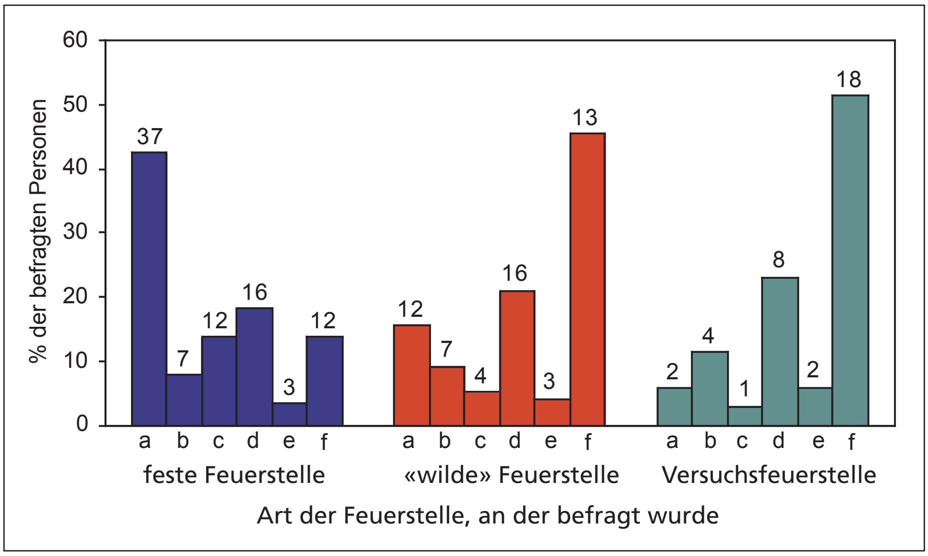

Abbildung 4: Prozentuale Verteilung der von Benutzern bevorzugten Feuerstellen-Varianten. Die Buchstaben bezeichnen die sechs Fotos, die zur Auswahl standen. Die Zahlen über den Balken bezeichnen die Anzahl der antwortenden Personen.

len Feuerstellen, weitere 26% verstanden die neuen Feuerstellen als Massnahme, die Zahl der «wilden» Feuerstellen einzudämmen, 8% fanden die Lage der neuen Feuerstellen gut und 4% gaben weitere Gründe an.

Die Umfrage zeigte, dass die Ausstattung der neuen Feuerstellen besonders bei Leuten Gefallen fand, die ansonsten «wilde» bevorzugen. Eine der vier neuen Versuchsfeuerstellen wurde deutlich häufiger benutzt als die anderen drei. Diese liegt direkt an einem Bach. Die Umfrage lieferte eine mögliche Erklärung: Bei der Frage nach den Auswahlkriterien gaben 44% aller Personen an, sie hätten die Feuerstelle aufgrund ihrer Lage ausgewählt. Bevorzugt wurden offene Flächen, Waldränder und Stellen am Rande eines Gewässers, zum Beispiel an einem Bach. Die Ausstattung der Feuerstelle hingegen war nur bei 19% der Befragten ausschlaggebend. Die Lage scheint also bei der Wahl einer Feuerstelle wichtiger zu sein als ihre Ausstattung.

Die Umfragen zeigten, dass «wilde» Feuerstellen nicht ausschliesslich wegen der ungenügenden Anzahl von Grillplätzen angelegt werden, sondern dass die Ansprüche und Vorlieben der Picknicker eine wichtige Rolle spielen. Es gibt zwei Gruppen von Benutzern: die einen bevorzugen fest eingerichtete, die anderen «wilde» Feuerstellen. Ein Angebot an naturnah gestalteten Feuerstellen an attraktiver Lage könnte dazu beitragen, die Zahl der «wilden» Feuerstellen zu reduzieren.

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General Discussion

Multifunctionality and increasing recreational use of urban forests are creating new challenges on how to manage these forests in a sustainable way (Niemelä et al. 2005). This thesis contributes to recreation management by exploring ecological, economical and social aspects of forest recreation using picnicking and grilling as an example.

Consequences of Fire Place Use

Picnicking and human trampling reduced plant height, cover, and species density of the forest vegetation. Soil compaction and soil pH were enhanced at fire places (chapters 2 and 3). These effects are commonly observed in areas impacted by human trampling (e.g. Liddle 1997, Kutiel and Zhevelev 2001, Thurston and Reader 2001, Cole and Monz 2003, Roovers et al. 2004). The ground vegetation of forests is particularly sensitive to trampling, because most species are shade-tolerant, have broad leaves and thin cell walls and are therefore vulnerable to mechanical influences (Kuss 1986, Cole and Monz 2003, Cole and Monz 2004). The amount of leaf litter was reduced in plots containing fire places compared to control plots in chapter 2. In chapter 3, leaf litter was reduced by short- and long-term trampling. Trampling increases the cover of litter on the ground by detaching dead and live materials from the plants. The litter is then broken up, blown away by the wind or incorporated into the soil (Liddle 1997). In addition, litter is reduced by decomposition. This can either lead to an increase or a decrease in organic matter, depending on which process prevails. In chapter 2, the observed reduction in the amount of leaf litter was not reflected in any changes in soil organic matter (SOM) content. Possibly, the counteracting processes were neutralizing each other, or the loss of leaf litter had only occurred recently and was too small to result in changes in SOM content. In chapter 3, short-term trampling reduced the amount of leaf litter. At the same time, β-glucosidase activity was lowest in plots with 300 passes. One possible explanation is that in plots with 100 and 300 passes, most of the broken up leaf litter was not incorporated into the soil, but was either kicked off the path or blown away. The missing leaf litter resulted in lower β-

glucosidase activities. However, the removal of litter had happened too recently to result in changes in SOM content. At the fire places studied in chapter 3, SOM content declined with increasing distance from the fire ring. This can be explained by the accumulation of charcoal around the fire rings. Charcoal degrades more slowly than non-charred woody materials (Hart et al. 2005).

In chapter 2, 39% of mature trees in the vicinity of fire places exhibited human damage. Damages such as wounded bark and nails driven in are frequently observed in recreation areas. The percentage of damaged trees ranges from 28–77% for campground areas in the USA (Reid and Marion 2005). The 39% of trees damaged in our study (chapter 2) lie within this range. In the frequently visited forest of Allschwil, damaged trees covered around 23% of the area (chapter 4). Forest visitors perceive damaged trees as aesthetically displeasing, and the number of injured trees has been found to be one of the most important factors influencing visitor experience (Smith and Newsome 2002). Wounding of trees makes them susceptible to pathogens, which may lead to the spread of diseases (Brown et al. 1977, Grünwald et al. 2002). In addition, visitor-induced tree damage leads to reductions in timber quality and subsequently to reduced revenues for the forest owner (chapter 4). These profit losses coupled with recreation-related costs can reach substantial amounts. In chapter 1, a quarter of the responding forestry experts working in large urban areas stated that more than 10% of their work was related to recreation. 40% of the experts working in large urban areas assumed that costs related to recreation exceeded 10% of the total expenditures of the forest enterprises. Not surprisingly, 63% of the forestry experts asked for additional financial support for tasks concerning recreation.

Creation and Usage of "Wild" Fire Rings

Forestry experts' perceptions on why forest visitors create and use "wild" fire rings (chapter 1) differed from the results of the two forest visitor surveys (chapters 5 and 6). Most experts attributed "wild" fire rings to an insufficient number of official picnic sites, available firewood and forest visitors seeking adventure and romanticism. Only a minority thought that an unattractive location or unattractive infrastructure of official sites might be a reason for the creation of new "wild" sites. However, the forest visitor surveys showed that visitors using official picnic sites differed in their preferences from visitors using fire rings outside official sites, and that the appropriate location of fire places is of high importance. Several other studies have demonstrated differences between perceptions of forest visitors and experts or forest managers. A survey in Denmark showed that the general public preferred a forest without special recreational facilities, even though experts assumed the opposite (Jensen 1993). In three recreation areas in Oregon and Washington (USA), forest managers presumed that visitors would appreciate more recreational infrastructure, which in reality was not the case (Hendee and Harris 1970).

Conclusions and Implications for Management

Intensive use of fire places reduces the diversity of the sensitive forest vegetation on several levels. Large amounts of woody debris are removed as firewood, leading to a habitat loss for numerous highly specialized organisms. Soil enzymatic activity is also reduced, resulting in a lower turnover of nutrients for plants. In addition, trees are frequently damaged by forest visitors. Especially the creation of fire rings in previously untouched areas allows damages to spread uncontrollably throughout the forest. Apart from the ecological and economical consequences, heavily used sites become unattractive to forest visitors. One aim of forest management must be to preserve recreational sites as attractive and diverse forest areas. Visitor management in Switzerland already includes installing new recreational infrastructure such as picnic sites. However, reasons for "wild" site creation and usage are poorly understood. In many cases, foresters are not aware of the important role forest visitor preferences play. Therefore, location and infrastructure of picnic sites are usually based on tradition, intuition of foresters and practicability rather than on visitor preferences. Fire places fulfilling the requirements of forest visitors that have steered away from official sites up to now, could help reduce the creation and usage of "wild" fire rings, under the condition that appropriate locations are chosen. These fire places can be installed away from ecologically sensitive areas. If necessary, short-term trampling experiments can be used to predict the effects of long-term usage. Depositing logging residues as firewood near picnic sites gives users the possibility of gathering firewood from the surrounding area without depleting the naturally occurring dead wood. Piles of branches and twigs can also be used to restrict the movements of forest visitors to a defined area. These measures should help to maintain the biodiversity of urban forests and at the same time ensure that these forests remain attractive recreation sites for the public.

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Ich erkläre, dass ich die Dissertation

"Ecological impact of fire place use in urban forests and consequences for visitor management"

nur mit der darin angegebenen Hilfe verfasst und bei keiner anderen Universität und keiner anderen Fakultät der Universität Basel eingereicht habe.

Tessa Hegetschweiler