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**CASE STUDY FOR THE
INTEGRATION OF FAUNISTIC
DATA SERIES IN SELECTED
ITALIAN LTER FOREST SITES**



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Case study for the integration of faunistic data series
in selected Italian LTER forest sites

Caso studio per l'integrazione di serie di dati faunistici
in alcuni siti forestali LTER italiani

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INTRODUCTION

The Long Term Ecological Research Project was founded in 1993 in the United States of America to integrate all site-based studies on ecosystems already started in the early 1900s in the country (Peters 2010). The original aims of Long Term Research were to share data, cooperate on global projects, integrate findings at local and national level and deliver peer-reviewed research to decision-makers and the public (Kaufmann & Anderson 2006).

Nowadays, the International Long Term Ecological Research Network (ILTER, <http://www.ilternet.edu>) includes 40 member countries in the world and addresses research questions of global concern on complex ecosystem processes, like pattern and frequency of disturbance, land use change, climate change, distribution of populations, biodiversity loss (Likens 1989, Risser 1991, Magurran 2010). The European Network (LTER Europe, <http://www.lter-europe.net/>) participates to the ILTER Network with 22 national members. The Network has several strengths: 1) a governance structure, coordinating all the efforts from national Networks and sites; 2) an international membership, allowing a multidisciplinary dialogue among scientists; 3) a wide coverage of biogeographical regions at global level, which represents an almost unique feature among existing research networks; 4) *in-situ* collection of ecological data at marine, freshwater and terrestrial sites; 5) long term data series on physical, chemical and biotic parameters, representing a valuable resource for research.

Italy entered the International LTER Network in 2006 (LTER Italy, <http://www.lteritalia.it/>). The Network today includes 20 sites, five of them are in forest ecosystems, with 15 research stations. Ten of these research stations belong to the ICP Forests Programme (<http://www.icp-forests.org/>), that started in Italy in 1995 (in the framework of Regulation EC no. 1091/94 and under the UN-ECE Convention on Long Range Transboundary Air Pollution) and is run by the National Forest Service, with the cooperation of several research institute and University Department (CONECOFOR Programme, Petriccione & Pompei 2002, Ferretti et al. 2006).

In each of these research stations, a permanent monitoring plot is installed in a fenced 50 x 50 m square area. The Programme had originally the main objective of monitoring the effects of air pollution on the health of forests (Bakker et al. 1996) and has been collecting about 15 years of data

on environmental parameters at plot level. Nevertheless, some weaknesses at LTER Italy forest sites have to be recognized: 1) a scientific focus limited to habitat variables like climate, soils, trees, shrubs and ground vegetation; 2) monitoring on habitat factors prevailing on research and producing a huge amount of data, but poor analysis and research outcomes; 3) rare investigations on biodiversity and fauna, implemented in a limited time-frame when present; 4) the small scale (plot scale) of activities at site, accomplishing the ICP Forests protocol; 5) the lack of a complete standardization of methods among sites belonging to different monitoring programmes and networks: design, duration, intensity, sampling period and even taxonomic targets often differ from one site to another, thus making comparisons between studies very difficult (Beard et al. 1999, Parr et al. 2002, Ferretti 2010).

For these reasons, the present research project has two main general goals:

- to propose the introduction of a new research line concerning a selected animal group into a subset of LTER Italian forest sites;
- to set the new research line in an organized way, addressing LTER general features and recommendations for harmonization of methods.

Structure of the research project

The research project was divided in two phases: Phase I and Phase II.

Phase I

Phase I of the project (first year of the Ph.D. research) had the objective of studying literature sources concerning LTER general features and state of the art of monitoring and/or research activities on animals in LTER Europe.

All of the 18 LTER Europe member countries in 2009 (they are today 22) were involved in the survey. The taxonomic coverage was set on amphibians, reptiles, birds, small mammals and beetles at terrestrial sites, because each LTER country is currently conducting monitoring or research activities on at least one animal group among the mentioned ones.

Search for bibliographic sources was performed by Internet engines (Google Scholar, Google UK, JStor, Scirus, Scopus, Zoological Record, etc.) and by means of a new questionnaire sent by email to the coordinators of LTER Europe national networks. The questionnaire was aimed at recording which animal groups, among the five selected taxa, are currently

under investigation at terrestrial LTER Europe sites and what kind of methods are adopted to study these animals. Seventeen articles regarding LTER general features were collected, from early publications showing the basic concepts of Long Term Ecological Research (e.g. Strayer 1986, Likens 1989, Risser 1991) to recent articles addressing more specific issues, like methodology (Beard et al. 1999), integration of existing monitoring networks in Europe (e.g. Parr et al. 2002, Ferretti 2010), feasible approaches to move from long term monitoring to research (e.g. Yoccoz et al. 2001, Legg & Nagy 2005, Lindenmayer & Likens 2009, Clutton-Brock et al. 2010, McDonald-Madden et al. 2010), and suitable research questions (Turner et al. 2003).

Seventy-three case studies regarding the 5 target animal groups were collected from 18 LTER Europe member countries, including both published articles and unpublished reports.

Literature data gathered during Phase I were organized in a published review concerning LTER basic concepts and research activities at LTER Italy forest sites (ARTICLE I).

At the end of Phase I, saproxylic beetles were selected as target animal group for the present project.

Saproxylic beetles

Saproxylic organisms are species depending on deadwood in one or more stages of their life cycle or on other saproxylic organisms, like fungi (Speight 1989, Mason et al. 2003, Alexander 2008). Most of forest dwelling beetles are saproxylic. Several saproxylic beetles have larvae feeding on decayed wood or dead parts of senescent trees, while adults of other species use different food resources available in the same kind of habitat, behaving like decomposers, fungivores, predators or inhabiting deadwood as hibernation site.

Saproxylic beetles can depend on a particular decay level of deadwood or on a specific part of the inhabited tree (bark, trunk, branches, holes) and are usually ecological specialists, showing marked preferences for restricted ranges of moisture and temperature.

As a consequence, a huge array of suitable microhabitats for saproxylic species can be found, especially in natural and semi-natural forests. Beetle assemblages occupy these microhabitats along successional stages, with a species turnover in their composition depending on both season and changes

in physical-chemical characteristics of decaying substrates. These assemblages represent relevant functional groups in forest ecosystems.

Saproxylic beetles were selected as study group for the present project for the following reasons:

- being linked to local microhabitat conditions, they are suitable for small scale investigations and for habitat-dependent community studies;

- several standardized trapping techniques are available;

- numerous studies on saproxylic beetles are available in Europe: Paillet et al. (2009) reported 17 published researches on saproxylic beetles among species richness studies in Europe; the survey performed in the frame of the present project collected 7 case studies on these insects at LTER Europe terrestrial sites, representing about 10% of total records collected;

- in Italy, in particular, a field study on saproxylic coleopterans at selected ICP Forests plots was successfully performed in 2003-2004 (Mason et al. 2006). A research team formed by Roma Tre University, Sapienza Rome University (Rome) and the National Center for the Study and Conservation of Forest Biodiversity (National Forest Service, Verona) is currently conducting ecological studies on saproxylic beetles.

Phase II

Phase II of the project (second and third year of the Ph.D. research) had the aims of testing in the field saproxylic beetle sampling at plot scale and analysing the new collected data with existing long term datasets on habitat variables, at different LTER forest sites in Italy.

Four different forest sites of the LTER Network, having ICP Forests monitoring plots, were selected in Abruzzo and Lazio Regions: Selva Piana (Collelongo, AQ), Rosello (Rosello, CH), Monte Rufeno (Acquapendente, VT) and Monte Circeo (San Felice Circeo, LT).

At all of the considered study plots, the following research questions were specifically addressed:

- What is the saproxylic beetle diversity at the selected forest study plots?

- How dissimilar is beetle assemblage composition at these plots?

- What environmental factors can affect saproxylic beetle diversity and assemblage composition at forest plot and microhabitat scale?

- Is the plot scale able to reveal ecological patterns concerning forest dwelling beetles?

Results from field tests are presented in ARTICLE 2 submitted to the Journal Insect Conservation and Diversity.

In the third year, a sampling test was performed in the U.S. LTER forest site HJ Andrews Experimental Forest (Blue River, OR; Hobbie 2003, Lugo et al. 2006) to start a scientific collaboration between Italy and USA on the study of saproxylic beetle communities. The objectives were the same as the Italian fieldwork, and preliminary results were submitted to the Journal Agricultural and Forest Entomology (ARTICLE 3). In this article, the taxonomic identification of specimen is at family level. A deeper insight to a fine taxonomic level (genus or species level) is ongoing, in collaboration with international experts.

ARTICLE 1

Basic concepts and research activities at Italian forest sites of the Long Term Ecological Research network

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Italy entered the International Long Term Ecological Research Network (ILTER) in 2006, contributing a group of research sites in marine, freshwater and terrestrial ecosystems to the global network. Five forest sites are included in the Italian Network. They are representative of the main forest ecosystems in Italy and integrate 15 research stations managed by different institutes. Starting from LTER rationale and basic concepts, the first part of the paper reviews the status of LTER Italy forest sites, the strengths resulting from multidisciplinary expertise and site management, current activities and available datasets. Long term data series on key environmental parameters show the high scientific value of these sites, where monitoring and/or research is still ongoing. But two main LTER issues are currently arising in the international context: (1) overall consistency of datasets; (2) harmonization of sampling methods. For this reason, the second part of the paper investigates the suitability of Italian forest sites to address recommended long term research topics and ecological issues of global concern and to investigate the shift from in-site monitoring to cross-site cooperation and inter-site research.

Keywords: Long term ecological research, Forest ecosystems, Research site, Datasets, Methodology, Biodiversity

Introduction

The International Long Term Ecological Research Network (ILTER)

The long term ecological research (LTER) was founded in 1993 in order to work at local, regional and national level to share data, cooperate on global projects, integrate findings and deliver peer-reviewed research to decision-makers and the public (Kaufmann & Anderson 2006). In the United States, studies of ecosystems based on sites (forest, watershed and rangeland) started in the early 1900s (Peters 2010). Currently, the international long term ecological research (ILTER) network (<http://www.ilternet.edu/>) involves 40 contributing countries (Tab. 1), reflecting the increased importance of long term research in addressing complex environmental issues at global scale. Italy entered the ILTER Network in 2006, following the initiative of a core group of experts from National Forest Service (Corpo Forestale dello Stato), National Research Council (Consiglio Nazionale delle Ricerche), Anthon Dohrn Zoological Station and Italian Society of Ecology. At the moment, LTER Italy (<http://www.lteritalia.it/>) consists of an integrated group of 20 sites in terrestrial, freshwater and marine ecosystems, where long term ecological monitoring is performed and historical dataset series are maintained and updated. Among terrestrial sites, five sites

represent forest ecosystems. Eighteen research institutes and university departments are responsible for coordination of scientific activities at LTER Italy sites. The national coordination of LTER is currently run by the National Research Council.

The basic concepts of Long Term Ecological Research

The most peculiar trait of long term studies is the historical data series they can rely on. A three to five years project is usually considered a long term study, just because it extends over the usual duration of classical projects (1 to 3 years); actually, it would be correct to label a research project as a long term study in relation to the time span of the target ecosystem cycle, that is only in case the study goes on for as long as the ecosystem process under investigation (Strayer et al. 1986). Long term studies have been building valuable historical ecological datasets across the world and addressing questions that involve phenomena that could be partially or incorrectly evaluated when observed over short (1-2 years) time scales (Risser 1991, Magurran et al. 2010). As a consequence, candidate subjects for long term studies are: (1) slow phenomena; (2) subtle patterns, obscured in large matrices of data; (3) rare events; (4) complex processes, depending on multiple variables (Likens 1989, Risser 1991, Magurran et al. 2010).

□ (1) CFS, Monitoraggio Ambientale e CONECOFOR, v. G. Carducci 5, I-00186 Rome (Italy); (2) CFS-CNBF, Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale Bosco della Fontana, v. C. Ederle 16/a, I-37100 Verona (Italy); (3) CNR, Istituto per i Sistemi Agricoli e Forestali del Mediterraneo (ISAFOM), Rende (CS -Italy); (4) Istituto di Biologia Agro-Ambientale e Forestale (IBAF), v. Salaria km 29.300, I-00015 Monterotondo Scalo (Roma - Italy); (5) Dipartimento di Biologia Ambientale, Università degli Studi Roma Tre, v.le G Marconi 446, I-00146 Roma (Italy)

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Long term studies are usually related to the health or functioning of ecosystems and may help in understanding ecosystem responses to global environmental changes. Lindenmayer & Likens (2009) have proposed the paradigm of adaptive monitoring for long term ecological research. The concept encompasses the maintenance of long term monitoring on a core set of variables, but with a background research question. As data collection goes on, the focused target question can change or evolve into a new question and monitoring adapts along an iterative and flexible process, where sampling design and overall analytical approach can be adjusted, keeping the integrity of long term series. Five core areas have been suggested for long term investigation of ecosystem processes (Strayer et al. 1986, Likens 1989, Risser 1991): (1) spatial and temporal distribution of populations; (2) pattern and frequency of disturbance; (3) pattern and control of primary production; (4) pattern and control of organic matter accumulation; (5) pattern of inorganic input and movements through soils. Moreover, ecological large scale phenomena of global concern like climate change, pollution, impact of management and land use change, biodiversity loss and distribution of invasive species comfortably match the LTER concept (Strayer et al. 1986, Likens 1989, Risser 1991). On the other side, studies on individual species, species lists or indices derived from species lists are generally not suitable to long term ecolog-

gical research, as this kind of studies requires equivalency among sites, which is hardly respected across huge environmental gradients like those covered by LTER sites (Seastedt & Briggs 1991).

Characteristics of LTER sites

Long term ecological research relies on a scientific approach that is strongly site-based. Though indoor experiments may be performed and modeling can be used to explore and use datasets (Likens 1989), basically long term ecological research works on a network of sites and/or research facilities across the world, where field observations and sampling are performed. According to an *ex-post* rule adopted within the European LTER governance structure (<http://www.lter-europe.net/>), a LTER “site” is a research and/or monitoring facility, that can be made up by one or more “research stations” (field sta-

tions - Tab. 2). But LTER governance structure and research mandate are built on a bottom-up rather than a top-down approach (Parr et al. 2002), thus creating a collection of sites rather than a network with a specific systematic or stratified design. Generally, sites represent habitat types in terrestrial, freshwater and marine ecosystems and are selected given the accomplishment of the following criteria: (1) the existence of long series of ecological data; (2) the development of research activities on ecological issues of global concern (biodiversity loss, climate change, land use change etc.); and finally (3) an open policy for cross-site scientific cooperation (Kaufmann & Anderson 2006). So, for the existing networks, a *post-hoc* adaptation of sites and measurements is strongly advised, though it may open the way to methodological issues (Beard et al. 1999, Sutherland 2006).

Forest sites within LTER Italy

LTER Italy includes five sites representing forest ecosystems (Tab. 3): (1) Forests of the Alps, made up of 5 stations, where the main biotic communities are primary and secondary stands dominated by spruce (*Picea abies* L.); (2) Forests of the Apennines, whose three stations are *Fagus sylvatica* L. high forests and coppice stands, the latter mixed with secondary meadows; (3) Mediterranean forests, represented by mixed old coppice of *Quercus ilex* L. and *Quercus cerris* L. dominated forests, over four stations; (4) Castelporziano Estate, including relevant patches of mixed deciduous oak forest (*Quercus cerris* L., *Quercus frainetto* TEN., *Quercus robur* L.), Mediterranean evergreen oak forest (*Quercus ilex* L., *Quercus suber* L.) and Mediterranean pine forest (*Pinus pinea* L.), once covering the whole estuary of the river Tevere and the surrounding landscape, to-

Tab. 1 - ILTER member Countries (<http://www.ilternet.edu/>).

Continent	ILTER member Country	Name of the National LTER Network
America	Canada	EMAN - Ecological Monitoring and Assessment Network
	U.S.A.	US LTER - United States Long Term Ecological Research Network
	Mexico	Mex LTER - Red Mexicana de Investigación Ecológica a Largo Plazo
	Costa Rica	CRLTER - Costa Rica Long Term Ecological Research Network
	Venezuela	ECORED - Red Venezolana de Estaciones de Investigación Ecológica a Largo Plazo
	Brazil	PELD - Pesquisas Ecológicas de Longa Duração
	Uruguay	IELDU - Investigaciones Ecológicas de Larga Duración
Europe	Finland	FinLTSER - Finnish Long Term Socio-Ecological Research Network
	Latvia	LTERLatvia - Latvia Long Term Ecological Research Network
	Lithuania	Lithuanian LTER - Lithuanian Long Term Ecological Research Network
	U.K.	ECN - Environmental Change Network
	Germany	LTER-D - German Long Term Ecological Research Network
	Poland	LTER Poland - Polish Long Term Ecological Research Network
	Czech Republic	CZLTER - Czech Long Term Ecological Research Network
	Slovakia	LTER Slovakia - Slovak Long Term Ecological Research Network
	Austria	LTER Austria - Austrian Long Term Ecological Research Network
	Slovenia	LTER Slovenia - Slovenia Long Term Ecological Research Network
	Romania	LTER Romania - Romanian Long Term Ecological Research Network
	Hungaria	LTER Hungaria - Hungarian Long Term Ecological Research Network
	Serbia	LTER Serbia - Serbia Long Term Ecological Research Network
	Bulgaria	LTER Bulgaria - Bulgarian Long Term Ecological Research Network
	Switzerland	LWF - Switzerland Long Term Forest Ecosystem Research
	Italy	LTER Italy - Italian Long Term Ecological Research Network
France	LTER France - French Long Term Ecological Research Network	
Spain	LTER Spain - Spanish Long Term Ecological Research Network	
Portugal	LTER Portugal - Portugal Long Term Ecological Research Network	
Middle East	Israel	LTER Israel - Israeli Long Term Ecological Research Network
Africa	Zambia	LTER Zambia - Zambia Long Term Ecological Research Network
	Malawi	LTER Malawi - Malawi Long Term Ecological Research Network
	Mozambique	LTER Mozambique - Mozambique Long Term Ecological Research Network
	Namibia	Gbb EON - Gobabeb Training and Research Centre - Environmental Observation Network
	South Africa	SAEON - South African Environmental Observation Network
Asia	Mongolia	Hövsgöl Ecology - Mongolian Long Term Ecological Research Network
	China	CERN - Chinese Ecosystem Research Network
	Korea	KLTER - Korea Long Term Ecological Research Network
	Japan	JaLTER - Japanese Long Term Ecological Research Network
	Taiwan	TERN - Taiwan Ecological Research Network
	Philippines	LTER Philippines - Philippines Long Term Ecological Research Network
	Thailand	LTER Thailand - Thailand Long Term Ecological Research Network
Pacific South East	Australia	LTER Australia - Australian Long Term Ecological Research Network

Tab. 2 - LTER Europe site main characteristics (Mirtl et al. 2008 - simplified).

Criteria	LTER site feature
Synonym	Traditional LTER site
Design	Simple (square, circular, irregular shape area)
Consists of	field stations within the site (plots, grid points, equipment)
Size	1-10 km ²
Frequency per country	5-20
Frequency in Europe	100-300
Number of institutions per site	1 or few
Plot scale	Yes
Habitat or local scale	Yes
Landscape scale	No

gether with other different, typically Mediterranean, ecosystems, like the Mediterranean maquis and coastal dunes; (5) Lowland forest "Bosco della Fontana", composed by

three main communities: a mesophilous *Quercus robur* L. stand, a mesoxerophilous forest with *Quercus cerris* L. and a mesohygrophilous one with *Fraxinus oxycarpa*

Bieb. (Campanaro et al. 2007). Ten of the 15 research stations included in forest sites belong to the CONECOFOR Network that started in Italy in 1995, as national branch of the ICP Forests Programme (<http://www.icp-forests.org>), in the framework of Regulation (EC) no. 1091/94 and under the UN-ECE Convention on Long Range Transboundary Air Pollution. In each of these stations, a permanent monitoring plot (pmp) is installed in a fenced 50 x 50 m square area. The Programme has the main objective of monitoring the effects of air pollution on the health of forests and has been collecting about 15 years of data on a robust set of environmental parameters at plot level (Tab. 4). Furthermore, five research stations are included in national or regional natural protected areas (Valbona Forest Reserve, Oriental Alps Pre-

Tab. 3 - European forest types and corresponding EUNIS habitats represented by LTER Italy research stations (European Environmental Agency 2007). (*): research stations belonging to the ICP Forests Programme.

Sites	LTER Italy forest sites and research stations	European forest types		EUNIS Habitat Classification	
		Code	Forest type	Code	Habitat
LTER Italy site no. 02: Forests of the Alps	*Val Masino (Val Masino - SO)	6.3.2	Subalpine and mountainous spruce and mountainous mixed spruce-silver fir forest	G3.1	Fir and spruce woodland
	*Renon (Renon - BZ)	6.3.2	Subalpine and mountainous spruce and mountainous mixed spruce-silver fir forest	G3.1	Fir and spruce woodland
	*Passo Lavazè (Daiano - TN)	6.3.2	Subalpine and mountainous spruce and mountainous mixed spruce-silver fir forest	G3.1	Fir and spruce woodland
	*Tarvisio (Tarvisio - UD)	6.3.2	Subalpine and mountainous spruce and mountainous mixed spruce-silver fir forest	G3.1	Fir and spruce woodland
	Valbona Reserve (Predazzo - TN)	6.3.2	Subalpine and mountainous spruce and mountainous mixed spruce-silver fir forest	G3.1	Fir and spruce woodland
LTER Italy site no. 03: Apennines forests	*Selva Piana (Collelongo - AQ)	6.7.3	Apennine - Corsican mountainous beech forest Southern Italian Beech forest	G1.68	Beech woodland
	*Piano Limina (Giffone - RC)	6.7.3	Apennine - Corsican mountainous beech forest Southern Italian Beech forest	G1.68	Beech woodland
	Torricchio Reserve (Macerata)	6.7.3 6.8.8	Apennine - Corsican mountainous beech forest, Other thermophilous deciduous forests	G1.6 G1.7	Beech woodland, Thermophilous deciduous forest
LTER Italy site no. 04: Mediterranean forests	*Monte Rufeno (Acquapendente - VT)	6.8.2	Turkey oak, Hungarian oak and Sessile oak forest	G1.7	Thermophilous deciduous forest
	*Ficuzza (Godrano - PA)	6.8.2	Turkey oak, Hungarian oak and Sessile oak forest	G1.7	Thermophilous deciduous forest
	*Colognole (Livorno)	6.9.1	Mediterranean evergreen oak forest	G2.1	Mediterranean evergreen oak woodland
	Monte Rufeno Reserve (Acquapendente - VT)	6.8.2	Turkey oak, Hungarian oak and Sessile oak forest	G1.7	Thermophilous deciduous forest
LTER Italy site no. 18: Castelporziano Estate	Castelporziano forest (Roma)	6.8.2	Turkey oak, Hungarian oak and Sessile oak forest	G1.7	Thermophilous deciduous forest,
		6.9.1	Mediterranean evergreen oak forest	G2.1	Mediterranean evergreen forest, Low-
		6.10.1	evergreen oak forest, Thermophilous pine forest	G3.7	land mediterranean pine woodland
LTER Italy site no. 05: Lowland forests	*Bosco Fontana (Mantova)	6.5.1	Pedunculata oak - hornbeam forest	G1.A	Meso- and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland
	Bosco Fontana Reserve (Mantova)	6.5.1	Pedunculata oak - hornbeam forest	G1.A	Meso- and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland

Tab. 4 - Environmental parameters assessed at LTER Italy forest sites. (*): Research stations belonging to the ICP Forests Programme. (a): the station Selva Piana is included in several other networks (FluxNet, CarboEurope-IP, NitroEurope) and research is coordinated by CNR-IBAF. (◆): monitoring parameters activated in 2009.

Sites	LTER Italy forest sites	Climate	Soil	Ozone	Atmospheric deposition	Ground vegetation	Tree growth	Stand structure	Crown condition	Deadwood	Leaves chemistry	Crown phenology	Remote sensing	Fauna
Forests of the Alps	*Val Masino	×	×	×	×	×	×	×	×	×	×	×	×	-
	*Renon	×	×	×	×	×	×	×	×	×	×	×	×	×
	*Passo Lavazè	×	×	×	×	×	×	×	×	×	×	×	×	×
	*Tarvisio	×	×	×	×	×	×	×	×	×	×	×	×	-
	Valbona Reserve	×	×	-	-	×	×	×	-	×	-	×	×	×
Apennines forests	*Selva Piana (a)	×	×	×	×	×	×	×	×	×	×	×	×	×
	*Piano Limina	×	×	×	×	×	×	×	×	×	×	×	×	-
	Torricchio Reserve	×	×	×	×	×	×	×	-	-	-	-	×	×
Mediterranean forests	*Monte Rufeno	×	×	×	×	×	×	×	×	-	×	×	×	-
	*Ficuzza	◆	×	×	×	×	×	×	×	×	×	×	×	-
	*Colognole	×	×	×	×	×	×	×	×	×	×	×	×	-
	Monte Rufeno Reserve	×	×	-	-	×	×	×	-	-	-	-	×	×
Castelporziano Estate	Castelporziano forest	×	×	-	-	×	×	×	-	-	×	-	×	
Lowland forests	*Bosco Fontana	◆	◆	×	◆	×	×	×	×	×	×	×	-	×
	Bosco Fontana Reserve	×	-	×	-	×	×	×	×	×	-	×	-	×

dazzo - Siror, Trento; Montagna di Torricchio, central Apennines, Pievetorina and Montecavallo - Macerata; Monte Rufeno Regional Natural Reserve, central Italy, Acquapendente - Viterbo; Castelporziano Estate, central Italy - Rome; Bosco della Fontana State Natural Reserve, Po Valley - Mantova), where additional research or monitoring activities are carried out according to national regulations, local management plans, as well as specific projects, thesis etc. In this case, the dataset is often enriched with more data on fauna biodiversity (Tab. 5) and the main aim of studies is conservation. The choice of clustering different research stations to form a forest site goes back to the starting phases of the implementation of the national LTER network: it is related to the aim of grouping different research stations, saving long and uninterrupted datasets, in major forest ecosystem types, also highlighting cooperation among several institutes responsible for different research lines. The ongoing processes of restructuring the European network and harmonizing monitoring activities will presumably lead to the selection of some stations that, while still complying with LTER criteria, will be specifically able to sustain research plans on common questions, parameters and methods as individual long term ecological research sites.

Examples of research and monitoring from LTER Italy forest sites

In this section, we present some examples of monitoring and research projects implemented at LTER Italy forest sites. We selected these projects to illustrate the research cooperation among different institutes. In

addition, we also discuss the CONECOFOR Programme, which includes one or more research stations in each LTER Italy forest site.

The CONECOFOR Programme

The CONECOFOR Programme is a long lasting forest monitoring programme started in Italy in 1995 under Regulation (EC) no. 1091/94 and the Convention on Long Range Transboundary Air Pollution of United-Nations Economic Commission for Europe (CLRTAP UN/ECE - Petriccione & Pompei 2002, Ferretti et al. 2006). At its beginning, the programme included 20 monitoring plots in forest ecosystems, selected on the base of their suitability to represent forest types in Italy and to provide rich datasets on environmental conditions. Later, new monitoring stations were incorporated to reach a total of 31 study areas in 2005. The investigations carried out at the permanent monitoring plots include crown condition assessment, chemical content of soil and foliage, deposition chemistry, tree growth, ground vegetation, meteorological conditions (Ferretti et al. 2006). At selected plots, litter fall, leaf area index, chemistry of soil solution and advanced soil parameters are also monitored. Additional biodiversity parameters (epiphytic lichens, deadwood, invertebrates) were studied in 2003 (<http://www.forestbiota.org>). The collected data are regularly submitted to the relevant bodies responsible for the database, including QA/QC data policy. From 1995 to 2000, the data collected from all CONECOFOR plots under Regulation (EC) no. 1091/94 were submitted to the FIMCI (Forest Intensive Monitoring Coordinating Institute, The Netherlands); data gathered

from 2001 to 2006 under Regulation (EC) no. 2152/2003 (Forest Focus) were submitted to the European Commission Joint Research Centre (Ispra, Italy). After Forest Focus regulation expiration in 2006, monitoring activities have been carried out under the financial support of the Project “FutMon”, a LIFE+ Project for the implementation of a European forest monitoring system (<http://www.futmon.org/>). CONECOFOR study areas and the activities implemented at plot level have been the basis for several studies about forest conditions (Petriccione et al. 2009a), effects of climate change on forest ecosystems (Petriccione et al. 2009b), biodiversity assessment (Bredemeier et al. 2007). Ten of these monitoring stations are today included in 4 LTER Italy forest sites.

The EFOMI Project

Between 2001 and 2004, the EFOMI Project (Ecological Evaluation in Alpine Forest Ecosystems by Integrated Monitoring - http://www.iasma.it/sperimentazione_context.jsp?ID_LINK=2424&area=6), funded by the Autonomous Province of Trento and coordinated by the Istituto Agrario di San Michele all’Adige (Trento, Italy) had the aim of assessing the health status of Trentino (north-east Italy) woodlands. Two sites were investigated for several ecosystem parameters, including climate, air, soil and water chemistry, vegetation and selected animal communities. One of the study areas (Passo Lavazè, Trento) is a subalpine spruce forest belonging to the ICP Forests Programme and the LTER Italy forest site “Forests of the Alps”. The general objectives of the Project were: (1) to achieve an in-depth knowledge of mechanisms regulating the ecological sta-

bility of forest stands, especially in relation to the main disturbance factors; (2) to clarify alterations in the complexity of forest ecosystems, induced by direct and indirect impacts and climate change. Within Work Package 5 of the Project, a characterization of zoocoenoses in relation to main environmental factors was developed, with regards to some insects (Lepidoptera, Coleoptera, Auchenorrhynca, Collembola) and small mammals communities. The Project contributed to the increase of collected data since 1992 and could assess the health state of the monitored forest stands and the high level of biodiversity of flora and fauna (Salvadori & Ambrosi 2005).

Bosco della Fontana State Natural Reserve

Bosco della Fontana (Mantova, northern Italy) is one of the last remaining portions of floodplain forest in the central Po plain. After 1950, forest management operations were gradually decreased and then completely interrupted (1990) and, although the total surface of the forest was heavily reduced (233 ha), quantities of live and dead wood have remarkably increased. The forest is a Biogenetic Nature Reserve since 1977, inserted in the Nature 2000 network as SPZ (Special Protected Zone) since 1998 and as SCIP (Site of Community Importance) since 2004. Bosco della Fontana is part of LTER Italy, as a single station within the “Lowland forests” site and is listed in the Italian Herpetological Society as a “Herpetological Area of National Relevance”. Research is coordinated by the Bosco della Fontana National Center for the Study and the Conservation of Forest Biodiversity, which is specialized in invertebrate taxonomy and deadwood, in a context of the long term monitoring of forest dynamics (Cerretti et al. 2004a). The structure of the forest is gradually evolving from a mixed coppice to more mature stages that may eventually lead to old growth forest. Currently alien species (*Quercus rubra* L., *Juglans nigra* L., *Platanus* spp.) are being eliminated and changed into deadwood and microhabitats for saproxylic organisms in the context of a Life Nature project for the restoration of deadwood and conservation of saproxylic fauna (LIFE Natura Project NAT/IT/99/6245 “Techniques for re-establishment of deadwood for saproxylic fauna conservation” - Cavalli & Mason 2003, Mason et al. 2003). Forest dynamics at Bosco della Fontana are monitored with a 10-year frequency in three permanent “nested” Core Areas. The monitoring developed in the Core Areas includes structural parameters (e.g., eight dendrometric measures for each georeferenced tree) and qualitative parameters (e.g., state of deadwood, biotic and abiotic damage), according to the method of Koop’s SILVI-

Tab. 5 - Animal groups investigated at LTER Italy forest sites. (*): research stations belonging to the ICP Forests Programme.

Sites	LTER Italy forest sites	Insects	Amphibians	Reptiles	Birds	Mammals
Forests of the Alps	*Val Masino	x	-	-	-	-
	*Renon	x	-	-	-	x
	*Passo Lavazè	x	-	-	-	-
	*Tarvisio	x	-	-	-	-
	Valbona Reserve	-	-	-	x	x
Apennines forests	*Selva Piana	x	-	-	x	-
	*Piano Limina	x	-	-	-	-
	Torricchio Reserve	x	-	x	-	x
Mediterranean forests	*Monte Rufeno	x	-	x	x	x
	*Ficuzza	x	x	x	x	-
	*Colognole	x	x	x	x	-
	Monte Rufeno Reserve	x	-	x	x	x
Castelporziano Estate	Castelporziano forest	-	-	-	x	x
Lowland forests	*Bosco Fontana	x	x	x	x	x
	Bosco Fontana Reserve	x	x	x	x	x

STAR program (Koop 1989); a central area nested within each Core Area is dedicated to monitoring of the dynamics of the herbaceous layer. The data from the core areas are interpreted with the Oldeman silvigenetic theory (Oldeman 1990) and regularly updated every 10 years (Mason 2002). Recently, studies on three-dimensional (3D) structure of the forest using Light Detection and Ranging (LiDAR) technique (Gianelle et al. 2007) were carried out in order to investigate relationships between 3D structure, arthropods biodiversity and habitat (Cerretti et al. 2004b, Stireman et al. 2011). An ICP Forests plot was set up at Bosco della Fontana in 2005.

The Valbona Forest Reserve

The Valbona forest reserve is located in Trentino (Oriental Alps), between 1500 and 2100 m a.s.l. It is included in the Paneveggio State forest, belonging to the Autonomous Province of Trento and is part of the natural park Paneveggio and Pale di S. Martino (Predazzo-Siror, Trento). The main purpose of the forest reserve is to develop forest management practices complying with biological processes, in order to address both protection and production values. Silviculture on spruce stands has been the object of studies in Paneveggio for more than 200 years. The Valbona Forest Reserve is divided into two parts: a 50 ha reserve for forestry applied research and a wider strict reserve for LTER. Between 1994 and 2004, six long-term 1-ha ecological permanent plots have been established, along an altitudinal gradient. The Universities of Turin and Florence have been carrying out measurements on living trees and deadwood, together with interpretation of records from historic archives. This investigation allowed to map the

present forest structure. Results also underlined the importance of long term research to understand dynamics over long time scales: evidence has been achieved that the expansion of forest area towards the upper altitudinal belt is mainly due to land use change and relief from grazing and human forest exploitation, while tree growth processes are related to climate fluctuations, especially regarding summer temperature (Motta & Piusi 2009).

Selva Piana intensive research and monitoring site

The research station Selva Piana, included in the site “Forests of the Apennines”, is another particular case within the Italian LTER Network. The station is located near the village of Collelongo (Abruzzo region, central Italy), close to the external belt of the Abruzzo, Lazio and Molise National Park. The Selva Piana forest stand (41°50'58" N, 13°35'17" E, 1560 m elevation) belongs to a 3000 ha forest community that is part of a wider forest area. The environmental and structural conditions of the stand are representative of central Apennines beech forests. The experimental facility was established in 1991 to study ecology and silviculture of typical Apennines beech forests (Scarascia Mugnozza 1999). In 1993-1994, the first tower in Europe to measure carbon and water vapor exchange between forest and atmosphere was installed at the station (Valentini et al. 1996). In 1995-1996, the station was one of the first permanent monitoring plots within the CONECOFOR monitoring network, under the ICP Forests programme. The site is currently equipped with a 26 m high scaffold tower with an additional mast reaching 32 m, approximately 8-10 m above the canopy. Together with the classic vari-

ables of the CONECOFOR programme, ecosystem water and CO₂ fluxes have been measured since 1993 with the eddy-covariance technique (Valentini et al. 1996, Valentini et al. 2000, Scartazza et al. 2004). Leaf Area Index, litter production and other ecosystem parameters are measured on seasonal or annual basis (Cutini et al. 1998), while detailed data on above- and below-ground primary productivity are available at regular intervals (Scarascia Mugnozza et al. 2000, Luysaert et al. 2009). The station, further to LTER, is currently part of the following networks: FluxNet (CarboEurope and CarboItaly), ICP Forests, ICP IM, FAO-GTOS, NitroEurope. In this respect, the station represents an example of cooperation efforts among research and monitoring that is also at the base of LTER way of operation.

Consistency of ecological datasets at Italian forest sites

The dataset built within the ICP Forests Programme is a relatively long one: data series started in 1995 in most cases and are still ongoing. Moreover, the ICP Forests Programme has produced standardized data, collected according to shared and harmonized protocols available on line (<http://www.icp-forests.org>, <http://www.forestbiota.org>). The dataset concerns mainly the vegetation component of forest ecosystems and particularly processes regarding vegetation and the effects of abiotic variables on crowns and growth of tree species, leaves chemistry, soil chemistry (Ferretti et al. 2006). At the interface between abiotic variables and forest

conditions there is a strong potential for ecological investigations. This potential has not been fully exploited yet, not only at plot level, but also for inter-site comparisons. Deadwood sampling, for example, is currently implemented at several research stations. Even though the plot size, the aims of studies and methods are different, the focal point represented by this common measurement among sites should be taken into consideration as a starting step toward harmonization. A gap is also to be recognized in data concerning consumers and biodiversity (Magurran et al. 2010). Invertebrates were monitored for three years in the frame of a pilot project (<http://www.forestbiota.org> - Ferretti et al. 2006) and sporadic case studies can be found concerning other animal groups, but a continuous and coordinated monitoring is not currently performed. Though the plot scale is not suited for investigations on spatial and temporal distribution of animal populations, some data on consumers would be of relevance for considerations on their impact on primary production, organic matter accumulation and overall evaluation of energy transformation, environmental stability and quality of ecosystems. Within the network, insects and birds are among the most investigated animal groups (Tab. 5). Different methods are currently available to survey and sample insects, depending on the aims of the study and the ecological traits of target families and study areas. Also, a wide and shared methodology is available for bird monitoring at LTER Europe level (Vadineanu et al. 2005). So, specific working groups would be necessary

to start or enhance harmonization of methods, based on the mentioned common parameters. The already existing research lines should be considered and maintained, while experiences from LTER Europe members show that overlaps and shifts of methods are possible (Sykes & Lane 1996). On a different ground, datasets from natural reserves included in LTER Italy forest sites have a stronger emphasis on both producers' and consumers' components of ecosystems. These datasets address specific ecological questions on processes, relying on data series going back in several cases to past centuries; however methods, duration, intensity and interval of sampling and even taxonomic targets often differ from one case to another, thus making harmonization and comparison between studies very difficult (Magurran et al. 2010).

Moreover, ecological issues of global concern should also be considered. Examples of LTER activities addressing biodiversity loss, climate change, land use change at large scale exist in LTER Europe: in UK LTER Network, ground beetles (Coleoptera, Carabidae) and the ubiquitous harvestman *Mitopus morio* are monitored at terrestrial sites for species abundance and features responding to climate change and changes in land management (Sykes & Lane 1996, Morecroft et al. 2009). Although not directly linked to LTER Europe, another example is the estimation of the effect of the 2003 heat wave on European ecosystems' carbon balance, that was assessed using data from research and monitoring networks, remote sensing and process modeling.

Tab. 6 - Potential suitability of LTER Italy forest research stations to address five suggested LTER core areas and current ecological issues of global concern. (*): research stations belonging to the ICP Forests Programme. (x): potential suitability of research station to address the corresponding question.

Sites	LTER Italy forest sites	Spatial and temporal distribution of populations	Pattern and frequency of disturbance	Pattern and control of primary production	Pattern and control of organic matter accumulation	Pattern of inorganic input and movements through soils	Biodiversity loss	Climate change	Land use change, management
Forests of the Alps	*Val Masino	-	X	X	X	X	-	X	-
	*Renon	-	X	X	X	X	X	X	-
	*Passo Lavazè	X	X	X	X	X	X	X	-
	*Tarvisio	-	X	X	X	X	-	X	-
	Valbona Reserve	X	X	X	-	X	X	X	X
Apennines forests	*Selva Piana	-	X	X	X	X	-	X	-
	*Piano Limina	-	X	X	X	X	-	X	-
	Torricchio Reserve	X	X	X	-	X	X	X	X
Mediterranean forests	*Monte Rufeno	-	X	X	X	X	X	X	-
	*Ficuzza	-	X	X	X	X	-	X	-
	*Colognole	-	X	X	X	X	-	X	-
	Monte Rufeno Reserve	X	X	X	-	X	X	X	X
Castelporziano Estate	Castelporziano forest	X	X	-	-	-	X	X	X
	*Bosco Fontana	X	X	X	X	X	X	X	-
Lowland forests	Bosco Fontana Reserve	X	X	X	X	-	X	X	X

Box 1 - Useful links.

- A long-term biodiversity, ecosystem and awareness research network. Home page.
[online] URL: <http://www.alter-net.info/>
- Corpo Forestale dello Stato. Home page.
[online] URL: <http://www3.corpoforestale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/443>
- EFOMI: Ecological valuation in alpine forest ecosystems by integrated monitoring. Home page.
[online] URL: http://www.iasma.it/sperimentazione_context.jsp?ID_LINK=2424&area=6
- Environmental quality and pressure assessment across Europe: the LTER Network as an integrated and shared system for ecosystem monitoring. EnvEurope LIFE co-financed project (2010-2013). Home page.
[online] URL: <http://www.enveurope.eu/>
- ForestBIOTA - forest biodiversity test-phase assessment. A forest biodiversity monitoring project developed by 10 European countries. Home page.
[online] URL: <http://www.forestbiota.org>
- Further development and implementation of an EU-level forest monitoring system. A LIFE co-financed project. Home page.
[online] URL: <http://www.futmon.org/>
- Long term ecological research Italy. Home page.
[online] URL: <http://www.lteritalia.it/>
- International co-operative programme on assessment and monitoring of air pollution effects on forests - ICP forests. Home page.
[online] URL: <http://www.icp-forests.org>
- European long term ecosystem research network. Home page.
[online] URL: <http://www.lter-europe.net/>
- International long term ecological research network. Home page.
[online] URL: <http://www.ilternet.edu/>

century) of monitoring and research on key environmental variables, the inclusion of selected forest study sites in the LTER Italian Network is a due and positive outcome. Today, the main forest ecosystems are represented in the national network. Through a strong coordination effort, LTER Italy has achieved awareness at national level and a foremost representation outside national borders, within the global and European LTER entities (ILTER and LTER Europe). LTER Italy forest sites reflect strengths and weaknesses of international networks. In fact, on one side, there are good examples of cooperation in terms of the institutions involved, while the set of fundamental variables assessed and the length of data series represent invaluable monitoring and research resources. On the other side, the bottom-up process of network implementation created a poorly harmonized collection of sites, where an overall agreement on key parameters seems evident, but methods are still very diversified and need to be discussed among experts. This is necessary in order to shift from in-site monitoring to inter-site and cross-site research and evaluation on ecosystem processes. Indeed, the framework of LTER, at national and international level, provides now the ground for starting this kind of discussion. As it is widely recommended to keep the existing set of variables unchanged as far as possible (to maintain the continuity of data series), a possible way is to start an adaptive monitoring following a specific research question, chosen among those suggested within LTER and adapted to the existing dataset. There is a potential frame to compare and eventually adjust measurements, in terms of methods, to the request of standardization of activities across sites and also across different networks. This process of harmonization of activities could also facilitate soundness of research results and enhance the benefits of long term research knowledge to the general public and the policy. The LIFE co-financed project EnvEurope, "Environmental quality and pressure assessment across Europe: the LTER Network as an integrated and shared system for ecosystem monitoring" (2010-2013, <http://www.enveurope.eu/>) has the main objectives of investigating these opportunities, developing a consistent classification of sites and network design.

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Methodology, methods and protocols in long term ecological research

The value of consistent methodology is widely recognized in long term ecological research (Beard et al. 1999). The words "methodology", "method" and "protocol" are often used as if they had the same meaning, somehow as synonymous. But actually they are not. The meaning of the word methodology is intended here as collection, comparative study and critical appraisal of individual methods (Patton 2002). In the frame of long term research, methodology should be developed: (1) across sites, to meet harmonization of monitoring or research and shape a restructured international network design; (2) at single site level, in order to set well-ground plans for new monitoring or research activities based on locally available datasets. Through this procedure, it would be also possible to create agreed protocols (Sykes & Lane 1996, Morecroft et al. 2009). A protocol (Sykes & Lane 1996) has to be defined as a written method for the design and implementation of experiments; it is usually a comprehensive document, also including lists of required sampling equipment, explanations of statistical analysis, rules to avoid bias. In a protocol, metadata on methods should also be fully registered and stored (Peters 2010), with detailed description of their time and space traits, equipment and suppliers, chronology of sampling, staff involved and others (Beard et

al. 1999). Few national LTER networks currently have agreed protocols for the implementation of activities at sites (Sykes & Lane 1996), but several of them share the objective of drafting protocols as common manuals for future monitoring or research steps.

In order to start with a sound planning of harmonization of research and monitoring in LTER Italy forest sites, a cross analysis of current activities with LTER ecological questions could be a first step, thus trying to answer the question: "Can LTER question «Y» be approached using dataset components of «forest site X» (Tab. 6)? While some researchers suggested that research questions could be profitably addressed by most of the stations (disturbance, primary production, soil chemistry, climate change), population dynamics and land use change can be properly investigated at a scale larger than plot level. An example of such questions can be provided by those sites included in protected areas, where ecological investigations are not carried out intensively at plot level, but considering a larger spatial scale and the relationship with the landscape. Additionally, up-scaling schemes, starting from plot level intensive surveys, should be designed to use results at plot level to understand broader-scale processes.

Conclusions

After decades (in some cases more than a

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References

- Beard GR, Scott WA, Adamson JK (1999). The value of consistent methodology in long-term environmental monitoring. *Environmental Monitoring and Assessment* 54 (3): 239-258. - doi: [10.1023/A:1005917929050](https://doi.org/10.1023/A:1005917929050)
- Bredemeier M, Dennis P, Sauberer N, Petriccione B, Torok K, Cocciufa C, Morabito G, Pugnetti A (2007). Biodiversity assessment and change. The challenge of appropriate methods. In: "Issues in environmental science and technology. Biodiversity under threat" (Hester RE, Harrison RM eds). The Royal Society of Chemistry, Cambridge, UK, vol. 5, pp. 217-240.
- Campanaro A, Hardersen S, Mason F (2007). Piano di gestione della riserva naturale statale e sito natura 2000 "Bosco della Fontana". Quaderni Conservazione Habitat 4, Cierre Ed., Verona, Italy, pp. 221.
- Cavalli R, Mason F (2003). Techniques for re-establishment of dead wood for saproxylic fauna conservation. LIFE Nature project NAT/IT/99/6245 "Bosco della Fontana" (Mantova, Italy). Scientific report 2, Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale di Verona - Bosco della Fontana, Gianluigi Arcari Ed., Mantova, Italy, pp. 112.
- Cerretti P, Hardersen S, Mason F, Nardi G, Tisato M, Zapparoli M (2004a). Ricerche naturalistiche a Bosco della Fontana. Quaderni Conservazione Habitat 3, Cierre Ed., Verona, Italy, pp. 96.
- Cerretti P, Whitmore S, Mason F, Vigna Taglianti A (2004b). Survey on the spatio-temporal distribution of Tachinid flies using Malaise traps (Diptera, Tachinidae). In: "Invertebrati di una foresta della Pianura Padana. Bosco della Fontana. Secondo contributo" (Cerretti P, Hardersen S, Mason F, Nardi G, Tisato M, Zapparoli M eds). Conservazione Habitat Invertebrati 3, Cierre Ed., Verona, Italy, pp. 229-256.
- Cutini A, Matteucci G, Scarascia Mugnozza G (1998). Estimation of leaf area index with the LiCor LAI 2000 in deciduous forests. *Forest Ecology and Management* 105 (1-3): 55-65. - doi: [10.1016/S0378-1127\(97\)00269-7](https://doi.org/10.1016/S0378-1127(97)00269-7)
- European Environment Agency (2007). European forest types. Categories and types for sustainable forest management reporting and policy. Technical Report no. 9/2006, 2nd Edition, Copenhagen, Denmark.
- Ferretti M, Petriccione B, Fabbio G, Bussotti F (2006). Aspects of biodiversity in selected forests ecosystems in Italy: status and changes over the period 1996-2003. Third report of the task force on integrated and combined (I & C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura* 30 (2): 112.
- Gianelle D, Travaglini D, Mason F, Minari E, Chirici G, Chemini C (2007). Canopy analysis and dynamics of a floodplain forest. Scientific report 3, Centro nazionale per lo studio e la conservazione della biodiversità forestale di Verona - Bosco della Fontana, Cierre Ed., Verona, Italy, pp. 96.
- Kaufmann H, Anderson M (2006). ILTER Strategic Plan. Environment & Enterprise Strategies, LLC, USA.
- Koop H (1989). Forest dynamics, SILVI-STAR: a comprehensive monitoring system. Springer, Berlin, Heidelberg, New York, pp. 229.
- Likens GE (1989). Long-term studies in ecology. Springer-Verlag, New York, USA.
- Lindenmayer DB, Likens GE (2009). Adaptive monitoring: a new paradigm for long-term research and monitoring. *Trends in Ecology and Evolution* 24 (9): 482-486. - doi: [10.1016/j.tree.2009.03.005](https://doi.org/10.1016/j.tree.2009.03.005)
- Luyssaert S, Reichstein M, Schulze ED, Janssens IA, Law BE, Papale D, Dragoni D, Goulden M, Granier A, Kutsch WL, Linder S, Matteucci G, Moors E, Munger JW, Pilegaard K, Saunders M, Falge EM (2009). Towards a consistency cross-check of eddy covariance flux based and biometric estimates of ecosystem carbon balance. *Global Biogeochemical Cycles* 23: GB3009. - doi: [10.1029/2008GB003377](https://doi.org/10.1029/2008GB003377)
- Magurran AE, Baillie SR, Buckland ST, Dick JM, Elston DA, Scott EM, Smith RI, Somerfield PJ, Watt AD (2010). Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. *Trends in Ecology and Evolution* 25 (10): 574-582. - doi: [10.1016/j.tree.2010.06.016](https://doi.org/10.1016/j.tree.2010.06.016)
- Mason F (2002). Dinamica di una foresta della pianura Padana. Primo contributo, monitoraggio 1995. Rapporti scientifici 1, Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale di Verona - Bosco della Fontana, Gianluigi Arcari Ed., Mantova, Italy, pp. 208.
- Mason F, Nardi G, Tisato M (2003). Proceedings of the International Symposium "Dead wood: a key to biodiversity" (Mason F, Nardi G, Tisato M eds). Mantova (Italy), 29-31 May 2003. *Sherwood* 95 (2): 99.
- Mirtl M, Frenzel M, Furman E, Ohl C, Krauze K, Grünbühel C (2008). LTER Europe criteria and recommendations. LTER Europe Report. [online] URL: http://www.uibk.ac.at/alpinerraum/meetings/ter/ter_europe_criteria.pdf
- Morecroft M, Bealey C, Beaumont D, Benham S, Brooks D, Burt T, Critchley C, Dick J, Littlewood N, Monteith D (2009). The UK Environmental Change Network: emerging trends in the composition of plant and animal communities and the physical environment. *Biological Conservation* 142 (12): 2814-2832. - doi: [10.1016/j.biocon.2009.07.004](https://doi.org/10.1016/j.biocon.2009.07.004)
- Motta R, Piussi P (2009). Ricerche ecologiche di lungo periodo (LTER) nella riserva forestale della Valbona (Paneveggio, TN). In: "Atti del Terzo Congresso Nazionale di Selvicoltura" (Ciancio O ed). Taormina (ME - Italy), 16-19 October 2008. Accademia Italiana di Scienze Forestali, Firenze, Italy, pp. 558-562.
- Oldeman RAA (1990). Forests: elements of silvology. Springer-Verlag, New York, Berlin, Heidelberg, pp. 624.
- Parr TW, Ferretti M, Simpson IC, Forsius M, Kovacs-Lang E (2002). Towards a long-term integrated monitoring programme in Europe: network design in theory and practice. *Environmental Monitoring and Assessment* 78 (3): 253-290. - doi: [10.1023/A:1019934919140](https://doi.org/10.1023/A:1019934919140)
- Patton MQ (2002). Qualitative research and evaluation methods (3rd edn.). Thousand oaks, Sage Publications, CA, USA.
- Peters DP (2010). Accessible ecology: synthesis of the long, deep, and broad. *Trends in Ecology and Evolution* 25 (10): 592-601. - doi: [10.1016/j.tree.2010.07.005](https://doi.org/10.1016/j.tree.2010.07.005)
- Petriccione B, Pompei E (2002). The CONECOFOR programme: general presentation, aims and coordination. In: "Long term ecological research in Italian forest ecosystems" (Mosello R, Petriccione B, Marchetto A eds). *Journal of Limnology* 61 (1) 3-11. [online] URL: http://www.iii.to.cnr.it/publicaz/JL_61_supl/JL61_Suppl-index.htm
- Petriccione B, Cindolo C, Cocciufa C, Ferlazzo S, Parisi G (2009a). Un indicatore dello stato della biodiversità delle foreste europee. In: "Atti del Terzo Congresso Nazionale di Selvicoltura" (Ciancio O ed). Taormina (ME- Italy) 16-19 October 2008. Accademia Italiana di Scienze Forestali, Firenze, Italy, pp. 240-242.
- Petriccione B, Cindolo C, Cocciufa C, Ferlazzo S, Parisi G (2009b). Gli effetti dei cambiamenti climatici sugli ecosistemi forestali. In: "Atti del Terzo Congresso Nazionale di Selvicoltura" (Ciancio O ed). Taormina (ME - Italy) 16-19 October 2008. Accademia Italiana di Scienze Forestali, Firenze, Italy, pp. 570-574.
- Risser PG (1991). Long-term ecological research. An international perspective. John Wiley and Sons, Chichester, New York, Brisbane, Toronto, Singapore.
- Salvadori C, Ambrosi P (2005). Ecological evaluation in alpine forest ecosystems by integrated monitoring. *Studi Trentini di Scienze Naturali, Acta Biologica* 81 (1): 31-40.
- Scarascia Mugnozza G (1999). Ecologia strutturale e funzionale di faggete italiane. Edagricole, Bologna, Italy, pp. 133-183.
- Scarascia Mugnozza G, Bauer G, Persson H, Matteucci G, Masci A (2000). Tree biomass, growth and nutrient pools. In: "Carbon and nitrogen cyc-

- ling in european forest Ecosystems” (Schulze ED ed). Ecological Studies 142, Springer Verlag, Heidelberg, Germany, pp 49-62.
- Scartazza A, Mata C, Matteucci G, Yakir D, Moscatello S, Brugnoli E (2004). Comparisons of $\delta^{13}\text{C}$ of photosynthetic products and ecosystem respiratory CO_2 and their responses to seasonal climate variability. *Oecologia* 140 (2): 340-351. - doi: [10.1007/s00442-004-1588-1](https://doi.org/10.1007/s00442-004-1588-1)
- Seastedt TR, Briggs JM (1991). Long-term ecological questions and considerations for taking long-term measurements: lessons from the LTER and FIFE programs on Tallgrass Prairie. In: “Long-term ecological research. An international perspective” (Risser PG ed). John Wiley and Sons, Chichester, New York, Brisbane, Toronto, Singapore.
- Stireman III JO, Cerretti P, Whitmore D, Hardersen S, Gianelle D (2011). Composition and stratification of a tachinid (Diptera: Tachinidae) parasitoid community in a European temperate plain forest. *Insect Conservation and Diversity* [early online]. - doi: [10.1111/j.1752-4598.2011.00168.x](https://doi.org/10.1111/j.1752-4598.2011.00168.x)
- Strayer D, Glitzenstein JS, Jones CG, Kalasa J, Likens GE, McDonnell MJ, Parker GG, Pickett STA (1986). Long term ecological studies: an illustrated account of their design, operation and importance to ecology. Occasional Publication no. 2, Institute of Ecosystem Study, Millbrook, New York, USA, pp. 38.
- Sykes JM, Lane AMJ (1996). The United Kingdom environmental change network. Protocol for standard measurements at terrestrial sites. The Stationery Office, Natural Environment Research Council, London, UK, pp. 219.
- Sutherland WJ (2006). Ecological census techniques: a handbook. Cambridge University Press, Cambridge, UK.
- Vadineanu A, Dacu S, Adamescu M, Cazacu C (2005). The state of the art for LTER activities in Europe. ALTER-Net WP I3 Report, Department of Systemic Ecology, University of Bucharest, Romania.
- Valentini R, Angelis P, Matteucci G, Monaco R, Dore S, Mugnozza GE (1996). Seasonal net carbon dioxide exchange of a beech forest with the atmosphere. *Global Change Biology* 2 (3): 199-207. - doi: [10.1111/j.1365-2486.1996.tb00072.x](https://doi.org/10.1111/j.1365-2486.1996.tb00072.x)
- Valentini R, Matteucci G, Dolman AJ, Schulze ED, Rebmann C, Moors EJ, Granier A, Gross P, Jensen NO, Pilegaard K, Lindroth A, Grelle A, Bernhofer C, Grünwald T, Aubinet M, Ceulemans R, Kowalski AS, Vesala T, Rannik Ü, Berbigier P, Loustau D, Guðmundsson J, Thorgeirsson H, Ibrom A, Morgenstern K, Clement R, Moncrieff J, Montagnani L, Minerbi S, Jarvis PG (2000). Respiration as the main determinant of carbon balance in European forests. *Nature* 404 (6780): 861-865. - doi: [10.1038/35009084](https://doi.org/10.1038/35009084)

ARTICLE 2

Saproxylic beetle assemblages at small scale. A test study at selected forest monitoring plots in central Italy

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Abstract

1. Diversity and composition of beetle assemblages were studied at four different forest monitoring plots (Selva Piana, Rosello, Monte Rufeno and Monte Circeo) in central Italy, with flight interception traps and emergence traps.

2. Considering the whole dataset, alpha-diversity values resulted particularly high at all of the four forest sites, while measured species richness, accumulation curves and species richness estimators agreed in attributing a higher species density at Rosello. 3. Monte Rufeno showed the highest abundance.

Monte Rufeno and Monte Circeo showed higher numbers of saproxylic species compared to the overall dataset at Rosello.

4. The variables that had the strongest correlations with the assemblage composition were plot-scale variables (slope, stand age, amount of deadwood). The only trap-scale variable that showed up as related to assemblage composition was decay-class.

Results were discussed considering the availability and quality of deadwood on the forest floor and the different forest structure at the four

study sites. The research showed that even at small and very small scale, traits of beetle assemblages can be revealed.

Key words: biodiversity, Coleoptera, deadwood, ICP Forests, long term ecological research

Introduction

Saproxyllic organisms depend, at some stage of their life cycle, upon deadwood of senescent trees or fallen timber, or upon other saproxyllics (Speight 1989, Mason *et al.* 2003). Several authors have further analyzed the microhabitat requirements and feeding ecology of saproxyllic beetles (Bouget *et al.* 2005, Alexander 2008). The relevance of deadwood as substrate for several organisms has thus been widely recognized during the last decades (Speight 1989, Mason *et al.* 2003, Jabin *et al.* 2004, Castagneri *et al.* 2010), but consequences of modern exploitation of forests have indeed given rise to increasing concern regarding current availability of suitable environmental conditions for several animal groups and among them for saproxyllic beetles (Similä *et al.* 2003, Alinvi *et al.* 2007, Hjältén *et al.* 2007). In northern boreal countries, modern intensive forest management, including short rotation periods and clear-cutting, have created monospecific, even-aged stands (Johansson *et al.* 2007, Gibb *et al.* 2006), consequently reducing the availability of deadwood for saproxyllic organisms. In central and southern Europe, exploitation of forests has followed different historical events. In the Mediterranean basin, woods have been overexploited by man since prehistoric ages (Castagneri *et al.* 2010) and through Roman and Byzantine times, resulting in degraded forms of woodlands and widespread regions cleared of mature woody vegetation (Cappelli 2000).

Disturbances such as grazing, fire management and agricultural techniques have influenced the external shape and type of these woodlands, though the abandonment of grazing during the 20th century (Franc & Götmark 2008) and the interruption of intensive clear cutting in the late 1970s produced a new propagation of trees. Decreasing interest in harvesting woody debris for energy production has led to the accumulation of small diameter deadwood materials on the forest floor, which may be relevant for the conservation of saproxyllic beetles (Jonsell & Hansson 2007, Jonsell 2008), even at the very small scale of single deadwood pieces (Johansson *et al.* 2007, Jonsell & Hansson 2007, Sirami *et al.* 2008). Several studies from northern Europe (Økland *et al.* 1996,

Grove 2002, Gibb *et al.* 2006, Alinvi *et al.* 2007, Franc *et al.* 2007, Johansson *et al.* 2007) have recently investigated the topic of interactions between forest structure, stand age, availability and quality of deadwood and diversity of forest dwelling and saproxylic beetles at different scales. On the other hand, studies in central and southern Europe are relatively few (Kappes & Topp 2004, Sirami *et al.* 2008, Buse *et al.* 2010, Brin *et al.* 2011, Bouget *et al.* 2011, Lassauce *et al.* 2011, Russo *et al.* 2011) and factors and scales affecting saproxylic beetle communities need further investigations, considering the different exploitation forests have been experiencing for decades in these areas.

In this paper, we studied saproxylic beetle assemblages inside selected forests having permanent monitoring plots in Italy. These sites were selected because they have been fenced and unmanaged for monitoring purpose since 1995, so the forest structure shows a condition of ongoing ageing as a result of the interruption of harvesting practices typical of central Europe forestry; in addition their environmental parameters have been recorded for several years. The aim of this paper was to investigate saproxylic beetle assemblages at small to very small scale and assess if the plot scale is able to reveal ecological patterns. The following questions were specifically addressed:

- 1- what is the beetle diversity at the four considered study plots? How dissimilar is beetle community composition at these plots?
- 2- what environmental factors can affect saproxylic beetle diversity and community composition at plot and at microhabitat (single deadwood piece) scale?

Materials and Methods

Study areas

We studied four different forest ecosystems in central Italy, three on the Apennines Range of Abruzzo and Lazio Regions and one near the Mediterranean Coast in Lazio Region.

Selva Piana (Collelongo-L'Aquila, 41°50'58.30''N, 13°35'21.8''E) is a beech (*Fagus sylvatica* L.) high stand (EUNIS code G1.68), about 125 years old, located at 1550 m asl. Rosello (Rosello-Chieti, 41°53'1.96''N, 14°21'11.48''E) is a high stand (about 95 years old) situated at 960 m asl, including *Carpinus betulus* L., *Acer campestre* L., *Tilia platyphyllos* Scop. with a significant presence of *Abies alba* Mill (EUNIS code G1.A). Monte Rufeno (Acquapendente-Viterbo, 42°49'25.07''N, 11°54'6.21''E), 690 m asl, is a thermophilous deciduous forest (EUNIS code G1.7), which has

been cut intensively until as recently as 1970 and is now unmanaged. The dominant tree species is *Quercus cerris* L. Monte Circeo - Peretto (San Felice Circeo-Latina, 41°14'9.10''N, 13°4'47.95''E) is a Mediterranean evergreen oak woodland with *Quercus ilex* L., *Quercus suber* L. and *Arbutus unedo* L. (EUNIS code G2.1), located at 190 m asl on the northern slope of a promontory looking over the central Tyrrhenian Sea. It is a coppice wood subject to cut and grazing until 1950, then left unmanaged. Sampling of beetles was performed inside ICP Forests monitoring plots (Ferretti *et al.* 2006), one plot at each study area. Each ICP Forests plot is a fenced square 50 x 50 m area, selected as a representative study site within an homogeneous type of ecosystem. Monte Rufeno and Selva Piana are included in the Italian Long Term Ecological Research Network (Cocciufa *et al.* 2011).

Sampling design

Two types of traps for insects were used: window interception traps and emergence traps (WT and ET respectively in this paper). WT were made following Mason *et al.* 2006. WT are suitable to sample flying forest beetles, which are intercepted by the hanging panels (Økland 1996, Ranius & Jansson 2002, Mason *et al.* 2006). ET were made according to Alinvi *et al.* 2007. The size of the fabric cloth was 50 x 70 cm; the collector bottle was located beneath the trap, near the ground. Boring insects emerging from deadwood are not able to escape from the closed envelope and fall into the collector bottle, attracted by daylight (Owen 1989, Owen 1992, Økland 1996, Wikars *et al.* 2005). In both types of traps, collector bottles were filled with 70% ethanol. One WT was located in the middle of each study plot, hanging from a tree branch, 1.50 m above ground. At each study plot, nine random points were extracted by means of Excel (as random coordinates inside the 50 x 50 m plot). Deadwood pieces for emergence trapping were detected in a circular area with a 10 m radius, centered at each random point. The criteria adopted to select deadwood were the following: 1) only logs were taken into consideration (no stumps or snags); 2) deadwood pieces of the same tree species and decay stage in each trap; 3) logs with diameter > 10 cm were primarily selected (one log per trap); 4) where logs > 10 cm were not available, logs with smaller diameters were also accepted, but at least three branches were included in the trap. Because suitable deadwood pieces were not always present at random points, number of emergence traps varied at each study plot (6 emergence traps at Selva Piana, 8 at Rosello and Monte Rufeno, 5

at Monte Circeo). Locations of traps were georeferenced. Traps were set in the field in spring and summer 2010, from early May until the end of August. Sampling was performed every fifteen days.

Environmental variables

Environmental variables at plot scale and at single trap scale recorded for the present study are listed in Appendix A (Tab. A.1). Percentage of canopy closure was measured by digital pictures of the canopy taken from the ground above each ET and analyzed by means of ImageJ Software (two pictures for each trap, one at the beginning and one at the end of the field campaign). Basal area of trees around the trap was calculated from circumferences of three trees shading the trap. Volume of deadwood inside emergence traps was calculated by the Huber formula ($V = \pi / 4 d^2 * l$).

Statistical analysis

Diversity of beetle assemblages was investigated by Alpha-diversity indices (Shannon-Wiener, Simpson and Evenness) and rarefaction curves. Alpha-diversity indices were also measured for the tree community at each study plot. Diversity indices were calculated with PAST (Hammer *et al.* 2001). Sample-based rarefaction curves (Mao's τ) were calculated with the software EstimateS (version 8.2.0, Colwell 2006) and displayed using Excel. To estimate the total species number at each plot, estimators of total species richness based on different algorithms (Chao2, first and second order Jackknife and Bootstrap) were calculated with PAST. Spearman's rank correlation coefficient was used to detect relationships between indices measured for beetle assemblages and tree communities at each study plot. Multivariate dissimilarities of beetle assemblages were calculated by the Bray-Curtis Index. Because we assumed there were differences in trapping efficiencies of WTs and ETs and there were more ETs than WTs, we used presence-absence data to examine the beetle species dissimilarities in the four plots and in the different trap-types within these plots. Keeping ET data separate, non-metric multidimensional scaling (NMDS) ordination with $\log(x+1)$ species abundance data and Bray-Curtis dissimilarity was used to illustrate the dissimilarities of beetle assemblages in traps and plots and to look for correlations between beetle assemblage composition in ETs and environmental variables. NMDS was chosen for the ordination because it is one of the best methods for exploring biological data that rarely meet

assumptions required for many other types of ordinations (McCune & Grace 2002). The ordination and Bray-Curtis index calculations were performed in PC-ORD (version 5.19, McCune & Mefford 2006).

Results

We collected a total of 1372 individuals, belonging to 133 species of 36 families (Appendix A, Tab. A.2). The highest numbers at all taxonomic levels (families, genera and species) were sampled at Rosello, the only site where ET were able to catch more species and individuals than WT (Fig. 1). Monte Rufeno showed the highest total abundance (405 individuals). Alpha diversity indices of tree communities at the four study areas revealed remarkable differences among plots, reflecting the actual difference in tree species composition and abundance: Selva Piana and Monte Rufeno scored a Simpson and Shannon Index equal to 0, with only one tree species present at each site, beech and Turkey oak, respectively; Monte Circeo had a Simpson Index = 0.69 and a Shannon Index = 1.35, while Rosello had higher values (Simpson Index = 0.75, Shannon Index = 1.74). Surprisingly, values of the same metrics for beetle assemblages were all particularly high: Simpson Index = 0.87, Shannon Index = 2.7 at Selva Piana; Simpson Index = 0.87, Shannon Index = 2.91 at Rosello; Simpson Index = 0.86, Shannon Index = 2.85 at Monte Rufeno; Simpson Index = 0.84, Shannon Index = 2.47 at Monte Circeo. Measures of evenness of beetle assemblages were similar at Rosello and Monte Circeo (Evenness Index = 0.28), but differed between Selva Piana (Evenness Index = 0.43) and Monte Rufeno (Evenness Index = 0.34). No significant correlation was detected between indices measured for tree layers and beetle assemblages at each study plot (Selva Piana $r_s = -0.86$, $n = 2$, $P = 0.66$; Rosello $r_s = 1$, $n = 2$, $P = 0.33$; Monte Rufeno $r_s = -0.5$, $n = 2$, $P = 1$; Monte Circeo $r_s = 1$, $n=2$, $P = 0.33$). The number of beetle species collected at each plot varied as follows: 34 species at Selva Piana, 64 at Rosello, 50 at Monte Rufeno and 41 at Monte Circeo. Observed sample-based rarefaction curves showed a positive slope at the maximum number of samples (Fig. 2). Selva Piana, Monte Rufeno and Monte Circeo curves exhibited similar trends, with the inception of an asymptotic progress with greater sampling effort, while the curve for Rosello confirmed a higher species density, growing up steeply. Outputs of species richness estimators for all of the four sites differed on the basis of the algorithm used, but they all listed a similar site ranking, with the highest species richness at Rosello and lowest at Monte Circeo, also confirming the trends shown by

rarefaction curves. The range of the estimators was wide: Bootstrap returned the smallest values, close to the actual numbers of species detected by sampling but, looking at the trends of rarefaction curves, second order Jackknife seemed to suggest the most correct number of beetle species present, also showing a clear peak value at Rosello. Considering Bootstrap and second order Jackknife, the following results may be suggested: between 44 and 77 beetle species at Selva Piana, 80 and 135 at Rosello, 61 and 100 at Monte Rufeno, 51 and 80 at Monte Circeo. Considering all types of captures to study beetle assemblage composition at the four study plots, a very high degree of dissimilarity was found (Tab.1). 90 species (67.7% of the species found in all plots combined) were found in only one plot, while only three species (*Diplocoelus fagi*, *Litargus connexus* and *Xyleborus dispar*), representing 2.3% of the species, were collected at all of the four plots.

Among the seven species shared by three plots, 4 species belong to the family Latridiidae (*Dienerella vincenti*, *Enicmus brevicornis*, *Enicmus rugosus*, *Cartodere (Aridius) nodifer*).

Comparing window and emergence traps captures within each plot, marked trap-type dissimilarities were also found, particularly at Rosello (Bray-Curtis Index = 0.80), where only 7 out of 64 species (10.9%) were sampled in both trap types. A lower degree of trap-type dissimilarity was exhibited at Monte Circeo, where Bray-Curtis Index was 0.57. A further analysis was performed considering only the specimens captured by ETs, assuming that they represent the subset of data including the higher proportion of true saproxylic species (eusaproxylic beetles). A 3-dimensional NMDS solution was recommended using the medium auto-pilot setting in PC-ORD (version 5.19, McCune & Mefford 2006); the final stress was 14.2 with about equal amounts of variation explained by each of the 3 axes (R^2 : axis 1 = 0.27, axis 2 = 0.23, axis 3 = 0.27). Axis 1 was primarily a gradient of traps from those that had high abundances of the scolytid, *Xyleborus dispar*, and none of the mycetophagid, *Litargus connexus*, to traps that had some *L. connexus* and no *X. dispar*. Axis 2 primarily represented a gradient of traps from those with some of the latridiid, *Dienerella clathrata*, and none of the scaptiid, *Anaspis lurida*, to traps with high abundances of *A. lurida* and no *D. clathrata*. Like Axis 1, Axis 3 distinguished sites with high abundances of *X. dispar* from those without this species, but Axis 3 did not exhibit a gradient related to *L. connexus*. The NMDS ordination plot showing the first 2 axes revealed that the ETs from each plot formed a cluster, indicating greater similarity of assemblages within plots than among them (Fig. 3). A

similar pattern was seen when axes 1 and 3 were plotted (not shown). From the same data subset, we looked at correlations between the assemblage composition (as shown in the ordination) and environmental variables. Relationships were evaluated for plot scale variables (elevation, slope, average precipitation, average temperature, stand age, basal area, amount of deadwood) and trap scale variables (decay-class, wood volume, average canopy closure, and basal area near the trap). The variables that had the strongest correlations with the assemblage composition were plot-scale variables. The only trap-scale variable that showed up as related to assemblage composition was decay-class, which represents a relevant explanatory variable for saproxylic species (Fig. 3). The majority of the environmental variables were related to the assemblage gradient along Axis 1, but slope was related to the assemblage gradient along axis 2; the assemblage gradient along Axis 3 had no strong correlations ($r \geq 0.6$) with environmental variables.

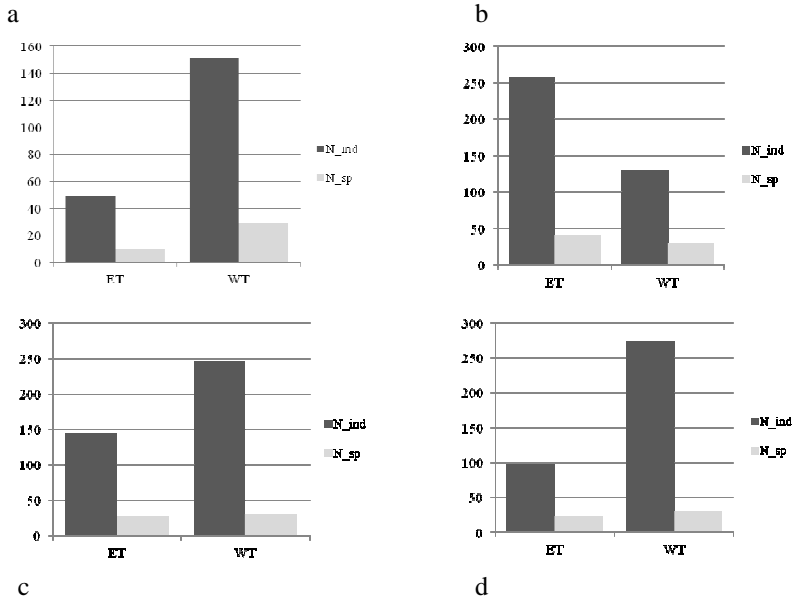


Figure 1

Number of individuals and species captured by emergence (ET) and interception (WT) traps at each study plot: a, Selva Piana; b, Rosello; c, Monte Rufeno; d, Monte Circeo.

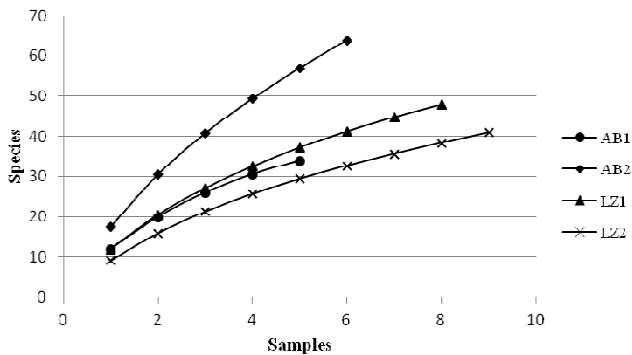


Figure 2

Comparison of sample-based rarefaction curves of beetle assemblages at Selva Piana, Rosello, Monte Rufeno and Monte Circeo plots.

Table 1

Bray-Curtis dissimilarity of plots based on presence/absence of 133 detected species by all types of traps.

	AB1	AB2	LZ1	LZ2
AB1	0	0.6735	0.8095	0.8667
AB2	0.6735	0	0.6842	0.8286
LZ1	0.8095	0.6842	0	0.6484
LZ2	0.8667	0.8286	0.6484	0

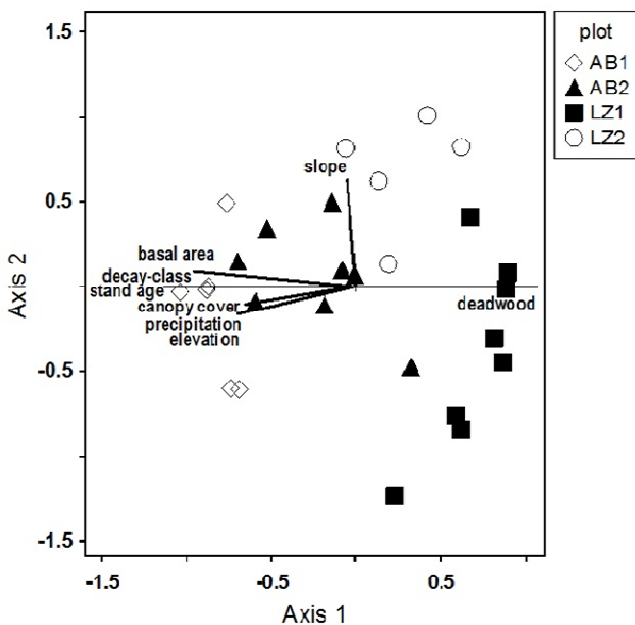


Figure 3

NMDS ordination, showing the distribution of ET assemblages at the four study plots, with respect to environmental variables.

Discussion

Despite the small size of the surveyed area, the plot scale was able to reveal differences among the four study sites. Emergence trapping allowed specificity of captures from a known substrate, qualifying investigations on habitat and microhabitat species requirements. Number of species and abundance were higher in WT compared to ET samples in three out of four plots. Considering all plots, each WT collected an average of 22 species and 200 individuals during the whole sampling period, while each ET in the same period trapped as average of 3 species and 20 individuals. There may be physical and ecological reasons for this outcome. The interception surface of WT is capable of collecting insects flying from all directions within a huge three-dimensional space inside the forest plot, compared to trapping sources of ET (about 3000 cm³ deadwood per trap as average in the frame of the present study). Considering that the diversity of beetle assemblages was not correlated to the diversity of tree communities, it may be suggested that the diversity of beetles is affected by forest structure rather than by richness and abundance in the tree community. We can hypothesize that the abundance of flying insects, and thus captures by WT, may be higher where the available flying space between the forest floor and the canopies is particularly vacuous, being occupied only by tree stems, like in even-aged stands. If this hypothesis is correct, it may also explain why Rosello was the only site characterized by a lower efficiency of WT compared to ET: the vertical structure at this site is a complex three-dimensional mosaic with a continuous ground vegetation and shrubs coverage, and old and younger trees and snags among spots of natural regeneration. At the same time, a complex forest structure is likely to create different available microhabitat conditions for forest dwelling insects, that may account for a higher species richness. Actually, among several forest structure diversity indices (Neumann & Starlinger 2001, Corona *et al.* 2005), Rosello scored high values regarding vertical evenness (Vertical Evenness Index = 85.72) and horizontal dimensional structure (DBH Variation Coefficient = 0.73) (Bertini & Pichi 2007). Several other metrics highlighted the Rosello study area. Considering all trap captures together, results concerning species richness all agree in assigning a higher number of species at Rosello, followed by Monte Rufeno. Estimations of total number of species returned similar ranges for Rosello and Monte Rufeno, both clearly differing from the other two study areas, which showed lower values of species richness. Nevertheless, the very steep accumulation curve for

Rosello (Fig. 3) demonstrated that a longer and more intense sampling would be needed at this plot to reach the target of actual species richness. This evidence may be due to the difficulty of sampling within a more complex environment, including several different microhabitats and potential niches. The investigation of beetle community composition at the four study plots revealed a significantly low species overlap and thus high dissimilarity among areas (Fig. 3).

The few species shared by all plots show a wide geographic distribution and were very abundant. Two of them live under bark or on deadwood fungi, while *Xyleborus dispar* is a saproxylophagous species. A wider array of functions and feeding ecology traits can be recognized in species assemblages that exhibited a preference to selected plots. This specificity becomes clearer when considering only saproxylic species. Among them, *Latridius consimilis* and *Trypodendrom domesticum* were collected only at Selva Piana; four species were only sampled at Rosello (*Obrium brunneum*, *Pediacus dermestoides*, *Ampedus pomorum*, *Silvanus bidentatus*); eleven species were found only at Monte Rufeno, among them *Ampedus quercicola*, *Xylotrechus arvicola*, *Leptura aurulenta*, *Rhaphitropis oxyacanthae*; nine saproxylics species were found exclusively at Monte Circeo, among them rare singletons like *Agrilus convexicollis mancinii* and *Nematodes filum*, the latter recorded in central Italy for the first time. The evaluation of species diversity at sites and dissimilarities among sites thus suggested that the four forest plots host four different highly diverse beetle faunas. This diversified pattern was confirmed by the subgroup of true saproxylic species, even though, unexpectedly, Monte Rufeno and Monte Circeo (in second order), showed a higher number of saproxylic species compared to the whole dataset at Rosello. This reversal may be explained by the amount of deadwood, one of the environmental variables that showed strong correlation with beetle assemblages at plot scale. In fact, according to recent studies (Travaglini *et al.* 2006, Bertini *et al.* 2010), the amount of deadwood on the ground is actually greater at Monte Rufeno (6.63 m³/ha) and at Monte Circeo (6.53 m³/ha) than at Rosello (2.66 m³/ha). Quality of deadwood is also different: early decaying wood still retaining bark is frequent at Monte Rufeno and Monte Circeo, while late decaying wood was found at Rosello. These qualitative differences also account for the different saproxylic fauna, being exclusive species at Monte Rufeno and Monte Circeo mainly connected to early wood decay stages (*e.g.* Scolytidae, Cerambycidae), while saproxylic species specialized on later stages of wood

decomposition were present at Rosello (*e.g.* Cucujidae, Silvanidae). The assessment of dissimilarities of captures within plots further showed how the two types of traps were suitable to collect different beetle samples and thus how it was relevant to use both to catch complementary aspects of biodiversity. Even within each plot ET set, it may be difficult to define two identical traps, because they were set randomly, without choosing the appropriate substrate and uncontrolled microhabitat variables may affect trap efficiency (*e.g.* sun-exposure, soil moisture, interaction with other micro- and macro fauna individuals like ants, shrews etc). Species exclusive of single ET were also detected: *e.g.* all specimens of *Nematodes filum* were collected in ET4 at Monte Circeo, set on *Arbutus unedo* dead branches.

Saproxylic beetles are subject to a growing interest as key species in forests detritus-based food chain, involved in soil fertility and productivity (Jabin *et al.* 2004), decomposition, nutrient cycling (Dollin 2008) and carbon storage functions (Castagneri *et al.* 2010).

Particularly, in the present paper, we investigated saproxylic beetle assemblages within forest ecosystems that were subject to heavy exploitation practices, recently interrupted, typical of central and southern Europe woodlands and are now growing unmanaged under natural conditions. We have shown that the ecology of saproxylic beetles is visible at these plot scale sites, despite the original focus on vegetation monitoring. Further studies are recommended, based on increased number of spatial and temporal replicates within similar and homogeneous forest environments.

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References

- Alexander, K.N.A., 2008. Tree biology and saproxylic coleopterans: issues of definitions and conservation language. *Revue d'Ecologie (la Terre et la Vie)* 63: 1-5.
- Alinvi, O., Ball, J.P., Danell, K., Hjältén, J., Pettersson, R.B., 2007. Sampling saproxylic beetle assemblages in deadwood logs: comparing window and eclector traps to traditional bark sieving and a refinement. *Journal of Insect Conservation* 11: 99-112.
- Bertini G., Fabbio G., Pichi M., Piovosi M., 2007. MainTrees (Mapping Indexing Trees' Structure): un software per la descrizione della diversità specifica e strutturale di soprassuoli forestali. VI SISEF National Congress, 25-27 Settembre 2007, Arezzo.
- Bertini, G., Fabbio, G., Piovosi, M., Calderisi, M., 2010. Densità di biomassa e necromassa legnosa in cedui di cerro in evoluzione naturale in Toscana. *Forest@* 7: 88-103.
- Bouget, C., Brustel, H., Nageleisen, L.M., 2005. Nomenclature des groups écologiques d'insectes liés au bois: synthèse et mise au point sémantique. *Comptes Rendus Biologies* 328: 936 – 948.
- Bouget, C., Brin, A., Brustel, H., 2011. Exploring the “last biotic frontier”: are temperate forest canopies special for saproxylic beetles? *Forest Ecology and Management*. 261: 211-220.
- Brin, A., Bouget, C., Brustel, H., Jactel, H., 2011. Diameter of downed woody debris does matter for saproxylic beetle assemblages in

- temperate oak and pine forests. *Journal of Insect Conservation* 15:653-669.
- Buse, J., Levanony, T., Timm, A., Dayan, T., Assmann, T., 2010. Saproxylic beetle assemblages in the Mediterranean region: impact of forest management on richness and structure. *Forest Ecology and Management* 259: 1376-1384.
- Cappelli, M., 2000. *Selvicoltura Generale*. Edizioni Agricole della Calderini Srl, Bologna.
- Castagneri, D., Garbarono, M., Berretti, R., Motta, R., 2010. Site and stand effects on coarse woody debris in montane mixed forests of Eastern Italian Alps. *Forest Ecology and Management* 260: 1592-1598.
- Cocciufa, C., Cerretti, P., Matteucci, G., Carpaneto, G.M. (2011). Basic concepts and research activities at Italian forest sites of the Long Term Ecological Research Network. *iForest - Journal of Biogeosciences and Forestry* 4: 233-241.
- Colwell, R.K., 2006. EstimateS: statistical estimation of species richness and shared species from samples. Version 8. [on line 28 August 2011] URL: <http://viceroy.eeb.uconn.edu/estimates>.
- Corona, P., D'Orazio, P., La Monaca, A., Portoghesi, I., 2005. L'indice Winkelmass per l'inventariazione a fini assestamentali della diversità strutturale di soprassuoli forestali. *Forest@* 2: 225-232.
- Dollin, P.E., Majka, C.G., Duinker, P.N., 2008. Saproxylic beetle (Coleoptera) communities and forest management practices in coniferous stands in southwestern Nova Scotia, Canada. *ZooKeys* 2: 291-336.
- European Environment Agency, 2007. European forest types. Categories and types for sustainable forest management reporting and policy. Technical Report no. 9/2006. Second Edition. Copenhagen.
- Ferretti, M., Petriccione, B., Fabbio, G., Bussotti, F., 2006. Aspects of biodiversity in selected forests ecosystems in Italy: status and changes over the period 1996 – 2003. Third Report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura*, 30(2): 112 pp.
- Franc, N., Götmark, F., Økland, B., Nordén, B., Paltto, H., 2007. Factors and scales potentially important for saproxylic beetles in temperate mixed oak forest. *Biological Conservation* 135: 86-98.

- Franc, N., Götmark, F., 2008. Openness in management: hands-off vs partial cutting in conservation forests and the response of beetles. *Biological Conservation* 141: 2310-2321.
- Gibb, H., Hjältén, J., Ball, J.P., Atlegrim, O., Pettersson, R.B., Hilszczański, J., Johansson, T., Danell, K., 2006. Effects of landscape composition and substrate availability on saproxylic beetles in boreal forests: a study using experimental logs for monitoring assemblages. *Ecography* 29: 191 – 204.
- Grove, S.J., 2002. Saproxylic insect ecology and the sustainable management of forests. *Annual Review of Ecology and Systematics* 33: 1-23.
- Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(2): 9 pp.
- Hedgren, O., Weslien, J., 2007. Detecting rare species with random or subjective sampling: a case study of red-listed saproxylic beetles in boreal Sweden. *Conservation Biology* 22: 212-215.
- Hjältén, J., Johansson, T., Alinvi, O., Danell, K., Ball, J.P., Pettersson, R., Gibb, H., Hilszczański, J., 2007. The importance of substrate type, shading and scorching for the attractiveness of deadwood to saproxylic beetles. *Basic Applied Ecology* 8: 364-376.
- Jabin, M., Mohr, D., Kappes, H., Topp, W., 2004. Influence of deadwood on density of soil macro-arthropods in a managed oak-beech forest. *Forest Ecology and Management* 194: 61-69.
- Johansson, T., Gibb, H., Hjältén, J., Pettersson, R.B., Hilszczański, J., Alinvi, O., Ball, J.P., Danell, K. 2007. The effects of substrate manipulations and forest management on predators of saproxylic beetles. *Forest Ecology and Management* 242: 518 – 529.
- Jonsell, M., 2008. Saproxylic beetles species in logging residues: which are they and what residues do they use? *Norwegian Journal of Entomology* 55: 109-122.
- Jonsell, M., Hansson, J., 2007. Comparison of methods for sampling saproxylic beetles in fine wood. *Entomologica Fennica* 18: 232-241.
- Kappes, H., Topp, W., 2004. Emergence of Coleoptera from deadwood in a managed broadleaved forest in central Europe. *Biodiversity Conservation* 13:1905-1924.
- Lassauce, A., Paillet, Y., Jactel, H., Bouget, C., 2011. Deadwood as a surrogate for forest biodiversity: meta-analysis of correlations between

- deadwood volume and species richness of saproxylic organisms. *Ecological Indicators* 11: 1027-1039.
- Mason, F., Cerretti, P., Nardi, G., Whitmore, D., Birtele, D., Hardersen, S., Gatti, E., 2006. Aspects of biological diversity in the CONECOFOR plots.IV. The InvertebrateBiodiv pilot project. in: Ferretti, M., Petriccione, B., Fabbio, G., Bussotti, F., (Eds). Aspects of biodiversity in selected forest ecosystems in Italy: status and changes over the period 1996-2003. Third report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura*, 30 (2): 51-70.
- Mason, F., Nardi, G., Tisato, M., 2003. Proceedings of the International Symposium “Dead Wood: a key to biodiversity”. Mantova, 29 – 31 May 2003. *Sherwood* 95 (2), pp 99.
- McCune, B., Grace, J.B., 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR.
- McCune B, Mefford M.J., 2006. PC-ORD: multivariate analysis of ecological data. Version 5.19. MjM Software Design, Gleneden Beach, OR.
- Neumann, M., Starlinger, F., 2001. The significance of different indices for stand structure and diversity in forests. *Forest Ecology and Management* 45: 91-106.
- Økland, B., 1996. A comparison of three methods of trapping saproxylic beetles. *European Journal of Entomology* 93:195-209.
- Owen, J.A., 1989. An emergence trap for insects breeding in deadwood. *British Journal of Entomology and Natural History* Vol. 2, 1989.
- Owen, J.A., 1992. Experience with an emergence trap for insects breeding in deadwood. *British Journal of Entomology and Natural History* Vol. 5, 1992.
- Ranius, T., Jansson, N., 2002. A comparison of three methods to survey saproxylic beetles in hollow oaks. *Biodiversity Conservation* 11: 1759-1771.
- Russo, D., Cistrone, L., Garonna, A.P., 2011. Habitat selection by the highly endangered long-horned beetle *Rosalia alpine* in Southern Europe: a multiple spatial scale assessment. *Journal of Insect Conservation* 15: 685-693.
- Similä, M., Kouki, J., Martikainen, P., 2003. Saproxylic beetles in managed and seminatural Scots pine forests: quality of deadwood matters. *Forest Ecology and Management* 174: 365-381.

- Sirami, C., Jay-Robert, P., Brustel, H., Valladares, L., Le Guilloux, S., Martin, J.L., 2008. Saproxylic beetles assemblages of old holm-oak trees in the Mediterranean region: role of a keystone structure in a changing heterogeneous landscape. *Revue d'Ecologie (la Terre et la Vie)* 63: 93-106.
- Speight, M.C.D., 1989. Saproxylic invertebrates and their conservation. Strasbourg, Council of Europe, 82 pp.
- Travaglini, D., Mason, F., Lopresti, M., Lombardi, F., Marchetti, M., Chirici, G., Corona, P., 2006. Aspects of biological diversity in the CONECOFOR plots.V. Deadwood surveying experiments in alpine and Mediterranean forest ecosystems. in: Ferretti, M., Petriccione, B., Fabbio, G., Bussotti, F., (Eds). *Aspects of biodiversity in selected forest ecosystems in Italy: status and changes over the period 1996-2003. Third report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. Annali Istituto Sperimentale per la Selvicoltura*, 30 (2): 51-70.
- Vodka, S., Konvicka, M., Cizek, L., 2008. Habitat preferences of oak-feeding xylophagous beetles in a temperate woodland: implications for forest history and management. *Journal of Insect Conservation*. DOI 10.1007/s10841-008-9202-1.
- Wikars, L., Sahlin, E., Ranius, T., 2005. A comparison of three methods to estimate species richness of saproxylic beetles (Coleoptera) in logs and high stumps of Norway spruce. *The Canadian Entomologist* 137:304-32.

Appendix A

Table A.1

Environmental variables* for the investigation of correlations between beetle assemblages and habitat and micro-habitat characteristics.

PLOT SCALE			TRAPSCALE		
<i>Variable</i>	<i>Unit</i>	<i>Explanation</i>	<i>Variable</i>	<i>Unit</i>	<i>Explanation</i>
Elevation	m asl	Elevation of the plot	Species	-	Tree species
Exposure	N,E,S,W	Main exposure of the plot	Type	-	Type of deadwood (log or branch)
Slope	(°)	Inclination of the plot	Decay class	Class 1-5	Decay stage of deadwood
Precipitation	mm/year	Mean daily precipitation	Volume	m ³	Volume enclosed in Et
Temperature	°C year	Mean daily temperature	Ants	1/0	Presence/absence of ants inside the Et
Stand age	years	Age of the stand	Canopy closure	%	% of sky covered by canopies above Et
Basal area	m ²	Stand basal area in the plot	Sun exposure	1/0	Exposure of Et during at least one sampling
Basal area increment	m ²	Increment of stand basal area 2005-09	Basal area	m ²	Basal area around each Et (three trees)
Deadwood	m ³ /ha	Amount of deadwood in the plot			

*Variables at plot scale were recorded in the frame of CONECOFOR Programme of National Forest Service and delivered by Enrico Pompei (National Forest Service) and by Gianfranco Fabbio, Giada Bertini (CRA - Centre for Silviculture), Luca Salvati, Tiziano Sorgi (CRA-Research Centre for the Study of Relationship between Plant and Soil), Giuseppe Scarascia Mugnozza, Giorgio Matteucci (CNR-Institute of Agro-environmental and Forest Biology), Franco Mason, Emma Minari (National Centre for the Study and Conservation of Forest Biodiversity) from the ICP Forests database.

Table A.2

List of beetle families and species collected by interception traps and emergence traps at Italian ICP Forests plots: Selva Piana (AB1), Rosello (AB2), Monte Rufeno (LZ1), Monte Circeo (LZ2).

Family	Species	No. of individuals				
		AB1	AB2	LZ1	LZ2	Tot
Anthribidae	<i>Choragus sheppardii</i> (Kirby, 1819)	0	0	0	2	2
	<i>Rhaphitropis oxyacanthae</i> (C. Brisout, 1863)	0	0	2	0	2
Biphylidae	<i>Diplacaelus fagi</i> (Guérin-Mèneville, 1844)	7	59	18	71	155
Buprestidae	<i>Agrius convexicollis mancinii</i> (Obenberger, 1927)	0	0	0	1	1
Carabidae	<i>Colathus montivagus</i> (Dejean, 1831)	0	2	0	0	2
Cerambycidae	<i>Aithopalus syriacus</i> (Reitter, 1895)	0	0	0	3	3
	<i>Callimus abdominalis</i> (Olivier, 1795)	0	0	0	2	2
	<i>Leptura aurilenta</i> (Fabricius, 1792)	0	0	1	0	1
	<i>Mesosa nebulosa</i> (Fabricius, 1781)	0	0	1	0	1
	<i>Nathrus brevipennis</i> (Mulsant, 1839)	0	0	0	1	1
	<i>Obrium brunneum</i> (Fabricius, 1792)	0	1	0	0	1
	<i>Prionus coriarius</i> (Linnaeus, 1758)	0	0	1	0	1
	<i>Pseudosphagesthes cinerea</i> (Castelnau & Gory, 1846)	0	0	1	1	2
	<i>Xylotrechus arvicola</i> (Olivier, 1795)	0	0	1	0	1
	<i>Xylotrechus arvicola</i> (Olivier, 1795)	0	0	1	0	1
Cetonidae	<i>Cetonia aurata</i> (Linnaeus, 1761)	0	0	1	0	1
Cidae	<i>Cis (Orthocis) pygmaeus</i> (Marsham, 1802)	0	0	2	0	2
	<i>Cis quadridentatus</i> (Perris, 2011)	0	0	0	3	3
	<i>Cis</i> sp.	0	0	0	2	2
	<i>Ennearthron polari</i> (Lohse, 1966)	0	0	1	0	1
Cryptophagidae	<i>Cryptophagus cylindrellus</i> (Johnson, 2007)	0	7	0	0	7
	<i>Cryptophagus dentatus</i> (Herbst, 1793)	1	1	0	0	2
	<i>Cryptophagus punctipennis</i> (C. Brisout de Barneville, 1863)	0	1	0	0	1
	<i>Cryptophagus reflexus</i> (Fey, 1889)	0	2	0	0	2
<i>Cryptophagus scanicus</i> (Linnaeus, 1758)	6	4	0	0	10	
Cucujidae	<i>Pediacus dermestoides</i> (Fabricius, 1792)	0	2	0	0	2
Curculionidae	<i>Acalles camelus</i> (Fabricius, 1792)	0	1	0	0	1
	<i>Acalles lemuriensis</i> (Stuben, 2003)	1	1	0	0	2
	<i>Acallocretes minutus</i> (Mulsant, 1869)	0	0	0	1	1
	<i>Aparopion chevrolati</i> (Jacquelin du Val, 1858)	0	5	0	0	5
	<i>Brachyomus hirtus</i> (Boheman, 1844)	0	1	0	0	1
	<i>Echinodera aspromontensis</i> (Stöck, 2008)	0	2	0	0	2
	<i>Echinodera hypocrita</i> (Boheman 1837)	0	0	0	0	0
	<i>Gasterocercus depressirostris</i> (Fabricius, 1792)	0	0	4	0	4
	<i>Mecinus pascuorum</i> (Gyllenhal, 1813)	0	1	0	0	1
	<i>Orchestes fagi</i> (Linnaeus, 1758)	5	0	0	0	5
<i>Orchestes piceus</i> (Fabricius, 1781)	0	1	14	0	15	
<i>Orchestes quercus</i> (Linnaeus, 1758)	0	0	23	0	23	
<i>Otiorynchus duinensis</i> (Germar, 1824)	0	2	0	0	2	

Table A.2
(continued)

	<i>Oliothynchus pseudoligneoides</i> (Magnano, 1996)	0	4	0	0	4
	<i>Phyllobius argentatus</i> (Linnaeus, 1758)	1	0	0	0	1
	<i>Phyllobius eurasicus</i> (Desbrochers, 1873)	0	2	4	0	6
	<i>Phyllobius oblongus</i> (Linnaeus, 1758)	0	2	0	0	2
	<i>Phyllobius romanus</i> (Faust, 1890)	0	1	0	0	1
	<i>Polydrusus corvinus</i> (Linnaeus, 1758)	0	2	1	0	3
	<i>Polydrusus elegantulus</i> (Boheman, 1840)	0	0	0	8	8
	<i>Polydrusus frater</i> (Rottenberg, 1871)	0	0	2	1	3
Dasyceridae	<i>Dasycerus sulcatus</i> (Brongniart, 1800)	0	3	0	0	3
Drilidae	<i>Drilus flavescens</i> (Olivier, 1790)	0	1	0	0	1
Dryophthoridae	<i>Dryophthorus corticalis</i> (Paykull, 1792)	0	2	0	0	2
Elateridae	<i>Agriotes infuscatus</i> (Desbrochers des Loges, 1870)	0	1	0	0	1
	<i>Ampedus pomorum</i> (Herbst, 1784)	0	1	0	0	1
	<i>Ampedus quercicola</i> (Bjysson, 1887)	0	0	1	0	1
	<i>Athous (Haploathous) subfuscus</i> (O.F. Muller, 1764)	3	0	0	0	3
	<i>Athous s. str. limoniiformis</i> (Candèze, 1865)	0	0	2	0	2
	<i>Athous s. str. vittatus</i> (Gmelin, 1790)	1	1	0	0	2
	<i>Dalopius marginatus</i> (Linnaeus, 1758)	2	0	0	0	2
	<i>Harminius spiniger</i> (Candèze, 1860)	0	0	0	2	2
	<i>Nothodes parvulus</i> (Panzer, 1793)	0	5	2	0	7
Geotrupidae	<i>Anoplotrupes stercorosus</i> (Scriba, 1751)	0	0	6	0	6
Laemophloeidae	<i>Cryptoiestes duplicatus</i> (Walli, 1839)	0	0	7	2	9
	<i>Cryptoiestes ferrugineus</i> (Stephens, 1831)	0	0	3	1	4
	<i>Laemophloeus nigricollis</i> (Lucas, 1845)	0	0	1	1	2
	<i>Piaconotus testaceus</i> (Fabricius, 1787)	0	1	1	0	2
Languridae	<i>Cryptophilus integer</i> (Loer, 1841)	0	0	0	1	1
Latridiidae	<i>Cartodere (Aridius) nodifer</i> (Westwood, 1839)	8	1	0	1	10
	<i>Corticaria similata</i> (Gyllenhal, 1827)	1	0	0	0	1
	<i>Corticaria gibbosa</i> (Herbst, 1793)	0	2	0	0	2
	<i>Dienerelia clathrata</i> (Mannerheim, 1844)	0	1	8	0	9
	<i>Dienerelia vincenti</i> (Johnson, 2007)	1	5	1	0	7
	<i>Enicmus aviceps</i> (Janson, 1962)	1	0	0	0	1
	<i>Enicmus brevicornis</i> (Mannerheim, 1844)	22	2	19	0	43
	<i>Enicmus rugosus</i> (Herbst, 1793)	0	12	5	3	20
	<i>Enicmus testaceus</i> (Stephens, 1830)	7	1	0	0	8
	<i>Enicmus vincenti</i> (Johnson, 2007)	2	0	0	0	2
	<i>Latridius consimilis</i> (Mannerheim, 1844)	3	0	0	0	3
	<i>Latridius minutus</i> (Linnaeus, 1767)	5	0	0	0	5
Melandryidae	<i>Abdera biflexuosa</i> (Curtis, 1829)	0	0	1	0	1
	<i>Abdera quadrifasciata</i> (Curtis, 1829)	0	0	19	1	20

Table A.2
(continued)

	<i>Phlaeotrypa vaudoueri</i> (Mulsant, 1855)	0	0	8	1	9
	<i>Serropalpus barbatus</i> (Schaller, 1783)	0	11	0	0	11
Melasidae	<i>Hylis simonae</i> (Olexa, 1970)	0	9	0	1	10
	<i>Nematodes filum</i> (Fabricius, 1801)	0	0	0	27	27
Mycetophagidae	<i>Litargus connexus</i> (Geoffroy)	2	14	130	11	166
	<i>Mycetophagus atomarius</i> (F.)	2	0	0	0	2
	<i>Mycetophagus quadripustulatus</i> (Linnaeus, 1761)	1	0	0	0	1
	<i>Typhaea stercorea</i> (Linnaeus, 1758)	0	0	0	4	4
Nitidulidae	<i>Epuraea fuscicollis</i> (Stehens, 1835)	0	0	0	2	2
	<i>Epuraea guttata</i> (Olivier, 1811)	0	1	0	0	1
	<i>Epuraea marseuli</i> (Reitter, 1762)	0	1	0	0	1
	<i>Epuraea ocularis</i> (Fairmaire, 1849)	0	0	0	16	16
	<i>Epuraea siliacea</i> (Herbst, 1784)	18	0	0	0	18
	<i>Epuraea unicolor</i> (Olivier, 1790)	0	1	0	0	1
	<i>Omasita discoides</i> (Fabricius, 1775)	0	1	0	0	1
Omalisidae	<i>Omalisus</i> sp.	1	1	0	0	2
Platypodiidae	<i>Piatypus cylindrus</i> (Fabricius, 1792)	0	0	0	1	1
Ptiliidae	<i>Acrotichis intermedia</i> (Gyllenhal, 1845)	0	1	0	0	1
	<i>Pteryx suturalis</i> (Voer, 1838)	0	1	0	0	1
	<i>Ptilolum fuscum</i> (Erichson, 1815)	1	0	0	0	1
	<i>Ptilolum schwarzi</i> (Erichson, 1845)	4	0	0	0	4
	<i>Pinella aptera</i> (Garin-Mènevillo, 1839)	0	0	1	5	6
	<i>Pinella denticollis</i> (Fairmaire, 1858)	0	0	17	0	17
Ptinidae	<i>Pinus corsicus</i> (Kieserwetter, 1877)	0	2	1	0	3
	<i>Pinus icherum</i> (Marsham, 1802)	0	0	0	2	2
	<i>Pinus sexpunctatus</i> (Panzer, 1789)	0	0	1	1	2
Rhizophagidae	<i>Monotoma longicollis</i> (Gyllenhal, 1827)	0	0	0	1	1
	<i>Rhizophagus fenestralis</i> (Linnaeus, 1758)	1	12	0	0	13
	<i>Rhizophagus parallellocollis</i> (Gyllenhal, 1827)	0	1	0	0	1
Salpingidae	<i>Lissodema denticolle</i> (Gyllenhal, 1813)	0	1	0	4	5
	<i>Salpingus planirostris</i> (Fabricius, 1787)	8	44	11	0	63
	<i>Salpingus ruficollis</i> (Linnaeus, 1761)	1	0	0	0	1
	<i>Vincezelus viridipennis</i> (Panzer, 1794)	0	1	0	0	1
Scaphidiidae	<i>Scaphidium quadrimaculatum</i> (Olivier, 1790)	0	1	0	0	1
Scarabaeidae	<i>Onthophagus vericicornis</i> (Leicharting, 1781)	0	0	4	0	4
	<i>Pachypus candidae</i> (Petagna, 1785)	0	0	0	1	1
	<i>Sisyphus schaefferi</i> (Linnaeus, 1758)	0	0	2	0	2
Scolytidae	<i>Crypturgus mediterraneus</i> (Eichhoff, 1871)	0	0	0	1	1
	<i>Dryocoetes villosus minor</i> (Eggers, 1903)	0	0	1	0	1
	<i>Enoporicus fagi</i> (Fabricius, 1798)	3	2	0	0	5

Table A.2
(continued)

	<i>Hylesinus taranio</i> (Dankhofer in Bernhard, 1788)	0	0	0	121	121
	<i>Scolytus rugulosus</i> (P.W.J. Müller, 1818)	0	0	2	0	2
	<i>Trypodendron domesticum</i> (Linnaeus, 1758)	18	0	0	0	18
	<i>Xyleborinus saxeseni</i> (Ratzeburg, 1857)	7	0	5	7	19
	<i>Xyleborus dispar</i> (Fabricius, 1792)	58	108	3	9	178
	<i>Xyleborus monographus</i> (Fabricius, 1792)	0	1	14	24	39
Scraptiidae	<i>Anaspis (Anaspis) lurida</i> (Stephens, 1852)	0	0	5	31	36
	<i>Anaspis (Nassipa) flavo</i> (Linnaeus, 1758)	0	1	3	0	4
	<i>Scraptia ferruginea</i> (Kiesenwetter, 1862)	0	0	8	0	8
Silvanidae	<i>Silvanus bicoloratus</i> (Fabricius, 1792)	0	1	0	0	1
Tenebrionidae	<i>Enoplopus dentipes</i> (Rossi, 1790)	0	4	11	0	15
Trogositidae	<i>Nomosoma elongatum</i> (Linnaeus, 1761)	2	0	2	0	4
Zopheridae	<i>Corticus cellis</i> (Germar, 1824)	0	11	0	1	12
	<i>Coxelus pictus</i> (Stern, 1807)	1	2	0	0	3
	<i>Synchita undata</i> (Gérard-Ménèville, 1844)	0	3	2	0	4
	TDT	200	388	405	379	1372

ARTICLE 3

Old-growth forest and young stand: a comparison of beetle assemblages at HJ Andrews Experimental Forest

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Abstract

1. Beetle assemblages and phenology were compared between an old-growth and a young stand at HJ Andrews Experimental Forest (OR, U.S.A.).
2. Two trap types were used to collect insects: suspended traps (crossed panel interception traps) and traps set on the ground (log traps). Log traps were tested for the first time at Andrews Forest.
3. Abundance was higher in the old-growth forest while family richness was comparable (only slightly higher in the young stand).
4. Reasons for the unexpectedly high family richness found in the young stand may be: I) the huge amount of deadwood present in the young stand; II) the availability of beetle colonization sources inside and outside the young forest; III) the coverage of logs by mosses, lichens and ground vegetation, decreasing the availability of suitable microhabitat for saproxylic insects, in the old-growth stand compared to the young forest.

5. Assemblages of beetles differed consistently between the two sites and among traps. The seasonal increase in air temperature resulted in more abundant captures especially at the ancient forest site.

Key words: coleopterans, Douglas fir, deadwood, diversity, log trap, phenology

Introduction

Beetles represent a group of great biodiversity and play a primary role in forest environments, where several species are classified as saproxylic, *i.e.* depending on deadwood in one or more stages of their life cycle or on other saproxylic organisms, like fungi (Speight 1989, Mason *et al.* 2003, Alexander 2008). Deadwood is a distinctive feature of ancient, old-growth forests (Harmon *et al.* 1986, Franklin *et al.* 1991, Harmon 1992, Shaw *et al.* 2004, Castagneri *et al.* 2010), where the overall amount of deadwood is usually very high and large-diameter, heavily decayed logs are often present on the forest floor, together with stumps, snags and hard deadwood pieces.

This heterogeneous array of decomposed wood substrates, though in a variable arrangement, is available continuously through time (Siitonen & Saaristo 2000). Thus the functional significance of saproxylic beetles is enhanced: they can act as relevant plugs in food webs and complex ecosystem processes, occupy several potential niches, behave as decomposers, fungivores, predators or use deadwood as hibernation sites (Kappes & Topp 2004, Bouget *et al.* 2005). Moreover, saproxylic insects are often ecological specialists, being able to survive only in a restricted range of nutrients, moisture and temperature. For this reason, they show a strict relationship with deadwood microhabitat conditions and this specificity makes them suitable model *taxa* for habitat dependent community studies (Lassau *et al.* 2005). In the western Palearctic region, small patches of ancient forests remain in several countries, *e.g.* Finland (Martikainen *et al.* 2000), northern Italy (Motta 2002, Piovesan *et al.* 2005), Czech Republic (Svoboda & Panska 2008) and Poland (Zielonka 2006). In the United States, western Oregon and Washington have larger remnants of ancient forests, more than 250 years old (Franklin *et al.* 1981). Beetle diversity has been investigated in old-growth and managed or regenerated forests, in northern Europe (*e.g.* Martikainen *et al.* 2000, Sippola *et al.* 2002) and in the Nearctic (*e.g.* Heyborne *et al.* 2003, Paquin & Dupérré 2001, Dollin *et al.* 2008). Several of these entomological studies focused on

beetle families and species potentially dangerous as pest agents (Schowalter 1988, Zhong & Schowalter 1989, Schowalter 1991, Lattin 1998, Powers *et al.* 1999) or on log decomposition and matter and energy turnover mediated by heterotrophic activity of insects (Harmon *et al.* 1986, Carpenter *et al.* 1988, Harmon 1992). In the present research, we compared abundance and composition of beetle assemblages in an old-growth and a young stand at HJ Andrews Experimental Forest (Oregon , U.S.A.). One preliminary aim of the study was to test log traps in a coniferous temperate pluvial forest and eventually give suggestions on any adjustment needed to make the traps work efficiently under rainy meteorological conditions. Then we addressed particularly the following questions:

- 1) Do assemblages of beetle families differ significantly between old-growth and young forest, reflecting habitat complexity?
- 2) What is the phenology of beetle flying activity in the old-growth and young forest?

Materials and Methods

Study area

The Horace Justin Andrews (HJ Andrews) Experimental Forest (44°13'59'' N, 122°10'34'' W) is located in the Western Cascade Range of Oregon State (U.S.A.), in the 6400 ha drainage basin of Lookout Creek, a tributary of Blue River and McKenzie River, 80 Km east of the city of Eugene. Elevation ranges from 420 m to 1615 m and climate is characterized by wet, mild winters and dry, cool summers. The Andrews Forest landscape is representative of conifer mountainous environment of the United States Pacific Northwest (Franklin *et al.* 1981) and is classified into two major zones: 1) the western hemlock (*Tsuga heterophylla*) zone (300-1050 m elevation) and 2) the Pacific silver fir (*Abies amabilis*) zone (1050-1550 m elevation). Douglas-fir (*Pseudotsuga menziesii*) and western redcedar (*Thuja plicata*) are major components of both zones (Franklin *et al.* 1981; Harmon 1992). Common understory tree species include *Taxus brevifolia* and *Acer macrophyllum*. Old-growth stands, with dominant trees over 400 years old, still cover about 40 % of the Andrews Forest total area. Mature stands (100 to 140 years old) originating from wildfire cover about 20% of the total surface. From 85 to 190 tons of logs per hectare and 29% of the forest floor occupied by deadwood have been reported (Franklin *et al.* 1981).

Watershed 1 and Watershed 2 experimental plots

A large component of research at Andrews is based in small experimental basins (watersheds). The present research was performed inside forest plots at Watershed 1 and Watershed 2 (WS1 and WS2). WS1 was subject to artificial disturbances between 1962 and 1971 (harvesting and prescribed burn on the whole forest surface). WS 2 was left untreated as a “control site”. Subsequent aerial seeding and planting, later performed in WS1, were not very effective. As a consequence, today the two watersheds are respectively characterized by a young naturally regenerated forest and an unchanged old-growth forest, from 120 to 400 years old (Halpern & Spies 1995; Jones & Grant 1996; Jones 2000). In WS1, large Douglas fir stumps and logs are still present on the forest floor, as a result of past logging activity. Living trees are mostly represented by western hemlock and broadleaves (*i.e. Acer, Alnus*), favored by light availability after cutting.

Trapping devices

Two types of interception traps for beetles were used. The crossed panel interception trap (CPT in this paper) was made as described in Mason *et al.* 2006, with transparent panels measuring 20 x 55 cm. This type of trap is ideal to collect flying forest insects (Økland 1996, Ranius & Jansson 2002, Mason *et al.* 2006). The log interception trap (Lt in this paper) consisted of a transparent glass sheet, 40 x 36 cm, inserted vertically into two cracks cut on both sides of a plastic tray (35 x 20 x 13 cm). Each log trap was set perpendicularly next to a log on the forest floor and was able to stand alone steadily on the ground with no support. Lts were aimed at intercepting saproxylic beetles inhabiting or emerging from decaying wood. Lts have been widely tested in boreal forests of northern Europe (Alinvi *et al.* 2007, Franc *et al.* 2007), but have never been used at Andrews Forest. In both types of trap, the preservative liquid was glicole-based anti-freeze with a trace of soap (to prevent evaporation and to lower the liquid surface tension). Beetles were identified to family, using Arnett & Thomas 2001.

Sampling scheme and timetable

Within each watershed, beetles were trapped inside the circular 30 m ray plot (Phenology Core, PC), where phenology surveys on ground vegetation, birds and insects are conducted, as part of the HJ Andrews research program. In both watersheds, experimental plots (PC1 and PC2) are located at low elevation (about 500 m a.s.l.), a few hundred meters from

the main HJ Andrews road (road1506). Four traps were located randomly in each PC, one CPT and three Lt, eight traps in total. Random points were extracted by means of Excel Software as pairs of angle (degrees from the North) and distance (m from the plot centre). Each CPT was hung on a tree branch, about 1.5 m from the ground. Lts were set on the forest floor, next to logs found within 10 m circles centered at random points. For canopy closure assessment, digital photographs were taken above each Lt, on top (1 photograph per trap) and towards North, East, South and West directions at 45° and 90° angles from the Zenith (8 photographs per trap). Photographs were measured with ImageJ software, separately for 45° and 90° angles, to account for sunlight coming vertically and obliquely. Mean daily air temperatures during the sampling period were downloaded from HJ Andrews Forest web site (<http://andrewsforest.oregonstate.edu/>). Traps were set in the field on 28th of May 2011, georeferenced and kept active until 27th of June 2011 (last sampling and removal of traps). Traps were checked twice a week, to prevent damage, overflow by rain water, dilution or evaporation of preservative and samples were collected weekly (8 sampling sessions).

Statistical analysis

In order to search for significant differences in the ability of the two trap types to collect beetles, a χ^2 test was run, comparing captures performed by the same type of trap in both WS1 and WS2 and by the two types of trap within each WS. Because the number of CPTs and Lts were different, captures were standardized before running the test. For the aim of the present study, individual-based family accumulation curves were calculated with EcoSim (Gotelli & Entsminger 2001), to assess the richness of beetle assemblages. The diversity profile module (performed with PAST, Hammer *et al.* 2001) was used in this study to compare family diversity in WS1 and WS2. To look at dissimilarities among sites and traps, Bray-Curtis index based on $\log(x+1)$ of abundances was calculated using the software PC-ORD (McCune & Mefford 2006). The cluster analysis (PC-ORD) was based on a Bray-Curtis dissimilarity matrix, using a $\log(x+1)$ transformation of count data to balance contribution given by lower abundance beetle families. To investigate phenology of beetle flying activity, the seriation algorithm in PAST was used. The seriation criterion adopted for the present study was the chronological sequence of sampling. Spearman rank correlation run with PAST was used to search for correlations between

number of individuals captured per family and air temperature. Temperature values considered in the correlation matrix were calculated averaging daily records during intervals between each of the eight sampling date.

Results

Efficiency of trapping techniques

Three thousand six hundred and ninety-four beetles of 42 families were collected over the two-month period of sampling: 501 individuals (19 families) in CPt, 3193 individuals (40 families) in Lt (Appendix A). Twenty-three families were only sampled by Lt, while 2 families (Cleridae, 5 individuals and Throscidae, 1 individual) were only collected by CPt. No family was encountered in both traps of only one watershed. The CPt located in WS2 gave a “zero sample” twice (on 16th and 30th of May, second and third sampling respectively). Six families (Staphylinidae, Scolytidae, Ptiliidae, Leiodidae, Nitidulidae, Cerambycidae) contributed the greatest proportion of total abundance (88%). Staphylinidae and Scolytidae were the most abundant families (28% and 26%, respectively). Within the most abundant families, a comparison of pooled captures in CPt and in Lt by χ^2 test showed that: 1) the number of beetles collected by the two different trap types within each WS was significantly different ; 2) the number of specimen trapped by Lts compared between WS1 and WS2 was significantly different; 3) the difference in the number of beetles trapped by CPts compared between WS1 and WS2 was not significant (Tab. 1).

Differences in beetle assemblages in WS1 and WS2

Total abundance was higher in WS2 (2169 individuals vs 1525 in WS1) while family richness was comparable (37 families in WS1 vs 35 in WS2). Individual-based accumulation curves of beetles trapped in each watershed exhibited different shapes depending on the trap type: while Lt curves showed an initial rapid increase followed by an asymptotic phase, CPt curves kept a steep pattern. In this respect, for both types of traps, curves showed a higher richness of beetle families in WS1, more clearly visible for CPt samples (Fig. 1). A comparison of the diversity of beetle family assemblages in the two watersheds was run using the diversity profile module. Profiles were consistent for higher diversity in WS1 than in WS2, for both types of traps (Fig. 2). Looking at dissimilarities among sites, seven families were only caught in WS1, while 5 families were exclusively collected in WS2 (Bray-Curtis Index = 0.2112). On the other hand,

considering different traps within the same watershed, a low overlap of captures was recognized (CPT_{ws1} vs Lt_{ws1} Bray-Curtis Index = 0.4549; CPT_{ws2} vs Lt_{ws2} Bray-Curtis Index = 0.6081). The Cluster analysis provided a synthesis of how samples captured by the two types of trap were different in the two considered watersheds; three well separated clusters were formed: one including CPTs from both watersheds, one comprising Lts from WS1 and one including Lts from WS2. Although no complete overlap was found, dissimilarities among log traps within watersheds, were greater for WS2 than WS1 (Fig. 3).

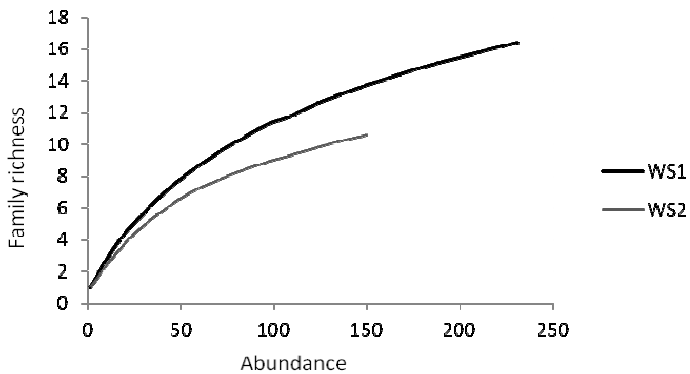
Phenology

A Gantt chart (phenogram) of presence/absence of beetle families along the eight sampling sessions (Fig. 4) showed a chronological shift, which was confirmed as a significant phenology pattern by the Seriation module in PAST (Z score=-2.05, $p=0.04$). Trends in air temperature during the sampling period were similar in WS1 and WS2 (not shown). Bursts in abundance of several families (Nitidulidae, Leiodidae, Ptiliidae, Scolytidae, Staphylinidae) occurred between 30th of May and 10th of June (fourth and fifth sampling respectively) and in late June (27th, last sampling), corresponding to seasonal increase in air temperature. Spearman rank correlation between abundance of beetle families and mean daily air temperature was highly significant only for Scolytidae in WS1 (Spearman's $r_s = 0.826$, $df = 7$, $P = 0.017$) and for Nitidulidae, Leiodidae, Ptiliidae, Scolytidae and Staphylinidae in WS2 (Nitidulidae $r_s = 0.94$, $df = 7$, $P = 0.002$; Leiodidae $r_s = 0.88$, $df = 7$, $P = 0.007$; Ptiliidae $r_s = 0.85$, $df = 7$, $P = 0.007$; Scolytidae $r_s = 0.90$, $df = 7$, $P = 0.005$; Staphylinidae $r_s = 0.80$, $df = 7$, $P = 0.02$).

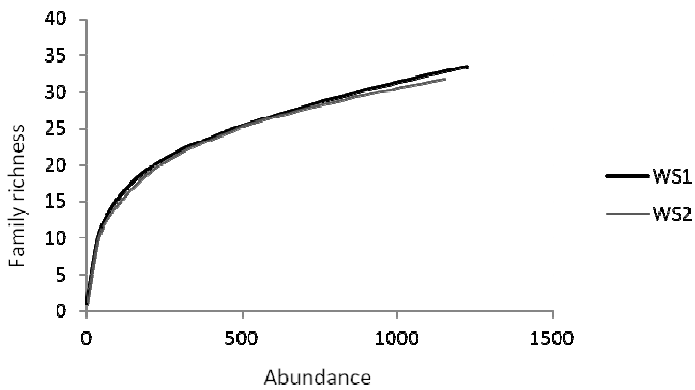
Table 1

Comparison by Chi-square test of captures performed by CPt and Lt between and within WS.

Beetle captures	d.f.	χ^2 test	P	
CPt_1/CPt_2	5	1.26	0.93	<i>n.s.</i>
Lt_1/Lt_2	5	39.61	0	*
CPt_1/Lt_1	5	66.58	0	*
CPt_2/Lt_2	5	107.44	0	*



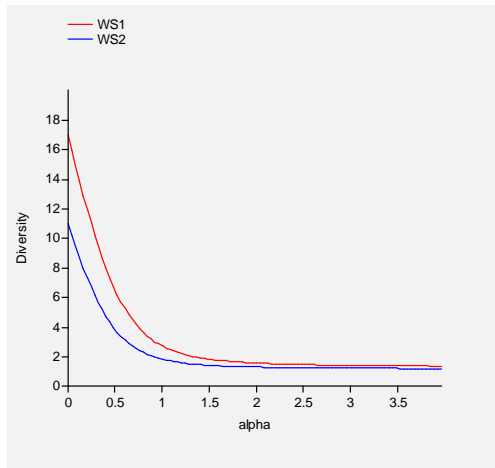
a



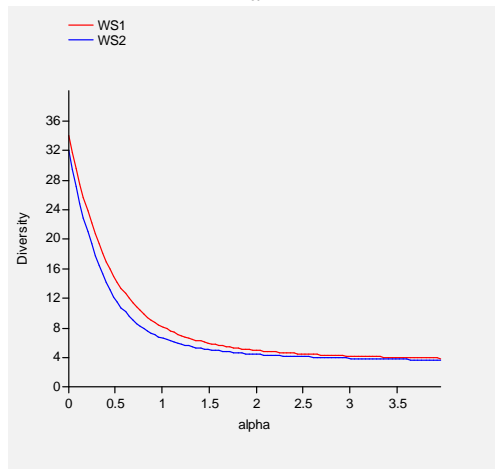
b

Figure 1

Individual based accumulation curves of beetle families trapped in WS1 and WS2 by Cpt (a) and Lt (b).



a



b

Figure 2
Diversity profiles for CPT (a) and Lt (b) at WS1 and WS2.

	Cpt 1	Lt 1.1	Lt 2.1	Lt 3.1	Cpt 2	Lt 1.2	Lt 2.2	Lt 3.2
Cpt 1	0	0.4333	0.4224	0.472	0.3014	0.5613	0.5238	0.5683
Lt 1.1	0.4333	0	0.2385	0.2653	0.5403	0.2958	0.2895	0.3048
Lt 2.1	0.4224	0.2385	0	0.1992	0.5322	0.2996	0.2767	0.2756
Lt 3.1	0.472	0.2653	0.1992	0	0.5762	0.2783	0.3412	0.2604
Cpt 2	0.3014	0.5403	0.5322	0.5762	0	0.5723	0.5974	0.6058
Lt 1.2	0.5613	0.2958	0.2996	0.2783	0.5723	0	0.2794	0.209
Lt 2.2	0.5238	0.2895	0.2767	0.3412	0.5974	0.2794	0	0.2642
Lt 3.2	0.5683	0.3048	0.2756	0.2604	0.6058	0.209	0.2642	0

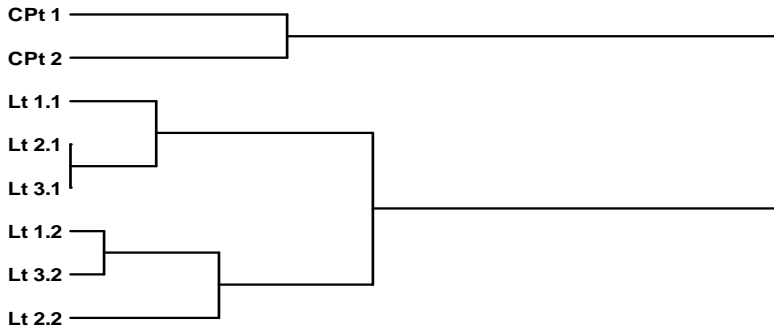


Figure 3

Cluster analysis using Bray-Curtis dissimilarity and flexible beta (-0.25) group linkage samples in the two watersheds. Data were log (x+1) transformed before dissimilarities were calculated.

Lt 1.1, Lt 2.1, Lt 3.1 = Log traps at WS1; Lt 1.2, Lt 2.2, Lt 3.2 = L traps at WS2. Cpt 1 and Cpt 2 = Crossed panel traps at WS1 and WS2.

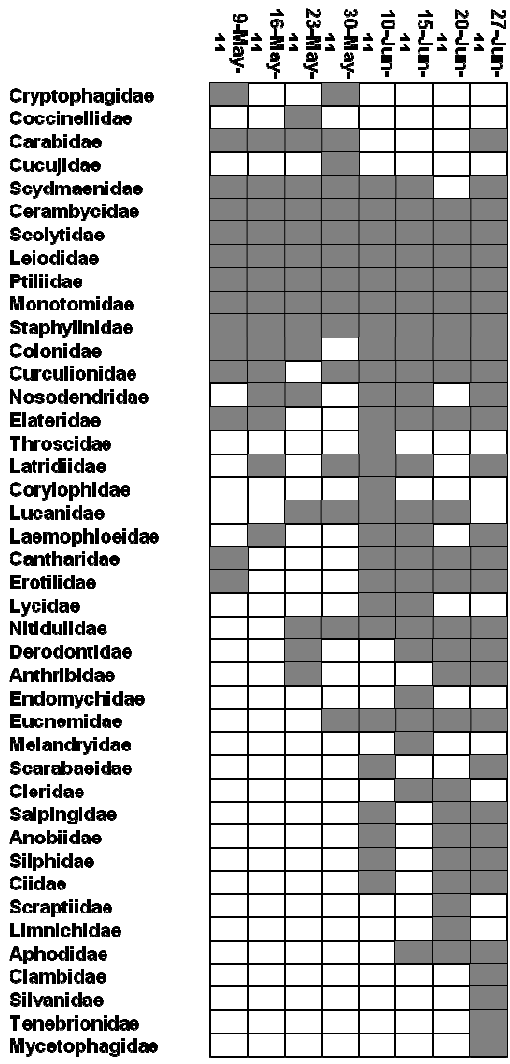


Figure 4
Phenogram of presence/absence of families captured along the eight sampling sessions.

Discussion

Free hanging interception traps with crossed panels usually exhibit a very high efficiency in terms of species richness and abundances. Surprisingly, CPTs used for the present research achieved lower values compared to Lts for both numbers of families and individuals. However, size and position (*e.g.* height) of hanging traps may markedly affect trap efficiency. For this reason, further investigations on trap performances in standardized conditions are recommended. Construction and field application of Lts were easy and cheap. Precipitation events, which are usual during spring in temperate forests of U.S. Pacific Northwest, can severely dilute preservative liquids inside trays of Lts. To avoid degradation of biological samples, one possible solution could be constructing a cover of transparent plastic fabric, suspended and stretched horizontally over the trap and the corresponding deadwood piece. This would prevent rain from filling the vessel, while keeping functionality of the trap with regards to beetles walking on logs (*e.g.* Carabidae). Complex forest environments show a diversity gradient from the forest floor to the canopy (Stiremann *et al.* in press, Stork & Grimbacher 2006, Wermelinger *et al.* 2007). CPTs and Lts at Andrews Forest were probably able to detect this pattern: being located on the forest floor, Lts collected a considerable fraction of the beetle community inhabiting the bottom layer of the forest environment, including saproxylic beetles (Cerambycidae, Scolytidae), beetles feeding on fungi (Leiodidae, Nitidulidae) or flowering herbs (Cerambycidae, Lucanidae, Nitidulidae), predators moving on logs (Carabidae), dwelling in humid leaf litter (Ptiliidae) or related to complex and diverse food webs (Staphylinidae). The development of diversity analysis at family level may be criticized, being a coarser taxonomic level than is often used to carry on ecological research (genus or species level). Nevertheless, it has to be stressed that, beside a huge number of singletons (one specimen per family), a surprisingly low number of morphospecies was trapped within more abundant families: only *Platyceroides* sp. among Lucanidae, only *Colon* sp. among Colonidae, only *Agathidium* sp. and *Catops* sp. among Leiodidae, only two genera among Cerambycidae, with 90% of the family represented by *Evodinus* sp.

Even at family level, several metrics investigating diversity and composition of beetle assemblages were capable of highlighting differences between watersheds. Results indicated higher number of individuals in the old-growth forest plot and a slightly higher number of families, and

presumably species richness, in the young stand plot. Similarly, Heyborne *et al.* (2003) found a higher species richness of ground dwelling beetles in clear cuts, but higher abundances in old-growth sites at Andrews Forest. Several reasons may explain this peculiar pattern. Canopy closure and structure is a relevant process included in forest regeneration (Parker *et al.* 2004, Swanson *et al.* 2011). A comparison of canopy closure percentages above Lt didn't result in marked differences between WS1 and WS2 (values not shown in the present paper), probably because western hemlock trees at WS1 had time enough, after past treatments, to regenerate, grow up and close the canopy layer at the expenses of the shade-intolerant Douglas fir. Nevertheless, understory conditions are deeply divergent between WS1 and WS2. In regenerating forest environments, one of the most important feature is the array of resources (light, solar radiation, nutrients) that become available in large amounts. These newly available resources switch on complex ecosystem processes, create diverse food webs and more balanced trophic pathways that may support a wider and more diverse community of survivor, generalist and ruderal coleopterans (Swanson *et al.* 2011).

Developmental processes are enriched by colonization events from within and outside the treated area (Swanson *et al.* 2011). Though structural complexity and patchiness is much higher in mature stands than in young ones, spatial heterogeneity can be found in young forests as well. Large stumps and logs derived from past logging activities are still present on the forest floor at WS1 and may act as colonization sources of saproxylic insects, while providing long term sources of energy and nutrients. Moreover, dispersing individuals from the old-growth forest, which continuously surround WS1, may be abundant in the latter watershed.

On the other hand, under shady and high moisture conditions, decomposition processes tend to be dominant in old-growth stands. The rate at which logs are covered, sink into the soil and/or are overgrown by ground vegetation, mosses and fungi, is likely to change quality of deadwood and remove this resource for deadwood-inhabiting organisms (Dynesius *et al.* 2010). All these factors together may be considered to explain the slight divergence of biodiversity values observed between WS1 and WS2. Diversity in WS2 may not be lower, but more difficult to detect, being expressed at smaller scale and at microhabitat level, as suggested by the 2-D space occupied by Lt of WS2 in the NMDS graph. The possibility of sorting beetle samples sequentially following each sampling session was relevant to

empirically see shifts and appearances of beetle families, variation in abundances and thus infer phenology of flying activities and emergence of insects. However, looking at results of the phenological analysis, most abundant families showed a consistent sensitivity to the seasonal increase in air temperature, as revealed by the increased number of individuals, mainly at WS2.

Stable microclimate conditions seem to characterize both old-growth and young forests at the study area, as showed by similar air temperature trends (not shown in the present paper). This is probably due to a comparable canopy closure, as measured by our estimation based on digital pictures. Therefore, insect phenology seasonal differences may be explained by intrinsic lifecycle traits. In conclusion, results obtained with the present research are consistent with knowledge achieved so far on the ecology of old-growth forests and their inhabiting beetle fauna and highlight the need of deeper investigations at smaller scale. The use of log traps in this type of environment is recommended, because they captured a higher number of beetle specimens and families than crossed panel traps.

Further investigations based on a wider sampling efforts, finer taxonomic level and beetle microhabitat preferences are advised.

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References

Alexander K.N.A. (2008). Tree biology and saproxylic coleopterans: issues of definitions and conservation language. *Rev. Écol. (Terre Vie)* 63: 1-5.

- Alinvi O., Ball J.P., Danell K., Hjältén J., Pettersson R.B. (2007). Sampling saproxylic beetle assemblages in deadwood logs: comparing window and elector traps to traditional bark sieving and a refinement. *Journal of Insect Conservation* 11:99-112.
- Arnett R.H., Thomas M.C., Skelley P.E., Frank H.J. (2001). American beetles. Polyphaga Scarabaeoidea through Curculionoidea. CRC Press LLC.
- Bouget C., Brustel H., Nageleisen L.M. (2005). Nomenclature des groupes écologiques d'insectes liés au bois: synthèse et mise au point sémantique. *Comptes Rendus Biologies* 328: 936 – 948.
- Carpenter S.E., Harmon M.E., Ingham E.R., Kelsey R.G., Lattin J.D., Schowalter TD (1988). Early patterns of heterotroph activity in conifer logs. *Proceedings of the Entomological Society of Edimburgh* 94B: 33-43.
- Castagneri D., Garbarino M., Berretti R., Motta R. (2010). Site and stand effects on coarse woody debris in montane mixed forests of Eastern Italian Alps. *Forest Ecology and Management* 260: 1592-1598.
- Dollin P.E., Majka C.G., Duinker P.N. (2008). Saproxylic beetle (Coleoptera) communities and forest management practices in coniferous stands in southwestern Nova Scotia, Canada. *ZooKeys* 2: 291-336.
- Dynesius M., Gibb H., Hjältén J. (2010). Surface covering of downed logs: drivers of a neglected process in dead wood ecology. *PLoS ONE* 5(10): e13237.
- Franc N., Götmark F., Økland B., Nordén B., Paltto H. (2007). Factors and scales potentially important for saproxylic beetles in temperate mixed oak forest. *Biological Conservation* 135: 86-98.
- Franklin J.F., Spies T.A. (1991). Ecological definitions of old-growth Douglas-fir stands. *Wildlife and vegetation of unmanaged Douglas-fir forests*. In: Ruggiero LF et al. (eds). US Department of Agriculture Forest Service, Portland (Oregon): 61-69.
- Franklin J.F., Cromack K., Denison W., McKee A., Maser C., Sedell J., Swanson F., Juday G. (1981). Ecological characteristics of old-growth Douglas fir forests. Gen. Tech. Rep. PNW – 118. Portland, OR (U.S.). Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, 48 pp.

- Gotelli N.J., Entsminger G.L. (2001). Ecosim: null model software for ecology. Acquired Intelligence Inc. & Kesity Bear. <http://homepages.together.net/~gentsmin/ecosim.htm>
- Halpern C.B., Spies T.A. (1995). Plant species diversity in natural and managed forests of the Pacific Northwest 1,2. *Ecological Applications* 5: 913-934.
- Hammer Ø., Harper D.A.T., Ryan P.D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4: 9 pp.
- Harmon M.E. (1992). Long-term Experiments on log decomposition at the H.J. Andrews Experimental Forest. Gen. Tech. Rep. PNW-GTR-280. Portland, OR (U.S.). Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, 36 pp.
- Harmon M.E., Franklin J.F., Swanson F.J., Sollins P., Gregory S.V., Lattin J.D., Anderson N.H., Cline S.P., Aumen N.G., Sedell J.R., Lienkaemper G.W., Cromack K., Cummins K.W. (1986). Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15: 133-302.
- Heyborne W.H., Miller J.C., Parsons G.L. (2003). Ground dwelling beetles and forest vegetation change over a 17-year-period, in western Oregon, USA. *Forest Ecology and Management* 179: 123-134.
- Kappes H., Topp W. (2004). Emergence of Coleoptera from deadwood in a managed broadleaved forest in central Europe. *Biodiversity and Conservation* 13:1905-1924.
- Jones J.A. (2000). Hydrological processes and peak discharge response to forest removal, regrowth and roads in ten small experimental basins, western Cascades, Oregon. *Water Resources Research* 36: 2621-2642.
- Jones J.A., Grant G.E. (1996). Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. *Water Resources Research* 32: 959-974.
- Lassau S.A., Hochuli D.F., Cassis G., Reid C.A.M. (2005). Effects of habitat complexity on forest beetle diversity: do functional groups respond consistently? *Diversity and Distributions* 11:73-82.
- Lattin J.D. (1998). A review of the insects and mites found on *Taxus* spp. with emphasis on Western North America. United States Department of Agriculture. Forest Service. Pacific Northwest Research Station. General Technical Report. PNW-GTR-433, November 1998.

- Martikainen P., Siitonen J., Punttila P., Kaila L., Rauh J. (2000). Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. *Biological Conservation* 94: 199-209.
- Mason F., Nardi G., Tisato M. (2003). Proceedings of the International Symposium "Dead Wood: a key to biodiversity". Mantova, 29 – 31 May 2003. Sherwood 95, pp 99.
- Mason F., Cerretti P., Nardi G., Whitmore D., Birtele D., Hardersen S., Gatti E. (2006). Aspects of biological diversity in the CONECOFOR plots. IV. The Invertebrate Biodiv pilot project. In: Ferretti M *et al.* (Eds). Aspects of biodiversity in selected forest ecosystems in Italy: status and changes over the period 1996-2003. Third report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura, Special Issue, Vol.30 – Supplemento 2 – 2006:112 pp.*
- Motta R. (2002). Old-growth forests and silviculture in the Italian Alps: the case-study of the strict reserve of Paneveggio (TN). *Plant Biosystems* 136: 223-232.
- Økland B. (1996). A comparison of three methods of trapping saproxylic beetles. *European Journal of Entomology* 93:195-209.
- Paquin P., Dupérré N. (2001). Beetles of the boreal forest: a faunistic survey carried out in western Québec. *Proceedings of the Entomological Society of Ontario* 132:57-98.
- Parker G.G., Harmon M.E., Lefsky M.A., Chen J., Van Pelt R., Weiss S.B., Thomas S.C., Winner W.E., Shaw D.C., Franklin J.F. (2004). Three-dimensional structure of an old-growth *Pseudotsuga-tsuga* canopy and its implications for radiation balance, microclimate and gas exchange. *Ecosystems* 7:440-453.
- Piovesan G., Di Filippo A., Alessandrini A., Biondi F., Schirone B. (2005). Structure, dynamics and dendroecology of an old-growth *Fagus* forest in the Apennines. *Journal of Vegetation Science*, 16: 13-28.
- Powers J.S., Sollins P., Harmon M.E., Jones J.A. (1999). Plant-pest interactions in time and space: a Douglas-fir bark beetle outbreak as a case study. *Landscape Ecology* 14: 105-120.
- Ranius T., Jansson N. (2002). A comparison of three methods to survey saproxylic beetles in hollow oaks. *Biodiversity and Conservation* 11: 1759-1771.

- Schowalter T.D. (1988). Primary productivity as affected by insects herbivores. Proceedings of the Third International Rangeland Congress. New-Delhi, 7-11 November, 1988.
- Schowalter T.D. (1991). Role of insects and diseases in sustaining forests. Proceedings of the Society of American National Conservation 262-267.
- Shaw D.C., Franklin J.F., Bible K., Klopatek J., Freeman E., Greene S., Parker G.G. (2004). Ecological setting of the Wind River old-growth forest. *Ecosystems* 7:427-439.
- Siitonen J., Saaristo L. (2000). Habitat requirements and conservation of *Pytho kolwensis*, a beetle species of old-growth boreal forests. *Biological Conservation* 94: 211-220.
- Sippola A.L., Siitonen J., Punttila P. (2002). Beetle diversity in timberline forests: a comparison between old-growth and regeneration areas in Finnish Lapland. *Ann. Zool. Fennici* 39: 69-86.
- Speight M.C.D. (1989). Saproxylic invertebrates and their conservation. Strasbourg, Council of Europe, 82 pp.
- Stireman III J.O., Cerretti P., Whitmore D., Hardersen S., Gianelle D. (2011). Composition and stratification of a tachinid (Diptera: Tachinidae) parasitoid community in a European temperate plain forest. *Insect Conservation and Diversity* [early online]. - doi: 10.1111/j.1752-4598.2011.
- Stork N.E., Grimbacher P.S. (2006). Beetle assemblages from an Australian tropical rainforest show that the canopy and the ground strata contribute equally to biodiversity. *Proceedings of the Royal Society B.* 273:1969-1975.
- Svoboda M., Panska V. (2008). Structure of a Central-European mountain spruce old-growth forest with respect to historical development. *Forest Ecology and Management* 255:2177-2188
- Swanson M.E., Franklin J.F., Beschta R.L., Crisafulli C.M., DellaSala D.A., Hutto R.L., Lindenmayer D.B., Swanson F.J. (2011). The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and Environments* 9: 117-125.
- Wermelinger B., Flückiger P.F., Obrist M.K., Duelli P. (2007). Horizontal and vertical distribution of saproxylic beetles (Col. Buprestidae, Cerambycidae, Scolytinae) across sections of forest edges. *Journal of Applied Entomology.* 131: 104-114.

- Zhong H., Schowalter T.D. (1989). Conifer bole utilization by wood-boring beetles in western Oregon. *Journal of Forest Research* 19:943-947.
- Zielonka T. (2006). Quantity and decay stages of coarse woody debris in old-growth subalpine spruce forests of the western Carpathians, Poland. *Canadian Journal of Forest Research* 36:2614-2622.

Appendix A

Families and individuals collected in WS1 and WS2 at HJ Andrews Experimental Forest by crossed panel interception traps (CPT) and log traps (Lt). In **bold**: families captured only in one WS; in *italics*: families captured only in one type of trap.

	WS1		WS2		tot
	CPT	Lt	CPT	Lt	
Anobiidae	0	2	1	0	3
Anthuridae	3	1	1	0	5
<i>Aphodidae</i>	0	2	0	1	3
Cantharidae	1	33	0	7	41
<i>Carabidae</i>	0	1	0	9	10
Cerambycidae	8	40	7	29	84
<i>Ciidae</i>	0	1	0	6	7
Clauidae	0	1	0	0	1
Cleridae	0	0	5	0	5
Coccinellidae	0	1	0	0	1
<i>Colletidae</i>	0	8	0	5	13
Corylophidae	0	0	0	1	1
<i>Cryptolepididae</i>	0	1	0	1	2
Cucujidae	0	1	0	0	1
<i>Cucujinidae</i>	0	7	0	7	14
Dermodontidae	3	7	0	7	17
Elateridae	0	7	1	25	33
Endomychidae	0	0	0	2	2
<i>Erotylidae</i>	0	6	0	7	13
<i>Brenthidae</i>	0	33	0	5	38
Laemophloeidae	2	23	0	1	26
Latridiidae	1	8	0	3	12
<i>Leiodidae</i>	0	120	0	176	296
Limonchidae	0	0	0	1	1
<i>Laccanidae</i>	0	5	0	4	9
Lycidae	1	1	0	1	3
Melanthridae	0	0	0	1	1
Monotomidae	6	19	1	2	28
Mycetophagidae	0	1	0	0	1
Nitidulidae	5	23	4	91	123
<i>Nosodendridae</i>	0	1	0	17	17
Ptiliidae	1	111	2	621	735
Salpingidae	2	1	2	0	5
<i>Scarabaeidae</i>	0	1	0	1	2
Scolytidae	200	337	221	209	967
Scaphitidae	0	1	0	0	1
Scydamenidae	4	18	2	14	38
<i>Silphidae</i>	0	2	0	27	29
Sitramidae	0	1	0	0	1
Staphylinidae	10	428	5	605	1048
Tenebrionidae	1	0	0	1	2
Throscidae	1	0	0	0	1
Tot	249	1276	252	1917	3694

CONCLUSIONS

Forest types, shape and size of plots usually differ markedly among LTER sites. Moreover, location, slope and exposition may affect environmental variables at sites: ICP Forests plots were set in the field within a huge homogeneous area of 10 ha but, in highly diverse forests like Rosello, sources of ecological discontinuities are present just over the borders of the fenced plot (trails, large logs or snags, rare tree species like *Abies alba* etc.); on the other hand, monitoring plots in Watershed 1 and Watershed 2 at Andrews forest are located at the bottom of the catchment and this is undoubtedly significant in shaping their ecology, compared with similar monitoring areas located at higher elevations, at the top of the basins.

All the mentioned aspects make comparisons of data among plots very difficult. Despite these potential weaknesses, significant differences concerning assemblages of saproxylic beetles were detected among plots. In fact, results from Italian field tests showed differences in the diversity of beetle faunas, in the actual and estimated number of total beetle species and of saproxylic species, in composition of assemblages. We found that, at the considered study areas, saproxylic beetles are poliphagous species, they are not linked to species composition of tree communities but they exhibit preferences for structural traits of forests. We also found that, among habitat factors, deadwood amount, decay class of deadwood, slope and stand age have the strongest effects on the composition of assemblages of beetles.

Results returned by the Andrews forest were consistent with the main findings, in spite of the coarser taxonomic identification, based on family level.

The plot scale was able to reveal ecological patterns. This also means that saproxylic beetles represented a suitable target animal group to be investigated at small (plot) scale. These outcomes are relevant with regards to Italian LTER forest sites, firstly because we demonstrated that studies at forest plots can shift from vegetation monitoring to investigations on animal community ecology; secondly, because we could integrate data on occurrence and abundance of forest dwelling beetles with existing sets of long term data measuring habitat factors.

From a methodological point of view, the introduction of this new research into the long term data series would comply with recommendations arising from LTER literature: 1) the research would start from past field

experiences already tested (Mason et al. 2006); 2) it would be possible to maintain the existing sampling design and data sampling scheme (Sykes & Lane 1996, Parr et al. 2002, Lindenmayer & Likens 2009); 3) existing data on habitat variables could be used to answer research questions referred to the target study group (Sykes & Lane 1996, Parr et al. 2002, Lindenmayer & Likens 2009).

A few suggestions to improve the consistency of researches on saproxylic beetles at LTER forest plots are the following:

- field sampling based on random points: in fact, locations of ICP Forests plots were not originally selected on a systematic grid, but subjectively chosen. Traps located randomly may overcome statistical constraints deriving from non-random locations of study sites;

- a higher number of space and time replicates of plot sampling: multiple 50 x 50m sampling plots within homogeneous areas and multiple year sampling may facilitate the ongoing process of plot upscaling.

Ultimately, results of the present project demonstrated that studies on lists of species may be suitable to long term ecological research, unlike what other authors stated in the past (Seastedt & Briggs 1991).

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References

The following list includes all the references quoted in Introduction, Conclusions and in the three articles produced by the candidate and comprised in the present work.

- Alexander K.N.A. (2008). Tree biology and saproxylic coleopteran: issues of definitions and conservation language. *Rev. Écol. (Terre Vie)* 63:1-5.
- Alinvi O., Ball J.P., Danell K., Hjältén J., Pettersson R.B. (2007). Sampling saproxylic beetle assemblages in deadwood logs: comparing window and elector traps to traditional bark sieving and a refinement. *Journal of Insect Conservation* 11:99-112.
- Arnett R.H., Thomas M.C., Skelley P.E., Frank H.J. (2001). American beetles. Polyphaga Scarabaeoidea through Curculionoidea. CRC Press, LLC.
- Bakker J.P., Olf H., Willems J.H., Zobel M. (1996). Why do we need permanent plots in the study of long-term vegetation dynamics? *Journal of Vegetation Science* 7: 147-156.
- Beard G.R., Scott W.A., Adamson J.K. (1999). The value of consistent methodology in long-term environmental monitoring. *Environmental Monitoring and Assessment* 54:239-258.
- Bertini G., Fabbio G., Pichi M., Piovosi M. (2007). MainTrees (Mapping Indexing Trees' Structure): un software per la descrizione della diversità specifica e strutturale di soprassuoli forestali. VI SISEF National Congress, 25-27 September 2007, Arezzo (Italy).
- Bertini G., Fabbio G., Piovosi M., Calderisi M. (2010). Densità di biomassa e necromassa legnosa in cedui di cerro in evoluzione naturale in Toscana. *Forest@ 7*: 88-103.
- Bouget C., Brustel H., Nageleisen L.M. (2005). Nomenclature des groupes écologiques d'insectes liés au bois: synthèse et mise au point sémantique. *Comptes Rendus Biologies* 328: 936 – 948.
- Bouget C., Brustel H., Brin A., Noblecourt T. (2008). Sampling saproxylic beetles with window flight traps: methodological insight. *Rev. Écol. (Terre Vie)* 63:13-23.
- Bouget C., Brin A., Brustel H. (2011). Exploring the “last biotic frontier”: are temperate forest canopies special for saproxylic beetles? *Forest Ecology and Management* 261: 211-220.

- Bredemeier M., Dennis P., Sauberer N., Petriccione B., Torok K., Cocciufa C., Morabito G., Pugnetti A. (2007). Biodiversity assessment and change. The challenge of appropriate methods. In: Hester R.E., Harrison R.M. (Eds). *Issues in Environmental Science and Technology. Biodiversity under threat*. Royal Society of Chemistry (Cambridge, UK), 5:217-240.
- Brin A., Bouget C., Brustel H., Jactel H. (2011). Diameter of downed woody debris does matter for saproxylic beetle assemblages in temperate oak and pine forests. *Journal of Insect Conservation* 15:653-669.
- Buse J., Levanony T., Timm A., Dayan T., Assmann T. (2010). Saproxylic beetle assemblages in the Mediterranean region: impact of forest management on richness and structure. *Forest Ecology and Management* 259: 1376-1384.
- Campanaro A., Hardersen S., Mason F. (2007). Piano di gestione della Riserva Naturale Statale e Sito Natura 2000 "Bosco della Fontana". Quaderni Conservazione Habitat, 4. Cierre Edizioni, Verona, 221pp.
- Cappelli M. (2000). *Selvicoltura Generale*. Edizioni Agricole della Calderini Srl, Bologna.
- Carpenter S.E., Harmon M.E., Ingham E.R., Kelsey R.G., Lattin J.D., Schowalter T.D. (1988). Early patterns of heterotroph activity in conifer logs. *Proceedings of the Entomological Society of Edinburgh* 94B: 33-43.
- Castagneri D., Garbarono M., Berretti R., Motta R. (2010). Site and stand effects on coarse woody debris in montane mixed forests of Eastern Italian Alps. *Forest Ecology and Management* 260: 1592-1598.
- Cavalli R., Mason F. (2003). Techniques for re-establishment of deadwood for saproxylic fauna conservation. LIFE Nature project NAT/IT/99/6245 "Bosco della Fontana" (Mantova, Italy). Scientific report, 2. Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale di Verona – Bosco della Fontana. Gianluigi Arcari Editore, Mantova, 112 pp.
- Cerretti P., Hardersen S., Mason F., Nardi G., Tisato M., Zapparoli M. (2004a). Ricerche naturalistiche a Bosco della Fontana. Quaderni Conservazione Habitat, 3. Cierre Edizioni, Verona, 96 pp.
- Cerretti P., Whitmore S., Mason F., Vigna Taglianti A. (2004b). Survey in the spatio-temporal distribution of Tachinid flies using Malaise traps (Diptera, Tachinidae). In: Cerretti P., Hardersen S., Mason F., Nardi G., Tisato M., Zapparoli M. (Eds) "Invertebrati di una foresta della Pianura

- Padana. Bosco della Fontana. Secondo contributo". *Conservazione Habitat Invertebrati* 3, Cierre Ed., Verona, Italy, pp. 229-256.
- Clutton-Brock T., Sheldon B.C. (2010). Individuals and populations: the role of long-term, individual-based studies of animals in ecology and evolutionary biology. *Trends in Ecology and Evolution* 25: 562-573.
- Cocciufa, C., Cerretti, P., Matteucci, G., Carpaneto, G.M. (2011). Basic concepts and research activities at Italian forest sites of the Long Term Ecological Research Network. *iForest - Journal of Biogeosciences and Forestry* 4: 233-241.
- Colwell R.K. (2006). EstimateS: statistical estimation of species richness and shared species from samples. Version 8. [on line 28 August 2011] URL: <http://viceroy.eeb.uconn.edu/estimates>.
- Corona P., D'Orazio P., La monaca A., Portoghesi I. (2005). L'indice Winkelmass per l'inventariazione a fini assestamentali della diversità strutturale di soprassuoli forestali. *Forest@* 2: 225-232.
- Cutini A., Matteucci G., Scarascia Mugnozza G. (1998). Estimation of leaf area index with the Li-Cor LAI 2000 in deciduous forests. *Forest Ecology and Management* 105 (1-3): 55-65. - doi: 10.1016/S0378-1127(97)00269-7.
- Dollin P.E., Majka C.G., Duinker P.N. (2008). Saproxyllic beetle (Coleoptera) communities and forest management practices in coniferous stands in southwestern Nova Scotia, Canada. *ZooKeys* 2: 291-336.
- Dynesius M., Gibb H, Hjältén J. (2010). Surface covering of downed logs: drivers of a neglected process in dead wood ecology. *PLoS ONE* 5(10): e13237.
- European Environment Agency (2007). European forest types. Categories and types for sustainable forest management reporting and policy. Technical Report no. 9/2006. Second Edition. Copenhagen.
- Ferretti M., Petriccione B., Fabbio G., Bussotti F. (2006). Aspects of biodiversity in selected forests ecosystems in Italy: status and changes over the period 1996 – 2003. Third Report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura, Special Issue* 30 (2):112 pp.
- Ferretti M. (2010). Harmonizing forest inventories and forest condition monitoring – the rise or the fall of harmonized forest condition monitoring in Europe? *iForest - Journal of Biogeosciences and Forestry* 3:1-4.

- Franc N., Götmark F., Økland B., Nordén B., Paltto H. (2007). Factors and scales potentially important for saproxylic beetles in temperate mixed oak forests. *Biological Conservation* 135:86-98.
- Franc N., Götmark F. (2008). Openness in management: hands-off vs partial cutting in conservation forests and the response of beetles. *Biological Conservation* 141: 2310-2321.
- Franklin J.F., Cromack K., Denison W., McKee A., Maser C., Sedell J., Swanson F., Juday G. (1981). Ecological characteristics of old-growth Douglas fir forests. United States Department of Agriculture. Forest Service. Pacific Northwest Research Station. General Technical Report PNW – 118.
- Franklin J.F., Spies T.A. (1991). Ecological definitions of old-growth Douglas-fir stands. Wildlife and vegetation of unmanaged Douglas-fir forests. In: Ruggiero LF et al. (eds). US Department of Agriculture Forest Service, Portland (Oregon): 61-69.
- Gianelle D., Travaglini D., Mason F., Minari E., Chirici G., Chemini C. (2007). Canopy analysis and dynamics of a floodplain forest. Scientific report 3, Centro nazionale per lo studio e la conservazione della biodiversità forestale di Verona - Bosco della Fontana, Cierre Ed., Verona, Italy, pp. 96.
- Gibb H., Hjäältén J., Ball J.P., Atlegrim O., Pettersson R.B., Hilszczański J., Johansson T., Danell K. (2006). Effects of landscape composition and substrate availability on saproxylic beetles in boreal forests: a study using experimental logs for monitoring assemblages. *Ecography* 29: 191 – 204.
- Grove S.J. (2002). Saproxylic insect ecology and the sustainable management of forests. *Annual Review of Ecology and Systematics* 33:1-23.
- Gotelli N.J., Entsminger G.L. (2001). Ecosim: null model software for ecology. Acquired Intelligence Inc. & Kesity Bear. <http://homepages.together.net/~gentsmin/ecosim.htm>.
- Halpern C.B., Spies T.A. (1995). Plant species diversity in natural and managed forests of the Pacific Northwest 1,2. *Ecological Applications* 5: 913-934.
- Hammer Ø., Harper D.A.T., Ryan P.D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4: 9 pp.
- Harmon M.E., Franklin J.F., Swanson F.J., Sollins P., Gregory S.V., Lattin J.D., Anderson N.H., Cline S.P., Aumen N.G., Sedell J.R.,

- Lienkaemper G.W., Cromack K., Cummins K.W. (1986). Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15: 133-302.
- Harmon M.E. (1992). Long-term Experiments on log decomposition at the H.J. Andrews Experimental Forest. United States Department of Agriculture. Forest Service. Pacific Northwest Research Station. General Technical Report PNW-GTR-280.
- Hedgren O., Weslien J. (2007). Detecting rare species with random or subjective sampling: a case study of red-listed saproxylic beetles in boreal Sweden. *Conservation Biology* 22: 212-215.
- Heyborne W.H., Miller J.C., Parsons G.L. (2003). Ground dwelling beetles and forest vegetation change over a 17-year-period, in western Oregon, USA. *Forest Ecology and Management* 179: 123-134.
- Hjältén J., Johansson T., Alinvi O., Danell K., Ball J.P., Pettersson R., Gibb H., Hilszczański J. (2007). The importance of substrate type, shading and scorching for the attractiveness of deadwood to saproxylics beetles. *Basic Applied Ecology* 8: 364-376.
- Hobbie J.E., Carpenter S.R., Grimm N.B., Gosz J.R., Seastedt T.R. (2003). The US Long Term Ecological Research Program. *BioScience* 53: 21-32.
- Jabin M., Mohr D., Kappes H., Topp W. (2004). Influence of deadwood on density of soil macro-arthropods in a managed oak-beech forest. *Forest Ecology and Management* 194: 61-69.
- Johansson T., Gibb H., Hjältén J., Pettersson R.B., Hilszczański J., Alinvi O., Ball J.P., Danell K. (2007). The effects of substrate manipulations and forest management on predators of saproxylic beetles. *Forest Ecology and Management* 242: 518 – 529.
- Jones J.A. (2000). Hydrological processes and peak discharge response to forest removal, regrowth and roads in ten small experimental basins, western Cascades, Oregon. *Water Resources Research* 36: 2621-2642.
- Jones J.A., Grant G.E. (1996). Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. *Water Resources Research* 32: 959-974.
- Jonsell M. (2008). Saproxylic beetles species in logging residues: which are they and what residues do they use? *Norwegian Journal of Entomology* 55: 109-122.
- Jonsell M., Hansson J. (2007). Comparison of methods for sampling saproxylic beetles in fine wood. *Entomologica Fennica* 18: 232-241.

- Kappes H., Topp W. (2004). Emergence of Coleoptera from deadwood in a managed broadleaved forest in central Europe. *Biodiversity and Conservation* 13:1905-1924.
- Kaufmann H., Anderson M. (2006). ILTER Strategic Plan. Environment & Enterprise Strategies, LLC, U.S.A.
- Koop H. (1989). Forest dynamics, SILVI-STAR: a comprehensive monitoring system. Springer, Berlin, Heidelberg, New York, pp. 229.
- Lassau S.A., Hochuli D.F., Cassis G., Reid C.A.M. (2005). Effects of habitat complexity on forest beetle diversity: do functional groups respond consistently? *Diversity and Distributions* 11:73-82.
- Lassauce A., Paillet Y., Jactel H., Bouget C. (2011). Deadwood as a surrogate for forest biodiversity: meta-analysis of correlations between deadwood volume and species richness of saproxylic organisms. *Ecological Indicators*.11: 1027-1039.
- Lattin J.D. (1998). A review of the insects and mites found on *Taxus* spp. with emphasis on Western North America. United States Department of Agriculture. Forest Service. Pacific Northwest Research Station. General Technical Report PNW-GTR-433.
- Legg C.J., Nagy L. (2005). Why most conservation monitoring is, but need not be, a waste of time. *Journal of Environmental Management* 78:194-199.
- Likens G.E. (1989). *Long-Term Studies in Ecology*. Springer-Verlag, New York.
- Lindenmayer D.B., Likens G.E. (2009). Adaptive monitoring: a new paradigm for long term monitoring and research. *Trends in Ecology and Evolution* 24 (9):482-486.
- Lugo A.E., Swanson F.J., González O.R., Adams M.B., Palik B., Thill L.E., Brockway D.G., Kern C., Woodsmith R., Musselman R. (2006). The US Long-term Research at the USDA Forest Service's experimental forests and ranges. *BioScience* 56:39-48.
- Luyssaert S., Reichstein M., Schulze E.D., Janssens I.A., Law B.E., Papale D., Dragoni D., Goulsten M., Granier A., Kutsch W.L., Linder S., Matteucci G., Moors E., Munger J.W., Pilegaard K., Saunders M., Falge E.M. (2009). Towards a consistency crosscheck of eddy covariance flux based and biometric estimates of ecosystem carbon balance. *Global Biogeochemical Cycles* 23: GB3009. - doi: 10.1029/2008GB003377
- Magurran A.E., Baillie S.R., Buckland S.T., Dick J.McP., Elston D.A., Scott E.M., Smith R.I., Somerfield P.J., Watt A.D. (2010). Long-term

- datasets in biodiversity research and monitoring: assessing change in ecological communities through time. *Trends in Ecology and Evolution* 25: 574 – 582.
- Martikainen P., Siitonen J., Punttila P., Kaila L., Rauh J. (2000). Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. *Biological Conservation* 94: 199-209.
- Mason F. (2002). Dinamica di una foresta della pianura Padana. Primo contributo, monitoraggio 1995. Rapporti scientifici 1, Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale di Verona - Bosco della Fontana, Gianluigi Arcari Ed., Mantova, Italy, pp. 208.
- Mason F., Cerretti P., Tagliapietra A., Speight M.C.D., Zapparoli M. (2002). Invertebrati di una foresta della Pianura Padana, Bosco della Fontana, Primo Contributo. Quaderni Conservazione Habitat. Invertebrati 1. Gianluigi Arcari Editore, Mantova, 176 pp.
- Mason F., Nardi G., Tisato M. (2003). Proceedings of the International Symposium “Dead Wood: a key to biodiversity”. Mantova, 29 – 31 May 2003. *Sherwood* 95 (2) 99 pp.
- Mason F., Cerretti P., Nardi G., Whitmore D., Birtele D., Hardersen S., Gatti E. (2006). Aspects of biological diversity in the CONECOFOR plots.IV. The Invertebrate Biodiv pilot project. In: Ferretti M., Petriccione B., Fabbio G., Bussotti F. (Eds). Aspects of biodiversity in selected forest ecosystems in Italy: status and changes over the period 1996-2003. Third report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura*, 30 (2): 51-70.
- McCune, B., Grace, J.B., 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR.
- McCune B, Mefford M.J., 2006. PC-ORD: multivariate analysis of ecological data. Version 5.19. MjM Software Design, Gleneden Beach, OR.
- McDonald-Madden E., Baxter P.W.J., Fuller R.A., Martin T.G., Game E.T., Montambault J., Possingham H.P. (2010). Monitoring does not always count. *Trends in Ecology and Evolution* 25:547-550.
- Mirtl M., Frenzel M., Furman E., Ohl C., Krauze K., Grünbühel C. (2008). LTER Europe criteria and recommendations. LTER Europe Report [on line 15 February 2009] URL: http://www.uibk.ac.at/alpinerraum/meetings/lter/lter_europe_criteria.pdf - 2008-11-12.

- Morecroft M.D., Bealey C.E., Beaumont D.A., Benham S., Brooks D.R., Burt T.P., Critchley C.N.R., Dick J., Littlewood N.A., Monteith D.T., Scott W.A., Smith R.I., Walmsley C. and Watson H. (2009). The UK Environmental Change Network: emerging trends in the composition of plant and animal communities and the physical environment. *Biological Conservation* 12: 2814 – 2832.
- Motta R. (2002). Old-growth forests and silviculture in the Italian Alps: the case-study of the strict reserve of Paneveggio (TN). *Plant Biosystems* 136: 223-232.
- Motta R., Piussi P. (2009). Ricerche ecologiche di lungo periodo (LTER) nella riserva forestale della Valbona (Paneveggio, TN). Atti del Terzo Congresso Nazionale di Selvicoltura. Taormina (ME), 16-19 ottobre 2008. Accademia Italiana di Scienze Forestali, Firenze: 558-562.
- Neumann, M., Starlinger, F., 2001. The significance of different indices for stand structure and diversity in forests. *Forest Ecology and Management* 45: 91-106.
- Økland B., (1996). A comparison of three methods of trapping saproxylic beetles. *European Journal of Entomology* 93:195-209.
- Oldeman RAA (1990). *Forests: elements of silvology*. Springer-Verlag, New York, Berlin, Heidelberg, pp. 624.
- Owen J.A. (1989). An emergence trap for insects breeding in deadwood. *British Journal of Entomology and Natural History* Vol. 2, 1989.
- Owen J.A. (1992). Experience with an emergence trap for insects breeding in deadwood. *British Journal of Entomology and Natural History* Vol. 5, 1992.
- Paillet Y., Bergès L., Hjältén J., Ódor P., Avon C., Bernhardt-Römermann M., Bijlsma R., De Bruyn L., Fuhr M., Grandin U., Kanka R., Lundin L., Luque S., Magura T., Matesanz S., Mészáros I., Sebastià M., Schmidt W., Standovár T., Tóthmérész B., Uotila A., Valladares F., Vellak K., Virtanen R. (2009). Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. *Conservation Biology* 24: 101-112.
- Paquin P., Dupérré N. (2001). Beetles of the boreal forest: a faunistic survey carried out in western Québec. *Proceedings of the Entomological Society of Ontario* 132:57-98.
- Parker G.G., Harmon M.E., Lefsky M.A., Chen J., Van Pelt R., Weiss S.B., Thomas S.C., Winner W.E., Shaw D.C., Franklin J.F. (2004). Three-dimensional structure of an old-growth *Pseudotsuga-tsuga* canopy and

- its implications for radiation balance, microclimate and gas exchange. *Ecosystems* 7:440-453.
- Parr T.W., Ferretti M., Simpson I.C., Forsius M., Kovacs-Lang E. (2002). Towards a long-term integrated monitoring programme in Europe: network design in theory and practice. *Environmental Monitoring and Assessment* 78:253-290.
- Patton M.Q. (2002). *Qualitative research and evaluation methods* (3rd edn.). Thousand oaks, Sage Publications, CA, USA.
- Peters D.P. (2010). Accessible ecology: synthesis of the long, deep and broad. *Trends in Ecology and Evolution* 25:592-601.
- Petriccione B., Pompei E. (2002). The CONECOFOR Programme: general presentation, aims and coordination. In: Mosello R., Petriccione B., Marchetto A. (Eds). *Long Term Ecological Research in Italian forest ecosystems*. *Journal of Limnology* 61: 3-11.
- Petriccione B., Cindolo C., Cocciufa C., Ferlazzo S., Parisi G. (2009a). Un indicatore dello stato della biodiversità delle foreste europee. In: Ciancio O. (Ed) “Atti del Terzo Congresso Nazionale di Selvicoltura”. Taormina (ME-Italy), 16-19 October 2008. *Accademia Italiana di Scienze Forestali*, Firenze, Italy, pp. 240-242.
- Petriccione B., Cindolo C., Cocciufa C., Ferlazzo S., Parisi G. (2009b). Gli effetti dei cambiamenti climatici sugli ecosistemi forestali. In: Ciancio O. (Ed) “Atti del Terzo Congresso Nazionale di Selvicoltura”. Taormina (ME-Italy) 16-19 October 2008. *Accademia Italiana di Scienze Forestali*, Firenze, Italy, pp. 570-574.
- Piovesan G., Di Filippo A., Alessandrini A., Biondi F., Schirone B. (2005). Structure, dynamics and dendroecology of an old-growth *Fagus* forest in the Apennines. *Journal of Vegetation Science* 16: 13-28.
- Powers J.S., Sollins P., Harmon M.E., Jones J.A. (1999). Plant-pest interactions in time and space: a Douglas-fir bark beetle outbreak as a case study. *Landscape Ecology* 14: 105-120.
- Ranius T., Jansson N. (2002). A comparison of three methods to survey saproxylic beetles in hollow oaks. *Biodiversity and Conservation* 11: 1759-1771.
- Risser P.G. (1991). *Long-Term Ecological Research. An International Perspective*. John Wiley & Sons Ltd.
- Russo D., Cistrone L., Garonna A.P. (2011). Habitat selection by the highly endangered long-horned beetle *Rosalia alpine* in Southern Europe: a multiple spatial scale assessment. *Journal of Insect Conservation* 15: 685-693.

- Salvadori C., Ambrosi P. (2005). Ecological evaluation in alpine forest ecosystems by integrated monitoring. *Studi Trentini di Scienze Naturali. Acta Biologica*. Vol. 81, Supplemento 1: 31-40.
- Scarascia Mugnozza G. (1999). *Ecologia strutturale e funzionale di faggete italiane*. Edagricole, Bologna, Italy, pp. 133-183.
- Scarascia Mugnozza G., Bauer G., Persson H., Matteucci G., Masci A. (2000). Tree biomass, growth and nutrient pools. In: Schulze E. (Ed) "Carbon and nitrogen cycling in european forest Ecosystems". *Ecological Studies* 142, Springer Verlag, Heidelberg, Germany, pp 49-62.
- Scartazza A., Mata C., Matteucci G., Yakir D., Moscatello S., Brugnoli E. (2004). Comparisons of $\delta^{13}\text{C}$ of photosynthetic products and ecosystem respiratory CO_2 and their responses to seasonal climate variability. *Oecologia* 140 (2): 340-351.- doi: 10.1007/s00442-004-1588-1.
- Schowalter T.D. (1988). Primary productivity as affected by insects herbivores. *Proceedings of the Third International Rangeland Congress*. New-Delhi, 7-11 November 1988.
- Schowalter T.D., Whitgott J. (2001). Rethinking insects: what should an ecosystem approach look like? *Conservation Biology in Practice* 2: 10-16.
- Seastedt T.R., Briggs J.M. (1991). Long-term Ecological questions and considerations for taking long-term measurements: lessons from the LTER and FIFE programs on Tallgrass Prairie. In Risser P.G. (ed). *Long-Term Ecological Research. An International Perspective*. John Wiley & Sons.
- Shaw D.C., Franklin J.F., Bible K., Klopatek J., Freeman E., Greene S., Parker G.G. (2004). Ecological setting of the Wind River old-growth forest. *Ecosystems* 7:427-439.
- Siitonen J., Saaristo L. (2000). Habitat requirements and conservation of *Pytho kolwensis*, a beetle species of old-growth boreal forests. *Biological Conservation* 94: 211-220.
- Similä M., Kouki J., Martikainen P. (2003). Saproxyllic beetles in managed and seminatural Scots pine forests: quality of deadwood matters. *Forest Ecology and Management* 174: 365-381.
- Sippola A.L., Siitonen J., Punttila P. (2002). Beetle diversity in timberline forests: a comparison between old-growth and regeneration areas in Finnish Lapland. *Ann. Zool. Fennici* 39: 69-86.

- Sirami C., Jay-Robert P., Brustel H., Valladares L., Le Guilloux S., Martin J.L. (2008). Saproxylic beetles assemblages of old holm-oak trees in the Mediterranean region: role of a keystone structure in a changing heterogeneous landscape. *Rev. Ecol. (la Terre et la Vie)* 63: 93-106.
- Speight M.C.D. (1989). Saproxylic invertebrates and their conservation. Strasbourg, Council of Europe, 82 pp.
- Stireman III J.O., Cerretti P., Whitmore D., Hardersen S., Gianelle D. (2011). Composition and stratification of a tachinid (Diptera: Tachinidae) parasitoid community in a European temperate plain forest. *Insect Conservation and Diversity* [early online]. - doi: 10.1111/j.1752-4598.2011.
- Stork N.E., Grimbacher P.S. (2006). Beetle assemblages from an Australian tropical rainforest show that the canopy and the ground strata contribute equally to biodiversity. *Proceedings of the Royal Society* 273:1969-1975.
- Strayer D., Glitzenstein J.S., Jones C.G., Kalasa J., Likens G.E., McDonnell M.J., Parker G.G., Pickett S.T.A. (1986). Long-Term ecological studies: an illustrated account of their design, operation and importance to ecology. Occasional Publication of the Institute of Ecosystem Study, no. 2, Millbrook, N.Y.
- Sutherland W.J. (2006). *Ecological Census Techniques: A Handbook*. Cambridge University Press.
- Svoboda M., Panska V. (2008). Structure of a Central-European mountain spruce old-growth forest with respect to historical development. *Forest Ecology and Management* 255:2177-2188.
- Swanson M.E., Franklin J.F., Beschta R.L., Crisafulli C.M., DellaSala D.A., Hutto R.L., Lindenmayer D.B., Swanson F.J. (2011). The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and Environments* 9: 117-125.
- Sykes J.M., Lane A.M.J. (1996). The United Kingdom Environmental Change Network. Protocol for Standard Measurements at Terrestrial Sites. Natural Environment Research Council, London, The Stationery Office, 219 pp.
- Travaglini D., Mason F., Lopresti M., Lombardi F., Marchetti M., Chirici G., Corona P. (2006). Aspects of biological diversity in the CONECOFOR plots.V. Deadwood surveying experiments in alpine and Mediterranean forest ecosystems. In: Ferretti M., Petriccione B., Fabbio G., Bussotti F. (Eds). *Aspects of biodiversity in selected forest ecosystems in Italy: status and changes over the period 1996-2003*.

- Third report of the Task Force on Integrated and Combined (I&C) evaluation of the CONECOFOR programme. *Annali Istituto Sperimentale per la Selvicoltura*, 30 (2): 51-70.
- Turner M.G., Collins S.L., Lugo A.E., Magnuson J.J., Rupp T.S., Swanson F.J. (2003). Disturbance dynamics and ecological response: the contribution of Long Term Ecological Research. *Bioscience* 53: 46-56.
- Vodka S., Konvicka M., Cizek L. (2008). Habitat preferences of oak-feeding xylophagous beetles in a temperate woodland: implications for forest history and management. *Journal of Insect Conservation* DOI 10.1007/s10841-008-9202-1.
- Vadineanu A., Datcu S., Adamescu M., Cazacu C. (2005). The state of the art for LTER activities in Europe. ALTER-Net WP I3 Report. University of Bucharest, Department of systemic ecology.
- Valentini R., Angelis P., Matteucci G., Monaco R., Dore S., Mugnozza G.E. (1996). Seasonal net carbon dioxide exchange of a beech forest with the atmosphere. *Global Change Biology* 2 (3): 199- 207. - doi: 10.1111/j.1365-2486.1996.tb00072.x.
- Valentini R., Matteucci G., Dolman A.J., Schulze E.D., Rebmann C., Moors E.J., Granier A., Gross P., Jensen N.O., Pilegaard K., Lindroth A., Grelle A., Bernhofer C., Grunwald T., Aubinet M., Ceulemans R., Kowalski A.S., Vesala T., Rannik U., Berbigier P., Loustau D., Gudmundsson J., Thorgeirsson H., Ibrom A., Morgenstern K., Clement R., Moncrieff J., Montagnani L., Minerbi S., Jarvis P.G. (2000). Respiration as the main determinant of carbon balance in European forests. *Nature* 404 (6780): 861-865. - doi: 10.1038/35009084.
- Wermelinger B., Flückiger P.F., Obrist M.K., Duelli P. (2007). Horizontal and vertical distribution of saproxylic beetles (Col. Buprestidae, Cerambycidae, Scolytinae) across sections of forest edges. *Journal of Applied Entomology* 131: 104-114.
- Wikars L., Sahlin E., Ranius T. (2005). A comparison of three methods to estimate species richness of saproxylic beetles (Coleoptera) in logs and high stumps of Norway spruce. *The Canadian Entomologist* 137:304-324.
- Yoccoz N.G., Nichols J.D., Boulinier T. (2001). Monitoring of biological diversity in space and time. *Trends in Ecology and Evolution* 16: 446-453.
- Zhong H., Schowalter T.D. (1989). Conifer bole utilization by wood-boring beetles in western Oregon. *Journal of Forest Research* 19:943-947.

Zielonka T. (2006). Quantity and decay stages of coarse woody debris in old-growth subalpine spruce forests of the western Carpathians, Poland. *Canadian Journal of Forest Research* 36:2614-2622.

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