La entomofauna como indicadora del tipo de manejo en el olivar

Belén Cotes Ramal

Tesis Doctoral

Editor: Editorial de la Universidad de Granada
Autor: Belén Cotes Ramal
D.L.: GR. 3487-2009
ISBN: 978-84-692-6388-4

LA ENTOMOFAUNA COMO INDICADORA DEL TIPO DE MANEJO EN EL OLIVAR

Memoria que presenta la Licenciada en Ciencias Ambientales
Belén Cotes Ramal para optar al grado de Doctor.

Fdo. Belén Cotes Ramal

V°B°
LOS DIRECTORES DEL TRABAJO

Fdo. Dra Francisca Ruano Díaz
Doctora en Ciencias Biológicas

Fdo. Dra Mercedes Campos Aranda
Doctora en Ciencias Biológicas

Fdo. Dr Felipe Pascual Torres
Doctor en Ciencias Biológicas

Granada, Septiembre de 2009

FRANCISCA RUANO DÍAZ, Profesor contratado Doctor de la Universidad de Granada, **MERCEDES CAMPOS ARANDA**, Profesor de Investigación del Consejo Superior de Investigaciones Científicas en la Estación Experimental del Zaidín y **FELIPE PASCUAL TORRES**, Catedrático de la Universidad de Granada

INFORMAN:

Que el trabajo "La entomofauna como indicadora del tipo de manejo en el olivar", realizado por la licenciada doña Belén Cotes Ramal bajo nuestra dirección, se considera ya finalizado y puede ser presentado para su exposición y defensa como Tesis Doctoral en la Universidad de Granada.

Granada, Septiembre 2009

Fdo. Dra Francisca Ruano Díaz

Fdo. Dra Mercedes Campos Aranda

Fdo. Dr Felipe Pascual Torres

Este Trabajo ha sido realizado en el Departamento de Protección Ambiental de la Estación Experimental del Zaidín (CSIC) y en el Departamento de Biología Animal de la Universidad de Granada, gracias a una Beca Predoctoral de Formación de Doctores en el marco de las Unidades Asociadas entre Universidades y Consejo Superior de Investigaciones Científicas del Ministerio de Educación y Ciencia.

Si para alcanzar lo alcanzado debí perder primero lo perdido.

Si para conseguir lo conseguido, tuve que soportar lo soportado.

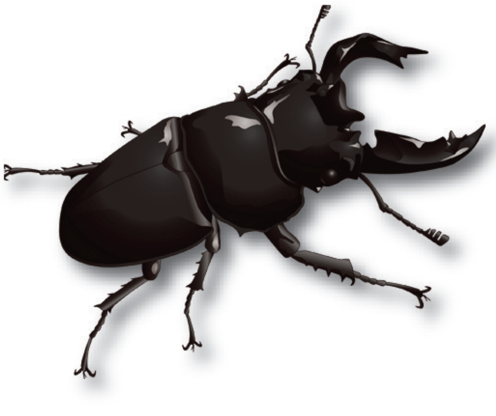
Si para estar ahora premiado, fue necesario haber sido herido.

Tengo por bien sufrido lo sufrido, tengo por bien pasado lo pasado.

Porque después de todo he comprobado, que no se goza bien de lo gozado sino después de haberlo padecido.

Porque después de todo he comprendido, que lo que el árbol tiene de florido, vive gracias a lo que tiene sepultado.

Francisco L. Bernárdez



Agradezco

Ante todo gracias a mis tres directores por dirigir esta Tesis hasta el final.

Individualmente a la Doctora Francisca Ruano por la exhaustividad, criticismo y riqueza aportada a todos los trabajos que componen esta Tesis y por su absoluta disponibilidad, a pesar de su complicada agenda.

A la Doctora Mercedes Campos por su día a día lleno de consejos, apoyo personal y continua motivación por nuestra formación científica.

Al Doctor Felipe Pascual por el tiempo dedicado a cada reunión, por no dejar ni un solo cabo sin atar y por la ayuda en múltiples trámites universitarios.

Al Doctor Pedro A. García, bien en la Facultad de Ciencias o en Ciencias del Trabajo, por asesorarme con la estadística y por el imperdonable café de las 10 am.

A Juan Castro por ofrecerme todo lo necesario para desarrollar esta Tesis y resto de trabajo.

A toda mi familia, aún muchas veces sin saber o entender a lo que me dediqué estos años, por su respeto y cariño, éste ha sido el fruto.

A Mario R. Escribano y por el día quinto de nuestras vidas.

A Carmen Gea, Javier Parra, a mis hermanitas Adela y Teresa que han sido y serán para mí un punto de referencia y apoyo en la vida, esta Tesis es el resultado de la confianza que depositáis en mí.

A Ana, mi Cere, gracias por estar en la infancia, en los viajes y por tu presencia muda cada día. También a tus padres.

Al increíble contacto sináptico que me mantiene unida a mi buena amiga Eli desde el primer día, gracias por dibujar, maquetar e idear en este trabajo que ahora es más nuestro.

A Ángel por llevarme siempre a las escuchas nocturnas del cárabo, aún siendo consciente que con mi presencia nunca cantará.

A Diana por los cuatro años de convivencia, por hacerme sentir toda una familia para tí, no te preocupes todo va a ir bien, llevas un ángel contigo.

A Toña por nuestro año en la calle Santa Paula, la amistad y lo que nos queda por compartir.

A Miriam por estar en los malos y buenos momentos de mi vida y por ser una de las personas más generosas que conozco.

A Pedro Jesús, que es mi Peter, mi hermano mellizo, la vida no sería lo mismo sin tí y a Mariapa por hacerlo feliz, gracias.

A Mari Carmen Alcaina por su fortaleza, a Jori, M. José, M. Trini, Antonia, Sevi, Alicia, Emilio, Silvia y su Silvia, M. Victoria, Diego, también a nuestro Jesús María que una primavera decidió marcharse.

A Estefanía por ser para mí un ejemplo de cordura, de amistad sincera y por ser probablemente una de las mejores investigadoras que nunca conoceré. Gracias también a tus dos Emilios.

A Mariu por compartir estas últimas semanas de presurización antes de la inmersión.

A Mario por su bondad, amistad, simpatía y por enseñarme tantas cosas de Neuropterología.

A "Tanta M. Luisa" por tanta ayuda en tantos aspectos y en tantas situaciones.

A Herminia por su ayuda, por tener siempre una forma mejor de hacer las cosas y unas pinzas entomológicas siempre para mí, a pesar de haber perdido otras la semana anterior.

A todos los compañeros del Departamento, grupo de Protección Vegetal, Emilio Benítez, Esperanza Romero, Amparo Salido, Rogelio Nogales, Francisco Gallardo, Juan Sánchez. A mis amigos y compañeros pasados y presentes: Bea, Manu, Jean, Rebeca, Erika Muñoz, Inma Garrido, Sol, Ciro,...

A Lola (cuando escribía esto me enteré que vas a ser mamá), Ire, Cristi, Pili y Ro, así como a sus respectivos por aceptarme como soy, eso sí "fustigándome" algún rato.

A mi tíos Juana y Pepe, Antonia y Adrián, Pedro y Consuelo por proyectar en mí y mis hermanos tantos cuidados, ayuda y amor.

A Celia Cifuentes por adoptarme en su laboratorio en tiempos revueltos, como madre y amiga eres increíble, a tu Antonio y Pablo (Antoñico a todos los efectos).

A Fer y Rubén cuya amistad fue concedida en el mismo BOE que esta beca predoctoral.

A Rosita y a Mar por quitarme el reinado de becaria ideal.

A Dani por ser muy Nui y a Fer por contar algún que otro chiste que me ha hecho reir.

A Manuel Saavedra por sus inyecciones de vida y alegría a ultramar.

A Germán por tener siempre algo mejor que hacer.

A Carlos (Carry) que tiene todas las herramientas, pero perdió las instrucciones, no soy tu tipo…, pero cuanto nos reímos juntos ¿verdad?

A Jesús (Perry) porque subió cuando yo bajaba y ascendía cuando yo caía, pero juntos supimos aconsejarnos y estar hoy tan bien como estamos.

A Ángeles y Jorge por las noches de Soriada, aunque luego me resienta de las cervicales.

To Vivan Vadakan, who accepted to be the best friend I had in Santa Cruz and taught me so many things about agroecology, Buddhism and Thailand.

To Jeffry Stroud (Jefe), who let me show him San Francisco, I am waiting now for your tour in Seville.

A Steve Gliessman por invitarme a Santa Cruz, por introducirme en la corriente agroecológica y facilitarme tantos trámites administrativos en California y en España.

Bei Beate und Vincent, die mich lieben, die mich inmSpanien besuchen haben und mit dem ich mich tot lache, ich liebe euch auch.

Bei Sigi Kotz, der meine Schwester glücklich macht und geholfen hat die kleine Paola auf die Welt zu bringen.

A Antonio Barroso, Laura Delgado, Lourdes Sánchez y Regina Fernández por ser tan especiales.

A Cristina Sánchez, Helena Blanca, M. Mar Ruano, Germán, Paloma, Lolo, Carmen, Iván, Carol, Marcela, M. José Lorite, Morad, Ana y Nieves por su simpatía.

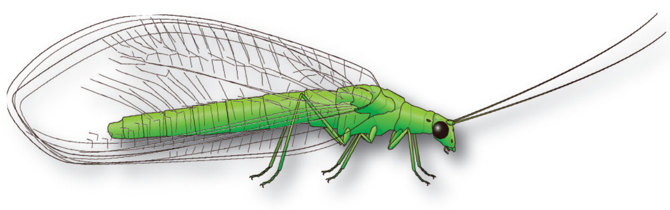
Al personal de la Estación Experimental del Zaidín, especialmente a Rosa Clares, Dolores Enciso y M. Dolores Maroto, al Departamento de Compras, Talleres e Informática (César y Javi). En la Biblioteca a Licy además de consejera, amiga, a Eugenia por los 40 libros que solicité para escribir sólo la introducción.

También a los compañeros del CIFAED Lara, Meli, Laia y Juanma quienes todavía creen que muchos cambios son posibles.

Al Doctor José Olivares por animarme a escribir la novela, eso sí, después de terminar esta Tesis, y una vez pasado el furor de *Millenium*.

A los compañeros y profesores del Departamento de Biología Animal, Carmen Zamora, José Miguel Ávila, Javier Alba, Alberto Tinaut, Manuel Tierno, Manu, Olivia, Carlos,…

Y a los que dejo sin mencionar por despiste, a otros voluntariamente por ser parte de una etapa en proceso de cura, gracias también.



A mi padre, la savia.
A mi madre, la raíz, a Paola, el brote.
A mi hermana y a mi hermano, pasado-presente-futuro.

Índice de contenidos

Resumen

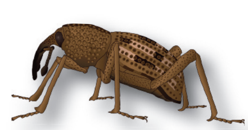
La evaluación de la entomofauna en el agroecosistema del olivar es considerada en este trabajo de Tesis como un método que puede llegar a diferenciar distintos tipos de manejo agronómicos, ya que está asociada a cambios en los usos agrícolas. Con el indicador apropiado y teniendo en cuenta el tipo de manejo, la estructura del paisaje y los usos del suelo en el olivar andaluz, es posible comparar olivares con diferente intensificación y determinar cuál es el más sostenible, en aras de conseguir un método rápido y fiable para poder certificar cultivos que muestran un manejo más respetuoso con el medio ambiente.

Con el fin de seleccionar un grupo o grupos de insectos como indicadores del tipo de manejo en el olivar, se eligieron parcelas en dos regiones olivareras de las provincias de Granada y Córdoba con tres manejos diferentes: convencional, ecológico e integrado. En la provincia de Granada (comarcas de Los Montes y de La Vega) tres parcelas fueron estudiadas de marzo a octubre entre 1999 y 2000. Posteriormente en 2003 otras nueve parcelas se incorporaron al estudio centrando los muestreos al periodo de prefloración (mayo) y postfloración (junio). En la provincia de Córdoba (Valle de Los Pedroches) nueve parcelas fueron muestreadas en mayo y junio en 2003. La recogida de los insectos se hizo en la copa de los olivos mediante vareo y en el suelo, bajo la copa, mediante trampas de caída.

Otro experimento fue llevado a cabo en la provincia de Jaén (municipio de Mancha Real) en 2005, donde se comprobó el efecto de la eliminación de la cubierta vegetal sobre los coleópteros del suelo mediante trampas de caída.

El contenido de la Tesis está estructurado en seis artículos científicos, los cuatro primeros (apartados del 4 al 7) están dedicados al estudio de la entomofauna capturada en la copa de los olivos y los dos siguientes (apartados 8 y 9) a la entomofauna capturada en el suelo.

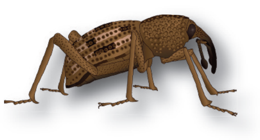
La investigación sobre los insectos de la copa comienza con el nivel taxonómico de orden (apartado 4), mediante el diseño de un análisis discriminante que reportó los dos órdenes que consiguen clasificar con el mayor porcentaje



parcelas bajo manejo ecológico y no ecológico en ambas provincias. Estos grupos discriminantes son los coleópteros, y en menor medida los hemípteros.

Otro aspecto (apartado 5) se centró en la búsqueda de familias de coleópteros que pudieran ser indicadoras del tipo de manejo. En este caso se determinó la respuesta de las diferentes familias frente a las prácticas agronómicas y a la configuración del paisaje mediante estadística multivariante. De este estudio se pudo concluir que los coccinélidos y los escráptidos son indicadores de manejo ecológico en la provincia de Granada. Por su gran abundancia y por su ecología, el grupo de coccinélidos fue escogido para ser estudiado a niveles taxonómicos más bajos (apartado 6) y para analizar su distribución geográfica en los olivares de Granada y Córdoba (apartado 7). La fiabilidad del uso de morfoespecies de coccinélidos quedó demostrada por su correlación con las especies taxonómicas, determinándose, además, que las morfoespecies más abundantes pueden distinguir entre manejo ecológico y no ecológico en la provincia de Granada. Se comprobó que las comunidades de coleópteros son diferentes de una región de olivar a otra, estando afectadas por la configuración del paisaje y la tradición en los usos del suelo.

Con los insectos capturados en trampas de suelo se siguió el mismo esquema de estudio aplicado a los insectos de la copa. Se comenzó analizando los órdenes encontrados en el suelo, continuando con las familias de coleópteros y finalmente las morfoespecies de carábidos. Se analizó la respuesta de cada grupo de los diferentes niveles taxonómicos en función de las diferentes prácticas agronómicas con el objetivo de determinar su potencial como indicadores del tipo de manejo (apartado 8). De los tres niveles analizados parece que el de orden distingue mejor los diferentes tipos de manejo, no obstante, las diferencias entre provincias en cuanto a la composición de insectos son muy marcadas en todos los taxones. Finalmente, y dada la importancia que tienen las cubiertas vegetales en los olivares andaluces, se estudió el efecto de la eliminación de la vegetación natural en un olivar de la provincia de Jaén, observándose un aumento en la diversidad, la riqueza y la dominancia de las familias de coleópteros en suelo desnudo (apartado 9).



Abstract

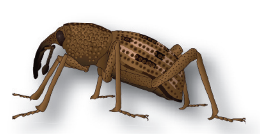
The assessment of entomofauna in olive agroecosystems is considered in this dissertation as a potential method for differentiating between various farm management systems. Using the entomofauna as an indicator and taking into account the type of farming system, the landscape, and land use practices in Andalusian olive orchards, it is possible to compare olive orchards with different levels of intensification and determine which farming system is more sustainable. Using entomofauna as an indicator would allow for the development of a rapid and reliable method to certify olive orchards which demonstrate more environmentally sound farming practices.

With the goal of selecting a group or several groups of insects as indicators in olive farming systems, orchards from two olive growing regions in the provinces of Granada and Córdoba were chosen. In each region, orchards under three different management systems were studied: organic, conventional and integrated. In the province of Granada (Los Montes and de La Vega regions) three orchards were investigated from March to October between 1999 and 2000. Afterwards, in 2003 nine other orchards were included in the study. Samples were restricted to the preblooming (May) and postblooming (June) period. In the province of Córdoba (Los Pedroches Valley) nine orchards were sampled in May and June 2003. The capture of insects was carried out in the tree canopies through branch beating and in soils underneath the tree canopies through pitfall traps.

Another experiment was undertaken in Jaén province (Mancha Real municipality) in 2005, where the effect of the removal of the groundcover on epigeal beetles was observed through the use of pitfall traps.

The contents of this dissertation are organized into six scientific papers, the first four (Chapters 4 to 7) are about the study of the entomofauna collected in olive tree canopies and the remaining two sections (Chapters 8 and 9) are about the collection of epigeal entomofauna.

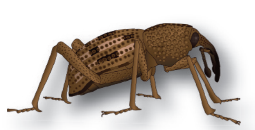
The study investigates canopy insects at the taxonomic level of order (Chapter 4). Analysis showed that two taxonomic orders were associated with



orchards under organic and non-organic management in both Granada and Córdoba provinces. These orders are Coleoptera and, to a lesser degree, Hemiptera. Another study (Chapter 5) was based on searching for families of Coleoptera which could be indicators of different olive farm management systems. In this case the response of different families to the farming practices and the landscape configuration through multivariate analysis were assessed.

From this study, it could be concluded that coccinellids and scraptiids are indicators in the organic farming system in Granada province. Due to the abundance of coccinellids and their ecological importance, the ladybeetles were evaluated to lower taxonomic levels (Chapter 6) and their geographic distribution in olive orchards of Granada and Córdoba (Chapter 7) was studied. The reliability of the use of coccinellid morphospecies was proved by its correlation with coccinellid taxonomic species, showing therefore that the most abundant morphospecies can distinguish between organic and non organic farming systems in Granada. It was shown that the coleopteran communities are different from one region to another, being influenced by the landscape configuration and traditional land uses.

The same method that was used for the canopy insects was applied to the epigeal insects. The initial analysis was on those orders found in the soil, followed by families of Coleoptera, and finally by morphospecies of carabids. The response of each group was evaluated in relation to the different farming practices, with the objective of determining their potential as indicators of the type of farming system (Chapter 8). From the three taxonomic levels studied, it seems that the order level can better distinguish the types of farming systems, nevertheless, the differences between provinces in terms of insect composition were very evident at all taxonomic levels. Finally, and due to the importance of groundcover in Andalusian olive orchards, the effects of the removal of the natural vegetation was studied in Jaén province, observing an increase of diversity, richness and dominance of the families of Coleoptera in bare soils (Chapter 9).



1. Introducción General

1.1 Ecosistema vs agroecosistema

La producción agraria es el resultado de las presiones socioeconómicas que realiza la sociedad sobre los ecosistemas naturales en el tiempo (Sevilla Guzmán, 1995), lo cual implica el manejo de los ecosistemas terrestres desviando su capacidad productiva al servicio de las necesidades humanas, y éstas están previstas que continúen aumentando durante las próximas décadas, por lo que el grado de apropiación del suelo aumentará (Millennium Ecosystem Assessment, 2005). Además, la agricultura en los países industrializados conlleva la simplificación de la diversidad natural (Jackson *et al.*, 2005; Perrings *et al.*, 2006) y alcanza su forma más extrema en los monocultivos. El resultado final es la producción de un ecosistema artificial que requiere una constante intervención humana. En muchos casos, esta intervención consiste en la introducción de productos agroquímicos que, aunque eleva temporalmente las producciones, da lugar a numerosos costes ambientales y sociales indeseables (Altieri, 1987).

Conforme progresa la modernización agrícola, los principios ecológicos son continuamente ignorados o desestimados, y en consecuencia los agroecosistemas modernos son inestables. Por tanto la preocupación no se centra sólo en el impacto ocasionado sobre los paisajes no agrícolas a nivel de conservación de la diversidad silvestre (Green *et al.*, 2005), sino que comienza a proponerse la "sostenibilidad" de los paisajes agrícolas.

Así, existe actualmente una polémica entre el aumento de las demandas agrícolas y la conservación de la diversidad en ecosistemas cultivados, puesto que hay evidencias de que distintas prácticas agronómicas influyen en la riqueza y abundancia de las especies (Altieri, 1999), de los riesgos que suponen los cambios agrícolas en la diversidad (Krebs *et al.*, 1999 ; Tilman *et al.*, 2001) y de cómo las prácticas agrícolas pueden ser modificadas para mitigar los efectos negativos y generar beneficios (McNeely & Scherr, 2003). Por ello, la cuestión básica a la que se enfrenta la agricultura moderna es la consecución de un aumento en la producción, sin comprometer la salud del medio ambiente y de los seres vivos, tal como contempla el principio de Desarrollo Sostenible (Comisión sobre Medio Ambiente y Desarrollo Comisión Brundtland, 1987). Este principio, entre los objetivos sociales, económicos y ecológicos que persigue, propone un cambio en las actuales formas de producción agrícola en el mundo. Tanto en los países desarrollados como en los países en desarrollo se pretende reorientar la agricultura teniendo en cuenta el respeto por el medio ambiente, la obtención de alimentos de calidad, así como la seguridad alimentaria.

El primer paso hacia la integración del medio ambiente en las políticas agrícolas fueron llevadas a cabo con la reforma de la Política Agraria Común (Common Agricultural Policy CAP) de 1992, que introdujo nuevos conceptos sobre las actividades de manejo y protección ambiental. La integración fue aún más profunda con la revitalización de la PAC (Agenda 2000 para 2000–2006), donde el medio ambiente comenzó a tener más influencia y fue económicamente priorizado (Zalidis *et al.*, 2004). En el año 1998 la Unión Europea adoptó una estrategia comunitaria en materia de biodiversidad, que preveía la aplicación de planes específicos en una serie de sectores de actividad para conseguir un desarrollo sostenible e integrar las consideraciones medioambientales en otras políticas y actuaciones. Así, en el año 2001 se crea el plan de acción sobre biodiversidad en la agricultura (volumen III) (COM 2001) con el objetivo específico de mejorar o mantener el estado de la biodiversidad biológica e impedir que las actividades agrarias provoquen su disminución. Las prioridades de dicho plan de acción son las siguientes:

- Mantener las prácticas de agricultura intensiva en un nivel que no sea perjudicial para la biodiversidad, lo cual implica: desarrollar prácticas agrícolas acertadas, reducir la utilización de abonos, promover sistemas de producción extensivos y lograr la gestión sostenible de los recursos.
- Conseguir que la actividad agrícola sea económicamente viable, socialmente aceptable y respetuosa con la biodiversidad.
- Aplicar medidas agroambientales para la explotación sostenible de la biodiversidad.
- Garantizar la existencia de la infraestructura ecológica necesaria.
- Apoyar medidas para mantener las razas y variedades locales, así como la diversidad de variedades utilizadas en la agricultura.
- Evitar la expansión de especies no autóctonas.

Sin embargo, la puesta en práctica de estas medidas para preservar la biodiversidad necesita de un conocimiento profundo de los agroecosistemas por lo que la UE ha determinado las necesidades en materia de investigación con objeto de integrarlas en los Programas Marco Europeo de Investigación y Desarrollo Tecnológico.

1.2 Olivar

Uno de los principales sectores agrícolas de mayor peso relativo en la PAC es el del olivar. La Comisión Europea (CE), el Gobierno Español y las diferentes Comunidades Autónomas con tierras agrícolas dedicadas al cultivo del olivo, han legislado en la materia a fin de regular la producción de un producto muy apreciado a nivel internacional.

Aunque el olivo (*Olea europaea* L.) es una especie botánica originaria de Asia, ha sido cultivada en los países de la cuenca mediterránea durante 3000 años (de Graaff & Eppink, 1999), habiéndose convertido en una especie emblemática que encarna uno de los más importantes cultivos en el área mediterránea (Loumou & Giourga, 2003).

La superficie oleícola mundial estimada en 2007 alcanza las 10.492.000 ha con un aumento anual medio entre el año 2001 y el año 2005 de 150.000 ha. El incremento más significativo, un 2%, se registró entre los años 2006 y 2007 y se debió principalmente a las plantaciones en países emergentes de América del Sur, Sudáfrica y Australia. Respecto a la producción de aceite de oliva, los hechos que han provocado un aumento mundial ligeramente superior en las últimas cuatro campañas han sido:

- El aumento de la producción de los aceites de oliva.
- El incremento del consumo mundial de los aceites de oliva a raíz de la confirmación de sus efectos positivos para la salud.
- El crecimiento del consumo de los aceites vírgenes de oliva de calidad.
- La estabilidad de los precios de los aceites de oliva a raíz del aumento más rápido de la oferta frente a la demanda.
- La aparición de nuevas industrias que utilizan los subproductos del olivo o aquellas que incorporan el aceite de oliva en los procesos productivos de la alimentación y la cosmética.

- La proliferación de los productos de substitución de los aceites de oliva de menor calidad y menor precio.
- Las exigencias del consumidor en materia de trazabilidad, seguridad alimentaria, salud y medioambiente.
- La reducción o eliminación de ciertas ayudas comunitarias para la liberalización del comercio mundial.
- La concentración en el sector de la distribución comercial y el aumento del peso de las marcas del distribuidor o marcas blancas.

El 53% de la superficie cultivada corresponde a los países de la UE, seguidos de los países del norte de África con un 27%, de los países de Oriente Próximo con un 18% y del continente americano con el 2%. Sin embargo, y según fuentes del Secretariado de la UNCTAD basado en los datos del Consejo Oleícola Internacional, la producción de aceite de oliva ha estado siempre concentrada en los países del perímetro mediterráneo: España, Portugal, Italia, Grecia, Turquía, Túnez y Marruecos. Solamente estos siete países representan el 90% de la producción mundial (Figura 1.1).

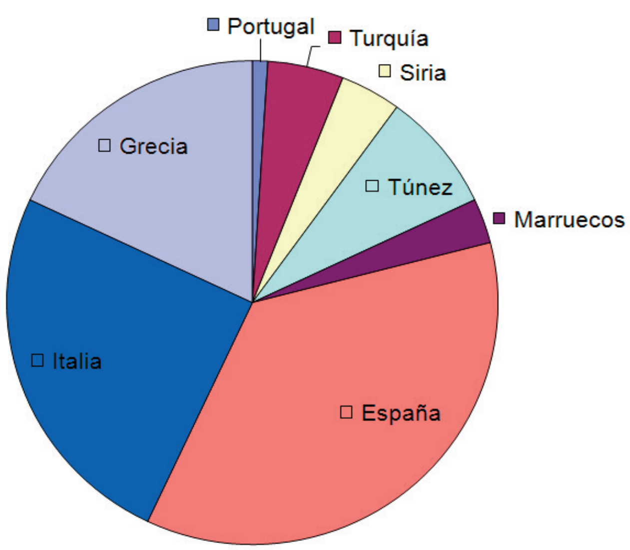


Figura 1.1: Principales países productores de aceite de oliva en 2005.

España está a la cabeza en la producción mundial de aceite de oliva, estimándose en 215 millones el número de árboles sembrados y ocupando una superficie de 2.300,000 ha (González-Andújar, 2009). Andalucía es la principal comunidad oleícola representando en el año 2001 el 61% de la superficie total de olivar.

La enorme importancia del olivar en Andalucía no sólo es consecuencia del proceso histórico (su relación se remonta al siglo IX a C.), sino porque juega un papel esencial en su economía (representa casi el 30% de la producción final agraria andaluza), por su papel decisivo en la creación de empleo, por ser un elemento primordial en la cohesión social y territorial y formar parte de su cultura y su dieta. La superficie cultivada se concentra fundamentalmente en el centro y noroeste de la comunidad andaluza, siendo Jaén y Córdoba las principales provincias olivareras, concentrando el 61% de superficie de olivar en Andalucía. Le siguen en importancia Sevilla, Granada y Málaga, y las restantes provincias no llegan a contabilizar conjuntamente el 5%.

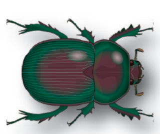
El olivar andaluz presenta numerosas formas de producción, técnicas de cultivo, etc., pudiéndose encontrar desde olivares intensivos en zonas tradicionales no olivareras a olivares de sierra de baja productividad, así como una amplia gama de situaciones intermedias (Consejería de Agricultura y Pesca. Junta de Andalucía, 2003). El siglo XX fue testigo de la simplificación de los agroecosistemas a nivel mundial, incluidos aquellos generados históricamente en el ámbito mediterráneo, como es el olivar. A través del tiempo, se impuso un modelo dominante de olivar con baja diversidad, especializado para satisfacer objetivos comerciales y de explotación, incorporando técnicas como riego, laboreo, fertilización y control químico de plagas y enfermedades. Este modelo ha generado una alta dependencia de insumos externos y diferentes impactos negativos como la pérdida de suelo, nutrientes y vegetación natural, con la consiguiente pérdida de biodiversidad asociada (Pajarón Sotomayor, 2003; Parra López & Calatrava Requena, 2006). Así, actualmente existe una creciente demanda social de una olivicultura menos dependiente de agroquímicos y más respetuosa con el medio ambiente, por lo que se están planteando nuevas políticas y reorientando las líneas de investigación hacia la denominada agricultura sostenible. Consciente del reto que supone el cambio de los sistemas convencionales de cultivo a otros que cumplan los requisitos del Desarrollo Sostenible, la Consejería de Agricultura y

Pesca de la Junta de Andalucía viene promoviendo desde hace años políticas agrarias que propicien el cambio perseguido como son el desarrollo de la producción integrada y ecológica.

La producción integrada es el sistema agrícola que utiliza los mecanismos de regulación naturales, teniendo en cuenta la protección del medio ambiente, la economía de las explotaciones y las exigencias sociales de acuerdo con los requisitos que se establezcan para cada cultivo en el correspondiente Reglamento de Producción. Así, las técnicas de producción utilizadas son más respetuosas con el medio ambiente, minimizan y racionalizan el empleo de productos químicos sin prohibirlos y pretenden obtener alimentos de máxima calidad.

La producción ecológica es un sistema agrario cuyo objetivo fundamental es la obtención de alimentos de calidad, respetando el medioambiente y conservando la fertilidad de la tierra, mediante la utilización óptima de los recursos naturales, excluyendo el empleo de productos químicos de síntesis y procurando un desarrollo agrario sostenible. La olivicultura ecológica presenta una serie de ventajas frente a otro tipo de manejos (convencional o integrado) tanto en relación con la calidad del aceite como desde el punto de vista medioambiental al proteger el suelo, incrementar la biodiversidad funcional y disminuir la contaminación (Guzmán & Alonso, 2004; Pajarón Sotomayor, 2008).

Aunque se ha iniciado un camino hacia la sostenibilidad en el cultivo del olivo, hacer operativo este concepto no es tarea sencilla dado que se trata de un sistema complejo donde se solapan un conjunto de relaciones sinérgicas y antagonistas (Alonso & Guzmán, 2006). Por ello, si se quieren optimizar los diferentes sistemas de producción, es fundamental incrementar los conocimientos sobre el propio agroecosistema, tanto a nivel de estructura como de funcionamiento y determinar el impacto de las diferentes prácticas agronómicas aplicadas. En este sentido hay que indicar que en el olivar es difícil de cuantificar, incluso en términos entomológicos, el efecto de las diferentes prácticas aplicadas, ya que el agroecosistema original e inalterado se desconoce. Es por tanto de interés disponer de un conocimiento básico de las características biológicas y ecológicas de los agroecosistemas originales o los más cercanos a éstos para poder comenzar a evaluar la acción de diferentes sistemas de manejo.



1.3 Bioindicación e indicadores agro-ambientales

1.3.1 Bioindicación

La bioindicación es una disciplina de conservación biológica y su primer objetivo es la aplicación del conocimiento científico al manejo de las relaciones ecológicas. Los organismos bioindicadores son especies vivas (animales o vegetales) cuyas funciones vitales están estrechamente relacionadas con ciertos factores ambientales y que reaccionan de forma conocida frente a ellos. Esta reacción permite caracterizar la calidad del medio ambiente, como por ejemplo al detectar la existencia de sustancias contaminantes en el medio natural y/o evaluar la gravedad de su presencia. El bioindicador está relacionado directa o indirectamente con uno o más factores y su reacción puede deberse a su sensibilidad o a su tolerancia (Paoletti & Bressan, 1996; van Straalen, 1998).

La diferencia entre las técnicas analíticas (físicas y químicas) y la bioindicación es que las primeras permiten identificar y cuantificar los contaminantes presentes, incluso en cantidades muy pequeñas, pero no aportan información sobre los efectos de estas sustancias en los sistemas biológicos. Realmente el uso de índices biológicos data desde muy antiguo, ya que las plantas y los animales eran utilizados para entender distintos fenómenos, como el cambio de estaciones, lluvia, etc. Sin embargo, fue a comienzos del siglo XX cuando el uso de bioindicadores pasó de ser un planteamiento de historia natural a ser considerado como una metodología más formal. Así, los botánicos comenzaron a utilizar la presencia de distintos tipos de plantas y asociaciones para definir diferentes tipos de suelo, aunque el concepto de especies indicadoras fue aplicado por primera vez en sistemas acuáticos (Wihlm & Dorris, 1968), y posteriormente en sistemas terrestres (McGeoch, 1998), convirtiéndose en una novedosa herramienta para evaluar las alteraciones ambientales, como contaminación, excesivo empleo de insumos en agricultura, inapropiado uso del agua, etc. (Paoletti, 1999a).

Partiendo de la definición de bioindicador propuesta por Paoletti (Paoletti, 1999a; 1999b) "*especie o conjunto de especies que está estrechamente unido a unas características concretas del paisaje y/o reacciona a impactos o cambios*", muchas han sido las clasificaciones dadas en la literatura sobre los diferentes tipos de indicadores (Döring *et al.*, 2003; Duelli & Obrist, 2003), dependiendo de los objetivos de cada estudio. A modo ilustrativo cabe destacar aquella clasificación en la que los indicadores son categorizados en indicadores ambientales (reflejan el estado biótico o abiótico del medio ambiente), indicadores ecológicos (muestran impactos de cambios ambientales) e indicadores de biodiversidad (señalan la complejidad taxonómica en relación con un hábitat o área) (Fauvel, 1999; Lawton *et al.*, 1998; McGeoch, 1998; Perner & Malt, 2003).

1.3.2 Indicadores agro-ambientales

La Organización de Cooperación y Desarrollo Económico (Organisation for Economic Co-operation and Development OECD) estableció los criterios básicos y nuevas metodologías para definir y estructurar el estudio del estado ambiental de los agroecosistemas (OECD, 2001). Entre las herramientas propuestas por la OCDE se encuentran los llamados indicadores agroambientales (Agri-environmental Indicators AEIs). En la Unión Europea, el desarrollo de indicadores agroambientales comenzó junto con el fortalecimiento de las políticas sostenibles y se utilizan para realizar un seguimiento de la aplicación de los planes de acción y evaluar sus resultados sobre el medio agrícola. Además, con ellos se pretende alcanzar más fácilmente una amplia visión del estado actual en el que se encuentran los agroecosistemas y mejorar la efectividad de las políticas en promover agriculturas sostenibles en el futuro. Así, los indicadores agroambientales pueden simplificar medidas adoptadas por las acciones políticas en materia de agricultura, como aquellas que están orientadas en la asignación de subvenciones en el sector público (OECD, 2001).

Con ayuda de los Estados Miembros, científicos y organizaciones interesadas, la UE decidirá los indicadores que van a utilizarse, puesto que éstos han sido definidos como potentes herramientas con múltiples fines (OECD, 1999b):

- Suministrar información a legisladores y para el público en general sobre el estado actual y los cambios en las condiciones del medio ambiente en la agricultura.
- Ayudar a los legisladores a comprender mejor las relaciones entre las

causas y los efectos del impacto de la agricultura y de las políticas agrícolas en el medio ambiente, y ayudar a guiar sus respuestas frente a cambios en las condiciones ambientales.

- Contribuir al monitoreo y evaluación de la efectividad de las políticas en la promoción de la agricultura sostenible.

Con el fin de mejorar la información sobre los actuales impactos y tendencias en los efectos ambientales de la agricultura, la OCDE está desarrollando un grupo de indicadores agro-ambientales. Para guiar la selección de indicadores de desarrollo sostenible toma como base el modelo "Fuerzas impulsoras – Estado – Respuesta" (Driving Force-State-Response; DSR Model). El marco de referencia se complementa con los compromisos especificados en la Agenda 21 bajo las cuatro dimensiones primarias del desarrollo sostenible: social, económica, ambiental e institucional.

El modelo DSR está basado en el modelo Presión-Estado-Respuesta y su objetivo es estimar el impacto ambiental de las actividades humanas y la respuesta de la sociedad hacia los problemas ambientales. Propone el uso de tres componentes dentro de los cuales deben ser ubicados los indicadores: (a) Fuerzas Impulsoras, (b) Estado y (c) Respuesta de la Sociedad:

(a) Las Fuerzas Impulsoras, representan a las actividades humanas, los procesos (p.e. industriales) y los patrones (p.e. de consumo) que impactan sobre el desarrollo sostenible ya sea de forma positiva o negativa.

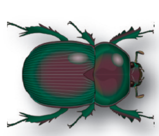
(b) Los Indicadores de Estado, proveen una lectura de la condición del desarrollo sostenible. En la dimensión ambiental se refieren a los cambios en las condiciones ambientales que son el resultado de varias fuerzas impulsoras; son, en esencia, un inventario de la condición existente de los recursos: agua, suelo, aire y biodiversidad.

(c) Los Indicadores de Respuesta, representan las acciones que la sociedad lleva a cabo con miras a lograr un desarrollo sostenible. Miden, de alguna forma, la reacción de la sociedad a los cambios percibidos en el ambiente, a través de instrumentos de política, financieros, tecnológicos o educativos.

Entre los distintos tipos de indicadores diseñados por la OCDE, los indicadores agro-ambientales están incluidos en aquellos que promueven la integración dentro de otras políticas sectoriales, enfocados en un sector específico (transporte, energía, turismo, agricultura) (OECD, 2003).

Dentro del marco de trabajo de DSR, basados en previos estudios de la OCDE (OECD, 1997; 1999c), se llegaron a importantes consensos tanto en la identificación y especificación de indicadores políticamente relevantes, clasificados según los objetivos que se persigan (OECD, 1999a) :

- Indicadores contextuales: suelo cultivado, población y estructuras agrícolas, y número y tipos de usos de cultivos.
- Uso de nutrientes: balance de nitrógeno y fósforo en la superficie del suelo, balance de nutrientes agrícolas, eficiencia (técnica/ económica) en el uso de nutrientes.
- Uso de plaguicidas: índice de uso de plaguicidas, eficiencia (técnica/ económica) en el uso de plaguicidas, riesgo de los pesticidas.
- Uso del agua: intensidad de uso de agua (porcentaje de de recursos hídricos destinados a fines agrícolas), estrés hídrico (porcentaje de ríos destinados a riego); eficiencia en el uso del agua, respuesta política y de gestión al estrés hídrico.
- Calidad del suelo: riesgo de erosión hídrica y eólica, calidad intrínseca del suelo.
- Calidad del agua: concentración de nitrato y fósforo en zonas de aguas, riesgo de contaminación de aguas por nitrógeno y plaguicidas.
- Conservación del suelo: capacidad de carga de agua, entrada de sedimentos en suelos agrícolas.
- Emisiones de gases efecto invernadero: emisiones agrícolas, contribución de la agricultura a la producción de energías renovables (producción de biomasa), red de emisiones de dióxido de carbono de los suelos agrícolas, eficiencia económica de las emisiones de gases invernadero.
- Biodiversidad: diversidad genética en ganadería y agricultura, especies silvestres.
- Hábitats silvestres: cultivados intensivamente, hábitats seminaturales y áreas no cultivadas de hábitats naturales, heterogeneidad del hábitat y variabilidad, impacto sobre hábitats de diferentes manejos o prácticas agrícolas.
- Paisaje: características de paisaje incluyendo características naturales, apariencia en los ecosistemas, tipos de características de usos del suelo, elementos



culturales, funciones de manejo de los paisajes agrícolas, tipologías de paisaje, evaluación monetaria de las presencias sociales de los paisajes.

• Tipo de manejo: capacidad del tipo de manejo, inversión en investigación agro-ambiental, nivel de formación de los agricultores, adopción de prácticas ambientales relacionadas con los nutrientes, suelo, plaguicidas, agua y la completa gestión agrícola.

• Recursos económicos: inversión agroambiental pública y privada, equilibrio económico entre impuestos y costes de capital.

• Viabilidad rural: ingresos agrícolas, incorporación de nuevos agricultores, capital social en comunidades agrícolas y rurales.

En resumen, los indicadores están siendo desarrollados para cubrir recursos básicos en agricultura:

• Uso de recursos naturales e inputs: nutrientes, pesticidas, agua y suelo.

• Impacto ambiental sobre: calidad de suelo y agua, conservación de suelo; gases efecto invernadero, hábitats silvestres y paisaje.

• Interacción entre factores ambientales, económicos y sociales, tales como las prácticas agrícolas, recursos económicos agrícolas, y viabilidad rural.

1.4 Agrodiversidad y factores relacionados

1.4.1 Agrodiversidad

El término "biodiversidad" alcanzó sus más altos niveles de popularidad después de la Convención de Diversidad Biológica que tuvo lugar en Río de Janiero en Junio de 1992. Mientras que el término utilizado en ecología es "diversidad", con un origen puramente científico, posteriormente cuando adquirió más popularidad en otras áreas de la sociedad el término "biodiversidad" fue utilizado de distintas, y a veces erróneas, maneras.

La biodiversidad, en lo relativo a la agricultura, ha sido descrita en tres niveles según la definición dada en la Convención de Diversidad Biológica:

• *Diversidad genética* ("within species"): se trata de la diversidad genética dentro de las especies animales y vegetales domesticadas y sus homólogas silvestres.

• *Diversidad de especies* ("between species"): el número y población de especies silvestres (flora y fauna), afectadas por la agricultura, incluyendo la biota del suelo y los efectos de las especies invasoras en agricultura y diversidad.

- *Diversidad de ecosistemas* (“of ecosystems”): los ecosistemas formados por las poblaciones de especies relevantes en agricultura o comunidades de especies dependientes de estos hábitats agrícolas.

El mantenimiento de estos tres niveles es interdependiente, ya que la diversidad genética posibilita la mejora de cultivos y ganado a través de la selección de rasgos, hibridación, etc. En el caso de la diversidad de especies silvestres, su relación con la agricultura es importante desde varios puntos de vista, puesto que las especies actúan como un sistema manteniendo la producción agrícola (microorganismos del suelo, gusanos, especies de control biológico o polinizadores); a su vez, también las especies están relacionadas con las actividades agrícolas, puesto que muchas de ellas dependen de los agroecosistemas como hábitats donde desarrollar sus ciclos de vida o dependen de otros hábitats que pueden estar indirectamente afectados por actividades agrícolas; y finalmente, las especies foráneas (plantas invasoras, plagas) que pueden amenazar la producción agrícola y los agroecosistemas. Respecto a la diversidad de ecosistemas, su relación con la agricultura se pone de manifiesto en los cambios en sistemas y prácticas agrícolas, en los cambios en los usos del suelo y en la interacción entre la agricultura y los ecosistemas adyacentes.

En Europa hay una gran conciencia acerca de la gran pérdida de especies, especialmente en hábitats agrícolas. Diversos estudios han demostrado que algunas especies de aves se encuentran en grave estado de conservación debido a su conexión en los cambios de uso del suelo y manejos agrícolas (Tucker & Heath, 1994). Muchas de las mermas de estas aves asociadas a usos agrícolas se deben a la disminución de alimento disponible (principalmente insectos) como consecuencia de la intensificación agrícola y el abandono de las prácticas agrícolas tradicionales (González *et al.*, 1990).

El monitoreo de poblaciones de especies en agroecosistemas es un hecho prioritario y requerido por las legislaciones internacionales, europeas y nacionales y algunas iniciativas conservacionistas (OECD, 2000).

Sin embargo, la evaluación del estado de las poblaciones de especies y los impactos que actúan sobre ellas es difícil, debido a:

- La gran diversidad de especies existentes, así como las complejas interacciones entre ellas.
- El incierto y continuo debate sobre objetivos de biodiversidad a corto y largo plazo.
- Los efectos de escala en la evaluación.
- La incompatibilidad de los datos y la pobre información sobre muchos de ellos.

El posible uso de poblaciones de especies como indicadores ha llevado a los científicos a desarrollar tipologías. Siguiendo la terminología propuesta por Rowell (1994), puede hablarse de:

- Indicadores ecológicos, donde la presencia de una o más especies ofrece información sobre el medio ambiente. La base lógica es que el ambiente determina la distribución y abundancia de organismos.
- Indicadores evaluadores, donde los indicadores son usados por ejemplo para estimar el estado real de conservación de un lugar, o la calidad de un hábitat porque se considera que están correlacionados con factores considerados como valiosos.
- Indicadores representativos, son usados como medio para describir y cuantificar, cuando sea posible en términos cuantificables, los objetivos de las estrategias y planes de acción y proyectos.

Las especies como indicadores también han sido criticadas por sus limitaciones (NERI, 1995):

- Calidad de los datos: los datos relacionados con los indicadores tienen que ser de alta calidad, por ejemplo los datos han de ser colectados usando un método estándar. Estos métodos tienen que ser independientes del observador y de factores como estacionalidad, clima, etc.
- Selección y evaluación: la relación entre la condición del ecosistema y los efectos sobre los indicadores seleccionados sólo en algunos casos han sido demostrados o evaluados previamente (Rowell, 1994). Como resultado del proceso de selección, prioridad y evaluación debe incorporarse un test de calidad para probar que el indicador seleccionado refleja cambios específicos en los ecosistemas para lo cual este ha sido escogido. Se ha determinado que muchos

indicadores tienen limitaciones, cuando se han evaluado posteriormente.

- Condición óptima: los indicadores tienen que estar teóricamente relacionados con un estado “natural” previo a la manipulación del ecosistema. Sin embargo, la naturaleza es dinámica, la cuestión de evaluar la “condición natural” es casi imposible, puesto que los cambios en las condiciones en los ecosistemas prístinos espacial y temporalmente tiene que ser tomados en cuenta, así como la probabilidad de lograr el “estado óptimo” en el medio ambiente antropizado.
- Escala: como cualquier otra actividad de monitoreo, en el caso de los indicadores tiene que darse en un periodo largo de tiempo. Si el periodo de monitoreo es demasiado corto, las tendencias observadas no van a ser significativas. Igualmente, algunos datos indicadores necesitan ser muestreados en una amplia escala geográfica para proporcionar información fiable. La cuestión de la escala es muy dependiente del indicador en cuestión. Algunos indicadores tienen valor limitado, cuando la escala de estudio es amplia para obtener datos fiables y/o cuando la obtención de éstos no es económicamente viable.

1.4.2 Entomofauna, paisaje y manejo agronómico

Un indicador clave del estado o sostenibilidad de un agroecosistema es la diversidad de invertebrados especialmente de insectos y otros artrópodos (Paoletti & Bressan, 1996; van Straalen, 1997; van Straalen & Verhoef, 1997). La evaluación de la biodiversidad está considerada como un método que puede llegar a comparar distintos tipos de manejo agronómicos ya que está asociada a cambios en los usos agrícolas (Büchs, 2003; Büchs *et al.*, 2003; Heyer *et al.*, 2003; Kleijn *et al.*, 2001; Muramoto & Gliessman, 2006; Paoletti, 1999a; Perner & Malt, 2003). Sin duda, el conocimiento de la entomofauna que compone los agroecosistemas permite manejarlos de una forma más sostenible (Labrador & Altieri, 2001).

Los procesos que relacionan agricultura y diversidad son muy numerosos e interactúan conjuntamente, de forma que es difícil atribuir una respuesta particular de la diversidad a una causa agrícola individual y única. De otra manera se puede decir que alteraciones en la diversidad responden a un complejo de cambios agrícolas que pueden ser observados conjuntamente como una intensificación agrícola (Chamberlain *et al.*, 2000). Firbank *et al.* (2008) propusieron que la intensificación agrícola podía ser medida teniendo en cuenta tres dimensiones: tipo de manejo, estructura del paisaje y usos del suelo (Figura 1.2).

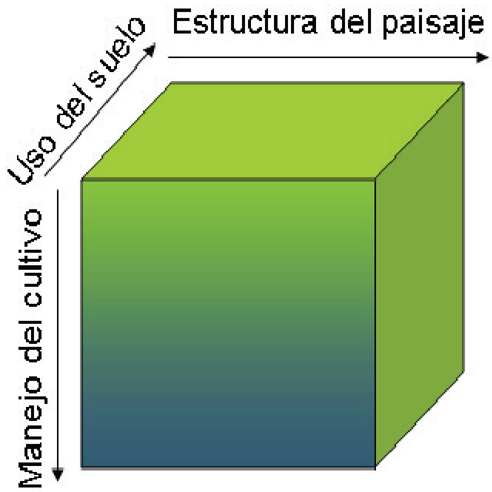


Figura 1.2: Modelo conceptual de un sistema agrícola definido en las tres dimensiones de intensificación agrícola.

Los paisajes están basados en características naturales que son evolutivas y abióticas, incluyendo el clima, relieve, disponibilidad de agua, fertilidad de suelos, roca madre, glaciaciones, vulcanismo, así como la intervención humana mediante la agricultura, transhumancia, silvicultura, políticas rurales, presiones económicas y otras influencias culturales.

1.4.3 Entomofauna como indicadora del manejo agronómico

Con el indicador apropiado, cualquier sistema de manejo, de cualquier escala agrícola, podría ser localizado teniendo en cuenta esas tres dimensiones, y permitiendo la comparación de presiones sobre la diversidad. Los efectos de estas presiones, que impactan sobre la diversidad, es necesario medirlos usando indicadores que sean particularmente sensibles a las presiones que operan a cada escala. En principio, es así posible caracterizar los tipos de manejo en términos de diversidad y a la vez, establecer una base comparativa para la evaluación estratégica de los impactos de la agricultura sobre la diversidad.

Los diferentes grupos de seres vivos difieren mucho en su idoneidad como indicadores. Con el fin de encontrar un buen indicador para el monitoreo de impactos deben cumplirse una serie de requisitos que varían mucho dependiendo de los grupos taxonómicos y sus atributos (Tucker, 1998) (Tabla 1.1).

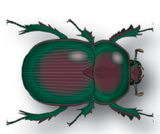
Tabla 1.1: Comparación del potencial de las especies de diferentes grupos taxonómicos que actúan como indicadores de los impactos de la agricultura sobre la biodiversidad.

Atributos	Mamíferos	Aves	Reptiles	Anfibios	Insectos y arañas	Otros invertebrados	Plantas superiores	Plantas inferiores
Muchas especies concentradas en hábitats agrícolas	♦	♦♦	♦	♦	♦♦♦	♦♦	♦♦♦	♦
Ampliamente distribuidas y comunes en agroecosistemas	♦♦	♦♦♦	♦	♦	♦♦♦	♦♦♦	♦♦	♦
Fácil identificación	♦♦♦	♦♦♦	♦♦	♦♦	♦	♦	♦♦	♦
Fácil observación y censo	♦	♦♦♦	♦	♦♦	♦♦	♦	♦♦♦	♦
Amplio conocimiento de su ecología e interacciones agrícolas	♦♦	♦♦	♦	♦	♦♦	♦	♦♦♦	♦♦
Sensibilidad a prácticas agrícolas	♦♦	♦♦	♦	♦	♦♦♦	♦♦	♦♦♦	♦♦
Representativos de un amplio número de otras especies	♦♦	♦♦	♦	♦	?	?	♦♦♦	♦
Bien monitoreados a escala local, nacional e internacional	♦	♦♦♦	♦	♦	♦♦	♦	♦♦	♦
Potencial como especies bandera[1]	♦♦	♦♦♦	♦♦	♦	♦	♦	♦♦	♦

Idoneidad de los taxones con respecto al atributo: ♦ pobre, ♦♦ moderado, ♦♦♦ bueno, ? desconocido

[1]especies que existen en ciertos grupos que nos aportan información clave para tomar decisiones en la elaboración de los planes de manejo que se quieran implementar.

Los artrópodos son los componentes dominantes y más diversos de los ecosistemas terrestres (La Salle, 1999), constituyen una parte sustancial de la biomasa y ocupan además una gran variedad de nichos funcionales y de microhábitats, tanto a nivel espacial como temporal. Por el importante papel que juegan en el funcionamiento de los ecosistemas, los efectos de la fragmentación



de los hábitats sobre artrópodos son relevantes (Bolger *et al.*, 2000). Conviriéndose así en una herramienta de gran interés para evaluar los daños ambientales provocados en los mismos (Harrington & Stork, 1995). Todas estas características determinan que la entomofauna y otros artrópodos constituyan una buena fuente de información a la hora de utilizarla en programas de conservación y manejo de diferentes ecosistemas, bien a nivel de especies, taxones o comunidades (Cole *et al.*, 2005; Kremen *et al.*, 1993; van Straalen, 1998).

De acuerdo con Moreno *et al.* (2007), los invertebrados son los organismos más habitualmente estudiados para agilizar la evaluación de la diversidad. Más concretamente los artrópodos han sido usados para indicar el grado de los impactos sobre los hábitats (Andersen, 1990; Kremen *et al.*, 1993; Lawton *et al.*, 1998; Platen *et al.*, 2001), para medir el efecto de las perturbaciones de origen humano (Kimberling *et al.*, 2001), e incluso para monitorear los distintos estadios en estudios de conservación (Brown, 1997). Los invertebrados se han utilizado con frecuencia para comparar manejos ecológicos y no ecológicos (Álvarez *et al.*, 2000; Clough *et al.*, 2007; Hadjicharalampous *et al.*, 2002; Letourneau & Goldstein, 2001; Purtauf *et al.*, 2005), obteniendo diferencias significativas entre los distintos tipos de manejo y la diversidad de la fauna.

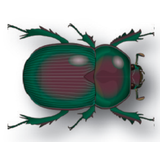
No todos los taxones son igualmente efectivos como bioindicadores, y aunque son numerosos los grupos citados como bioindicadores de diferentes alteraciones, como colémbolos, ácaros, mariposas, hormigas, son el grupo de las arañas y el de los coleópteros los más utilizados. El papel de las arañas como indicadores ha sido también ampliamente documentado en la literatura científica (Marc *et al.*, 1999) y este grupo ha sido propuesto como especies indicadoras por sus características (New, 1999), ya que son abundantes y diversas en la mayor parte de los sistemas terrestres; taxonómicamente es un grupo rico en especies, géneros y familias; tienen una considerable variedad de estilos de vida y especializaciones ecológicas; muchas especies pueden ser observadas y recolectadas de forma sencilla; algunas tienen un valor añadido como depredadoras en el contexto de manejo de plagas. Además, las arañas del suelo responden a cambios microclimáticos y en la estructura del suelo más rápidamente que otros organismos con capacidad bioindicadora como las plantas (Perner & Malt, 2003).

Los coleópteros son uno de los órdenes de artrópodos mejor representados en los agroecosistemas, debido por ejemplo a su contribución en el control de plagas (Iperti, 1999; Kromp, 1999) o a su papel como recurso alimenticio para pájaros asociados a los cultivos (Holland & Luff, 2000). Como resultado de su sensibilidad, su reacción puede ser usada para detectar e identificar la naturaleza de los impactos o los cambios en la calidad (Çilgi, 1994), o predecir el impacto sobre toda la entomofauna (Bohac, 1999), siendo por tanto considerados como indicadores (McGeoch, 1998). Diferentes familias de coleópteros han sido propuestas como tales, en algunos casos junto con otros grupos como el de las arañas (Pearce & Venier, 2006) o isópodos (Hadjicharalampous *et al.*, 2002). Los grupos de coleópteros indicadores más comúnmente citados en la literatura son los estafilínidos y carábidos (Bohac, 1999; Luka, 1996; Melke & Gutowski, 1995; Rainio & Niemelä, 2003).

1.4.4 Taxonomía sustitutiva

La identificación a nivel de especie es complicada y requiere la inversión de muchos recursos económicos y en términos de tiempo (Biaggini *et al.*, 2007), sobretodo teniendo en cuenta el extenso número de familias con distintas ecologías, biologías y requerimientos ambientales. Así, con objetivo de reducir el tiempo y el esfuerzo del proceso de identificación de especies, disminuir ampliamente la dependencia de taxónomos especialistas (Wilkie *et al.*, 2003) y permitir así diseños más ambiciosos de muestreo, surge la idea de "evaluación rápida de la biodiversidad" (Rapid Biodiversity Assessment: RBA) propuesta por Oliver y Beattie (1996). La "taxonomía sustitutiva" (taxonomic surrogacy) es una de las cuatro categorías de rápida asistencia de la diversidad y la aproximación mediante RBA ha sido desarrollada para encontrar en un corto plazo de tiempo, orientación científica para las personas que se encargan de gestionar y realizar políticas ambientales y agrícolas (Boone *et al.*, 2005).

De la misma manera el uso de altos taxones o morfoespecies sustitutas de especies (species surrogacy) soporta esta aproximación como una rápida, económica y efectiva herramienta de atajo para conseguir los diferentes objetivos (Derraik *et al.*, 2002; Krell, 2004; Kremen *et al.*, 1993; Woodcock *et al.*, 2006).



Algunos grupos de coleópteros, arañas o lepidópteros (Derraik *et al.*, 2002) pueden ser identificados a nivel de morfoespecie, por lo que ésta puede ser utilizada como unidad taxonómica (recognizable taxonomic unit RTU). Este término se refiere a la identificación unificando características de acuerdo con similitudes morfológicas sin considerar la literatura taxonómica o los estándares taxonómicos (Krell, 2004). La precisión en la identificación de morfoespecies es bastante variable dependiendo del tipo de grupo de artrópodos del que se trate, y además deberá ser establecido sobre la base de la relación de especies-morfoespecies para cada grupo (Derraik *et al.*, 2002). De acuerdo con Lawton *et al.* (1998), una alta proporción de morfoespecies no puede ser asignadas a especies concretas, y el número de horas que los científicos requieren en el proceso de identificación disminuyen enormemente con el tamaño de los cuerpos de los taxones.

1.5 Bibliografía

Alonso, A. M. & Guzmán, G. I. (2006). Evaluación comparada de la sostenibilidad agraria en el olivar ecológico y convencional. *Agroecologí*a **1**, 63-73.

Altieri, M. A. (1987). *Agroecology: the scientific basis of alternative agriculture.* Westview Press, Boulder, Colorado, 227 pp.

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment*, **74**, 19-31.

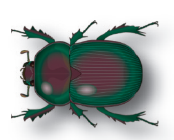
Álvarez, T., Frampton, G. K. & Goulson, D. (2000). Epigeic Collembola in winter wheat under organic, integrated and conventional farm management regimes. *Agriculture, Ecosystems & Environment*, **83**, 95-110.

Andersen, A. N. (1990). The use of ant communities to evaluate change in Australian terrestrial ecosystems: a review and a recipe. *Proceedings of the Ecological Society of Australia*, **16**, 347-357.

Biaggini, M., Consorti, R., Dapporto, L., Dellacasa, M., Paggetti, E. & Corti, C. (2007). The taxonomic level order as a possible tool for rapid assessment of Arthropod diversity in agricultural landscapes. *Agriculture, Ecosystems & Environment*, **122**, 183-191

Bohac, J. (1999). Staphylinid beetles as bioindicators. *Agriculture, Ecosystems & Environment*, **74**, 357-372.

Bolger, D. T., Suarez, A. V., Crooks, K. R., Morrison, S. A. & Case, T. J. (2000). Arthropods in urban habitat fragments in southern California: area, age, and edge effects. *Ecological Applications*, **10**, 1230-1248.



Boone, J. H., Mahan, C. G. & Kim, K. C. (2005). Biodiversity inventory: approaches, analysis, and synthesis. Technical Report NPS/NER/NRTR-2005/015 ed. N. P. S. Dept. Interior, Northeast Region, National Park Service. Philadelphia, PA, pp. 38.

Brown, K. S. (1997). Diversity, disturbance, and sustainable use of Neotropical forests: insects as indicators for conservation monitoring. *Journal of Insect Conservation*, **1**, 25-42.

Büchs, W. (2003). Biodiversity and agri-environmental indicators-general scopes and skills with special reference to the habitat level. *Agriculture, Ecosystems & Environment*, **98**, 35-78.

Büchs, W., Harenberg, A., Zimmermann, J. & Weiß, B. (2003). Biodiversity, the ultimate agri-environmental indicator? Potential and limits for the application faunistic elements as gradual indicators in agroecosystems. *Agriculture, Ecosystems & Environment*, **98**, 99-123.

Çilgi, T. (1994). Selecting arthropod "indicator species" for environmental impact assessment of pesticides in field studies. *Aspects of Applied Biology*, **37**, 131-140.

Clough, Y., Kruess, A. & Tscharntke, T. (2007). Organic versus conventional arable farming systems: Functional grouping helps understand staphylinidresponse. *Agriculture, Ecosystems & Environment*, **118**, 285-290.

Cole, L. J., McCracken, D. I., Downie, I. S., Dennis, P., Foster, G. N., Waterhouse, A., Murphy, K. J., Griffen, A. L. & Kennedy, M. P. (2005). Comparing the effects of farming practices on ground beetle (Coleoptera: Carabidae) and spider (Araneae) assemblages on Scottish farmland. *Biodiversity & Conservation*, **14**, 441-460.

Comisión sobre Medio Ambiente y Desarrollo *Comisión Brundtland* (1987). Our common future, Oxford University Press. Oxford, Reino Unido/ Nueva York, Estados Unidos.

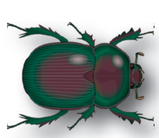
Consejería de Agricultura y Pesca. Junta de Andalucía (2003). *El olivar andaluz.* Servicio de Publicaciones y Divulgación, Sevilla.

Chamberlain, D. E., Fuller, R. J., Bunce, R. G. H., Duckworth, J. C. & Shrubb, M. (2000). Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of Applied Ecology*, **37**, 771-788.

de Graaff, J. & Eppink, L. A. A. J. (1999). Olive oil production and soil conservation in southern Spain, in relation to EU subsidy policies. *Land Use Policy*, **16**, 259-267.

Derraik, J., Closs, G., Dickinson, K., Sirvid, P., Barratt, B. & Patrick, B. (2002). Arthropod morphospecies versus taxonomic species: a case study with Araneae, Coleoptera, and Lepidoptera. *Conservation Biology*, **16**, 1015-1023.

Döring, T. F., Möller, A., Wehke, S., Schulte, G. & Broll, G. (2003). Biotic indicators of carabid species richness on organically and conventionally managed arable fields. Agriculture, *Ecosystems & Environment*, **98**, 133-139.



Duelli, P. & Obrist, M. K. (2003). Regional biodiversity in an agricultural landscape: the contribution of semi-natural habitat islands. *Basic and Applied Ecology*, **4**, 129-138.

Fauvel, G. (1999). Diversity of Heteroptera in agroecosystems: role of sustainability and bioindication. *Agriculture, Ecosystems & Environment*, **74**, 275-303.

Firbank, L. G., Petit, S., Smart, S., Blain, A. & Fuller, R. J. (2008). Assessing the impacts of agricultural intensification on biodiversity: a British perspective. *Philosophical Transactions of the Royal Society (B)*, **363**, 777-787.

González-Andújar, J. L. (2009). Expert system for pests, diseases and weeds identification in olive crops. *Expert Systems with Applications*, **36**, 3278-3283.

González, J. L., Garzón, P. & Merino, M. (1990). Census of the Lesser Krestrel population in Spain. *Quercus*, **49**, 6-12.

Green, R. E., Cornell, S. J., Scharlemann, P. W. & Balmford, A. (2005). Farming and the fate of wild nature. *Science*, **307**, 550-555.

Guzmán, G. & Alonso, A. (2004). Manejo del suelo en el olivar ecológico. In *Manual de Olivicultura ecológica*, Vol. II, Universidad de Córdoba. Córdoba, pp. 27-51.

Hadjicharalampous, E., Kalburtji, K. L. & Mamolos, A. P. (2002). Soil Arthropods (Coleoptera, Isopoda) in Organic and Conventional Agroecosystems. *Environmental Management*, **29**, 683-690.

Harrington, R. & Stork, N. E. (1995). *Insects in a changing environment*. Academic press, 533 pp.

Heyer, W., Hülsbergen, K. J., Wittman, C., Papaja, S. & Christen, O. (2003). Field related organisms as possible indicators for evaluation of land use intensity. *Agriculture, Ecosystems & Environment,* **98**, 453-461.

Holland, J. M. & Luff, M. L. (2000). The Effects of Agricultural Practices on Carabidae in Temperate Agroecosystems. *Integrated Pest Management Reviews*, **5**, 109-129.

Iperti, G. (1999). Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture, Ecosystems & Environment*, **74**, 323-342.

Jackson, L., Bawa, K., Pascual, U. & Perrings, C. (2005). *agroBIODIVERSITY: A New Science Agenda for Biodiversity in Support of Sustainable Agroecosystems*. DIVERSITAS Report N°4, Paris, 40 pp.

Kimberling, D. N., Karr, J. R. & Fore, L. S. (2001). Measuring human disturbance using terrestrial invertebrates in the shrub-steppe of eastern Washington (USA). *Ecological Indicators*, **1**, 63-81.

Kleijn, D., Berendse, F., Smit, R. & Gilissen, N. (2001). Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes? *Nature*, **413**, 723-725.

Krebs, J. R., Wilson, J. D., Bradbury, R. B. & Siriwardena, G. M. (1999). The second silent spring? *Nature*, **400**, 611-612.

Krell, F. T. (2004). Parataxonomy vs. taxonomy in biodiversity studies-pitfalls and applicability of "morphospecies" sorting. *Biodiversity and Conservation*, **13**, 795-812.

Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R. F. & Sanjayan, M. A. (1993). Terrestrial arthropod assemblages: their use in conservation planning. *Conservation Biology,* **7**, 796-808.

Kromp, B. (1999). Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems & Environment*, **74**, 187-228.

La Salle, J. (1999). Insect biodiversity in agroecosystems: function, value and optimization. In *Wood D, Lenné JM. Agrobiodiversity: Characterization, Utilization and Management*, CAB International. Wallingford, UK, pp. 155-182.

Labrador, J. & Altieri, M. A. (2001). *Agroecología y desarrollo. Aproximación a los fundamentos agroecológicos para la gestión sustentable de agrosistemas mediterráneos*. Universidad de Extremadura. Ediciones Mundi-Prensa, Cáceres-Madrid.

Lawton, J. H., Bignell, D. E., Bolton, R., Bloemers, G. F., Eggleton, P., Hammond, P. M., Hodda, M., Holt, R. D., Larsen, T. B., Mawdsley, N. A., Stork, N. E., Srivastava, D. S. & Watt, A. D. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forests. *Nature*, **391**, 72-75.

Letourneau, D. K. & Goldstein, B. (2001). Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology*, **38**, 557-570.

Loumou, A. & Giourga, C. (2003). Olive groves: "The life and identity of the Mediterranean". *Agriculture and Human Values*, **20**, 87-95.

Luka, H. (1996). Laufkäfer: Nützlinge und Bioindikatoren in der Landwirtschaft. *Agrarforschung*, **3**, 33-36.

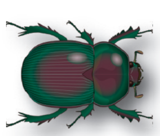
Marc, P., Canard, A. & Ysnel, F. (1999). Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture, Ecosystems & Environment*, **74**, 229-273.

McGeoch, M. A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, **73**, 181-201.

McNeely, J. A. & Scherr, S. J. (2003). *Ecoagriculture : strategies to feed the world and save biodiversity*. Island Press, Washington, 323 pp.

Melke, A. & Gutowski, J. M. (1995). Zmiany fauny kusakowatych (Coleoptera: Staphylinidae) œro-dowiska leœnego jako element monitoringu ekologicznego w pónocno-wschodniej Polsce. *Prace Inst. Bad. Leœn., A.*, **793**, 87-105.

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: biodiversity synthesis, DC: World Resources Institute. Washington.



Moreno, C. E., Sanchez-Rojas, G., Pineda, E. & Escobar, F. (2007). Shortcuts for biodiversity evaluation: a review of terminology and recommendations for the use of target groups, bioindicators and surrogates. *International Journal of Environment and Health*, **1**, 71-86.

Muramoto, J. & Gliessman, S. R. (2006). Bioindicators: Use for Assessing Sustainability of Farming Practices. In *Encyclopedia of Pest Management*, Taylor & Francis, pp. 1-5.

NERI (1995). *Nature indicators survey. Report to Topic Centre Paris*. Ministry ofthe Environment and Energy & National Environmental Research Institute, Denmark.

New, T. R. (1999). Untangling the web: spiders and the challenges of invertebrate conservation. *Journal of Insect Conservation*, **3**, 251-256.

OECD (1997). Environmental Indicators for Agriculture, Paris.

OECD (1999a). Agri-environmental Indicators: Work in Progress.

OECD (1999b). Environmental Indicators for Agriculture. Concepts and Framework, Paris.

OECD (1999c). Measuring the Environmental Impacts of Agriculture: The York Workshop, Paris.

OECD (2000). Agri-environmental indicators for sustainable agriculture in Europe.

OECD (2001). Environmental Indicators for agriculture. Methods and Results. Organization for Economic Co-operation and Development, Paris, France.

OECD (2003). Environmental Indicators: Development, Measurement and Use.

Oliver, I. & Beattie, A. J. (1996). Designing a cost-effective invertebrate survey: A test of methods for rapid assessment of biodiversity. *Ecological Applications*, **6**, 594- 607.

Pajarón Sotomayor, M. (2003). La reconversión al olivar ecológico: el caso de Andalucía. In *Fundamentos de agricultura ecológica: realidad y perspectivas*, eds. R. Meco, C. Fabeiro & J. De las Heras, Universidad de Castilla-La Mancha. Cuenca, pp. 213-238.

Pajarón Sotomayor, M. (2008). *El olivar ecológico*. La Fertilidad de la Tierra, Estella, 153 pp.

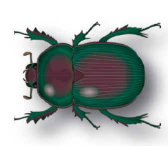
Paoletti, M. G. (1999a). Using bioindicators based on biodiversity to assess landscape sustainability. *Agriculture, Ecosystems & Environment*, **74**, 1-18.

Paoletti, M. G. (1999b). The role of earthworms for assessment of sustainability and as bioindicators. *Agriculture, Ecosystems & Environment*, **74**, 137-155.

Paoletti, M. G. & Bressan, M. (1996). Soil Invertebrates as bioindicators of Human Disturbance. *Critical Reviews in Plant Sciences*, **15**, 21-62.

Parra López, C. & Calatrava Requena, J. (2006). Comparison of farming techniques actually implemented and their rationality in organic and conventional olive groves in Andalusia, Spain. *Biological Agriculture & Horticulture*, **24**, 35-59.

Pearce, J. L. & Venier, L. A. (2006). The use of ground beetles (Coleoptera: Carabidae) and spiders(Araneae) as bioindicators of sustainable forest management: A review. *Ecological Indicators*, **6**, 780-793.



Perner, J. & Malt, S. (2003). Assessment of changing agricultural land use: response of vegetation, ground-dwelling spiders and beetles to the conversion of arable land into grassland. *Agriculture, Ecosystems & Environment*, **98**, 169-181.

Perrings, C., Jackson, L., Bawa, K., Brussaard, L., Brush, S., Gavin, T., Papa, R., Pascual, U. & de Ruiter, P. (2006). Biodiversity in agricultural landscapes: Saving natural capital without losing interest. *Conservation Biology in Practice*, **20**, 263-264.

Platen, R., Rademacher, J. & Schultz-Sternberg, R. (2001). Beurteilung des ökologischen Zustandes eines Niedermoores mit Hilfe von Arthropoden als Bioindikatoren. Naturschutz und Nandschaftsplanung. *Naturschutz und Landschaftspflege in Brandenburg*, **10**, 29-35.

Purtauf, T., Roschewitz, I., Dauber, J., Thies, C., Tscharntke, T. & Wolters, V. (2005). Landscape context of organic and conventional farms: influences on carabid beetle diversity. Agriculture, *Ecosystems & Environment*, **108**, 165-174.

Rainio, J. & Niemelä, J. (2003). Ground Beetles (Coleoptera : Carabidae) as Bioindicators. *Biodiversity and Conservation*, **12**, 487-506.

Rowell, T. A. (1994). *Ecological indicators for nature conservation monitoring*. Joint Nature Conservation Committee Report, no. 196, Peterborough.

Sevilla Guzmán, E. (1995). El marco teórico de la agroecología. Agroecología y conocimiento social. Módulo I - Agroecología y Conocimiento Local In *Materiales de trabajo de Ciclos de Cursos y Seminarios sobre Agroecologia y Desarrollo Sosbenible en América Latina y Europa*, ed. S. M. d. l. R. Univers, Universidad Internacional de Andalucía/Universidad de Córdoba-ISEC. pp. 3-28. La Rábida, Huelva.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D.,Schlesinger, W. H., Simberloff, D. & Swackhamer, D. (2001). Forecasting agriculturally driven global environmental change. *Science*, **292**, 281-284.

Tucker, G. M. (1998). *Measuring the impacts of agriculture on biodiversity*. F. Brower and B. Crabtree (eds), Wallingford, UK.

Tucker, G. M. & Heath, M. F. (1994). *Birds in Europe: Their Conservation Status*, Cambridge, UK, 600 pp.

van Straalen, N. M. (1997). Community structure of soil arthropods as a bioindicator of soil health. In *Biology Indicators of Soil Health*, eds. C. E. Pankhurst,B.M. Doube & V. V. S. R. Gupta. CAB International, Wallingford, pp. 235-264.

van Straalen, N. M. (1998). Evaluation of bioindicator systems derived from soil arthropod communities. *Applied Soil Ecology*, **9**, 429-437.

van Straalen, N. M. & Verhoef, H. A. (1997). The development of a bioindicator system from soil acidity based on arthropod pH preferences. *Journal of Applied Ecology*, **34**, 217-232.

Wihlm, J. L. & Dorris, T. C. (1968). Biological parameters for quality criteria. *Bioscience*, **8**, 477-481.

Wilkie, L., Cassis, G. & Gray, M. R. (2003). A quality control protocol for terrestrial invertebrate biodiversity assessment. *Biodiversity and Conservation*, **12**, 121-146.

Woodcock, B. A., Lawson, C. S., Mann, D. J. & McDonald, A. W. (2006). Effects of grazing management on beetle and plant assemblages during the recreation of a flood-plain meadow. *Agriculture, Ecosystems & Environment*, **116**, 225-234.

Zalidis, C. Z., Tsiafouli, M. A., Takavakoglou, V., Bilas, G. & Misopolinos, N. (2004). Selecting agri-environmental indicators to facilitate monitoring and assessment of EU agri-environmental measures effectiveness. *Journal of Environmental Management*, **70**, 315-321.

2. Objetivos

2. Objetivos

En este trabajo de tesis doctoral los dos objetivos generales propuestos fueron (1) conocer el impacto que tienen los diferentes manejos agronómicos y la estructura del paisaje sobre la entomofauna que habita en el olivar y (2) evaluar el potencial de distintos grupos taxonómicos de insectos como agentes indicadores del tipo de manejo del mismo. Estos dos grandes objetivos generales se desglosaron en seis objetivos específicos que se han desarrollado en seis apartados distintos:

- Objetivo específico 1: establecer la posibilidad de utilizar determinados órdenes de insectos capturados en la copa de los olivos como predictores del tipo de manejo aplicado.

- Objetivo específico 2: estudiar la abundancia y diversidad de las distintas familias de coleópteros capturados en la copa del olivo, teniendo en cuenta los distintos manejos y las características del paisaje.

- Objetivo específico 3: evaluar la eficacia del uso de morfoespecies de coccinélidos capturados en la copa del olivo, para diferenciar el tipo de manejo agronómico.

- Objetivo específico 4: utilizar los coccinélidos capturados en la copa del olivo como indicadores del tipo de manejo en otras regiones olivareras de Andalucía.

- Objetivo específico 5: estudiar la abundancia y diversidad de los insectos del suelo del olivar a nivel de orden y las familias de coleópteros.

- Objetivo específico 6: determinar el efecto de la eliminación de la cubierta vegetal en un olivar ecológico sobre los coleópteros de suelo.

3. Material y métodos

3.1 Zonas de estudio

Las tres provincias donde se ha realizado este estudio se localizan en el sureste español y pertenecen a la comunidad autónoma de Andalucía (Figura 3.1). Se escogieron cuatro comarcas con una larga tradición olivarera, la comarca de Los Pedroches en la provincia de Córdoba, la comarca de Los Montes y la comarca de La Vega en la provincia de Granada y el municipio de Mancha Real en la provincia de Jaén.

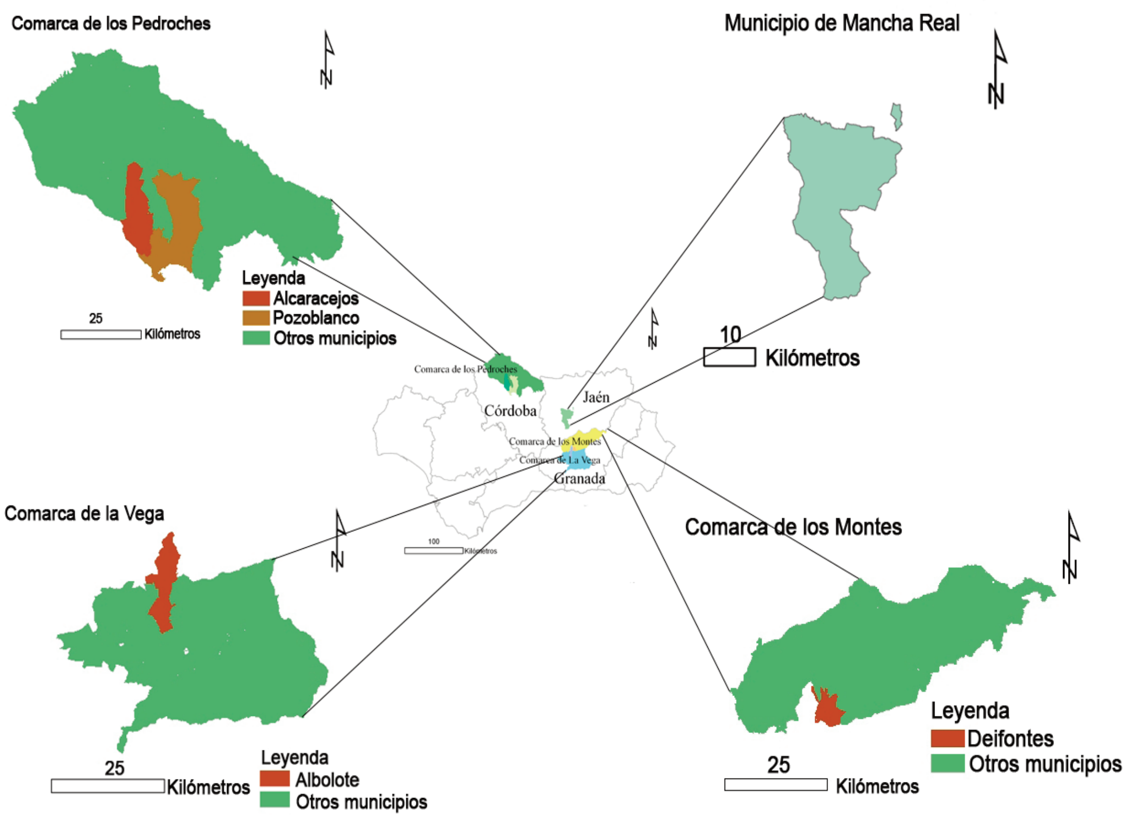


Figura 3.1: Localización de las parcelas muestreadas, indicando el municipio y la comarca a la que pertenecen.

3.1.1 Provincia de Córdoba

En la provincia de Córdoba, la zona escogida para desarrollar el estudio es la comarca de Los Pedroches, también llamada Valle de los Pedroches. Las características más relevantes de dicha comarca son:

- Ubicación: Los Pedroches es una comarca de 3.612 km² localizada al norte de la provincia de Córdoba. Con una altitud media de 615 msnm limita al noroeste con Extremadura, al noreste con la comunidad autónoma de Castilla la Mancha, al sureste con la provincia de Jaén y por el sur y suroeste con el resto de la provincia de Córdoba.

• Características naturales: presenta un clima mediterráneo subhúmedo, con una temperatura media de 27 ºC en verano y 8 ºC en invierno. La presencia de lluvias es irregular en invierno con una media de 600 mm por año.

• Paisaje: caracterizado por la presencia de dehesa alternando con tierras de cultivo y porciones de bosque o matorrales herbáceos o leñosos.

• Población: este municipio cuenta con una población de 60.000 habitantes y se encuentra concentrada principalmente en tres núcleos: Pozoblanco, Villanueva de Córdoba e Hinojosa, los cuales albergan más de la mitad de sus habitantes.

• Olivar: la comarca presenta un paisaje donde los olivos cubren las laderas de Sierra Morena. Existen diversas variedades como Nevado Blanco, Lechín, Nevado Negro, Picudo o Picual entre otros. La abundante vegetación natural y orografía, así como las características socioeconómicas de la zona originaron explotaciones de olivar ecológico. Este cultivo sólo representa una pequeña parte de los ingresos de la unidad familiar. En esta región los olivares están cultivados de forma extensiva, puesto que se trata de olivares adhesados para el pastoreo de ovino, vacuno o el recebo de porcino, y ciertos tipos (Figura 3.2), así como olivares explotados con criterios ecológicos (Álvarez Guzmán, 1999).

Un total de nueve parcelas fueron muestreadas en esta comarca, tres de las cuales estaban bajo manejo ecológico, tres bajo integrado y tres bajo convencional (Tabla 3.1) (Figura 3.3).

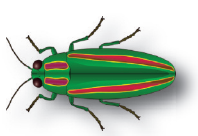
Figura 3.2: Paisaje de olivar en Pedroches.

Figura 3.3: Vista parcial de una parcela ecológica en Pedroches.

Tabla 3.1: Parcelas muestreadas en Córdoba, indicando prácticas agronómicas en cada manejo, coordenadas geográficas y características generales en cada parcela.

Parcela	Tipo de Manejo	Riego	Arado	Insecticidas	Herbicidas	Cubierta vegetal	Setos	Coordenadas geográficas	Altura (m)	Pendiente media (%)	Superficie total (Ha)	Nº total de olivos	Variedad
A	Convencional	No	No	Sí	Sí	No	No	333326,38E 4233356,26N	597	28,21	9,70	1469	Picual
B	Integrado	No	No	Sí	Sí	Sí	No	334979,59E 4231316,19N	637	20,40	31,90	3450	Picual
C	Ecológico	No	Sí	No	No	Sí	No	335710,00E 4231255,00N	638	25,70	44,70	Sin datos	Picual
D	Convencional	No	Si	Sí	Sí	Sí	Sí	335648,08E 4231810,27N	616	25,48	27,60	3378	Picual
E	Ecológico	Sí	No	No	No	Sí	No	335548,10E 4229775,36N	597	26,71	24,30	2752	Picual
F	Convencional	No	Sí	Sí	Sí	No	Sí	334642,17E 4228002,36N	456	35,00	7,40	702	Picual
G	Integrado	No	No	Sí	No	Sí	No	340016,00E 4227788,00N	562	15,20	5,90	Sin datos	Picual
H	Ecológico	No	Sí	No	No	Sí	Sí	336971,55E 4228473,74N	650	31,13	6,80	935	Picual
I	Integrado	No	No	Sí	Sí	No	No	336763,00E 4228376,00NS	562	15,20	5,90	Sin datos	Picual

Las nueve parcelas de Córdoba se nombraron de la A a la I y pertenecen a los municipios de Alcaracejos y Pozoblanco. Están distribuidas geográficamente como muestra la Figura 3.4.



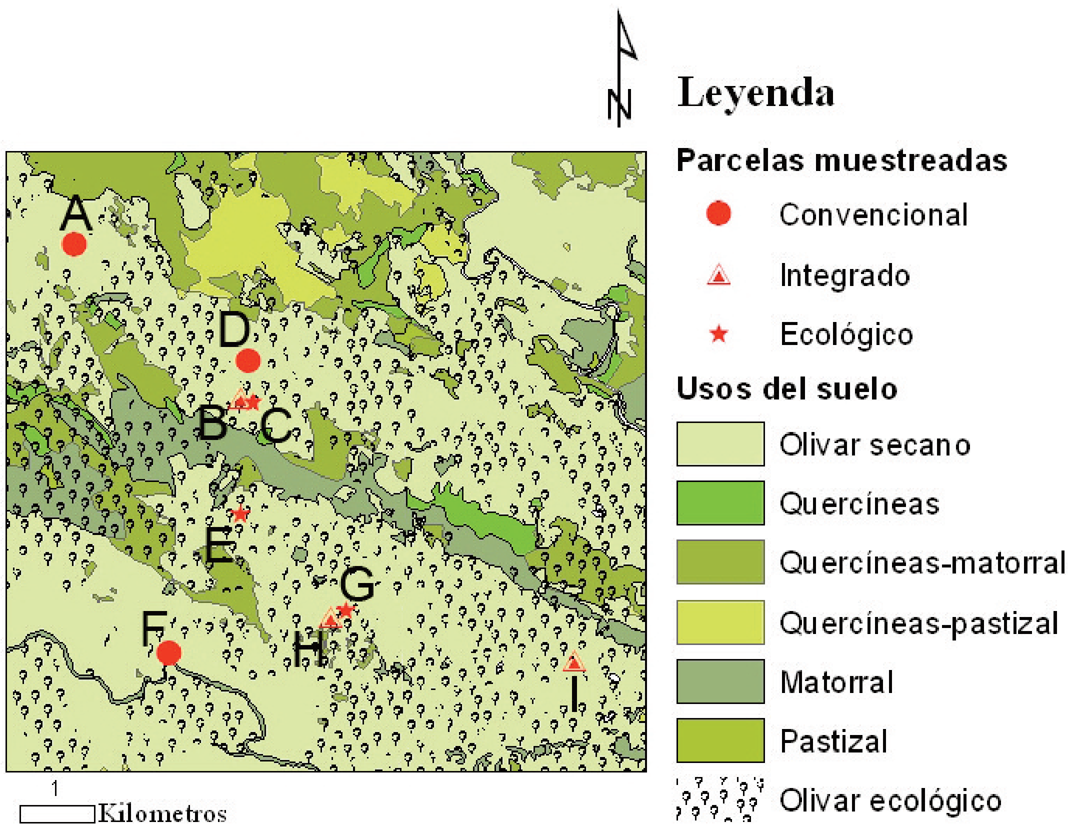


Figura 3.4: Localización de las parcelas muestreadas en la provincia de Córdoba indicando las características del paisaje.

3.1.2 Provincia de Granada

En la provincia de Granada, las parcelas de estudio están enmarcadas en la comarca de Los Montes Orientales y en la de La Vega. Las características de estas dos comarcas son:

- Ubicación: la comarca de Los Montes Orientales se encuentra situada en la parte nororiental de la provincia de Granada (subbética granadina). Ocupa aproximadamente 1.400 km², extendiéndose desde los ríos Fardes y Guadiana Menor hasta el río Frailes / Velillos. Su principal sistema montañoso, situado al este, es Sierra Arana, un doble alineamiento calizo anticlinal de 30 km de longitud, con una altitud media de 1.200 msnm, siendo su cota más alta el cerro de la Cruz, con 2.030 msnm. La comarca de La Vega está situada en la parte central, y ocupa una extensión de 1.363,22 km². Limita al norte con la comarca de Los Montes, al este con Guadix, al sureste con la Alpujarra granadina, al sur con el Valle de Lecrín, al suroeste con Alhama, y al oeste con Loja.

• Características naturales: la comarca de los Montes presenta un clima mediterráneo continental extremo, con inviernos largos, fríos y nevadas frecuentes, la temperatura media en enero oscila entre 6 y 7 ºC, como consecuencia de su gran altitud, y su proximidad a Sierra Nevada. En contraste, los veranos son largos, calurosos y secos, con casi 26 ºC de temperatura media en julio. Las precipitaciones son escasas y de distribución desigual, descendiendo de oeste a este: 700 mm/año en Iznalloz a 300 mm/año en Pedro Martínez. La Vega es una comarca caracterizada por su llanura en la parte occidental -a excepción de Sierra Elvira- y su relieve montañoso en el resto, con Sierra Nevada, Sierra de Huétor y Sierra de la Alfaguara.

• Paisaje: la comarca de Los Montes está dominada por colinas con agricultura tradicional, principalmente cultivos herbáceos, apareciendo zonas de montaña y lomas con vegetación natural y repoblada, aunque también cultivadas. Existen algunas llanuras irrigadas. La comarca de La Vega presenta zonas de cultivo de excelente fertilidad agrícola y masas arbóreas muy diversas, en especial las choperas.

• Población: los municipios que integran la comarca de Los Montes tienen aproximadamente 21.000 habitantes, mientras que La Vega está formada por cuarenta municipios y una población cercana a los 500.000 habitantes, puesto que engloba el municipio más poblado (ciudad de Granada).

• Olivar: ambas comarcas tienen una larga tradición olivarera reconocida como tal desde la época árabe. Dentro de la zona coexisten varios tipos variedades de olivo: Picual o Lucio, Loaime y variedades secundarias como Negrillo de Iznalloz, Escarabajuelo, Gordal de Granada y Hojiblanca. Según la descripción de Guzmán Álvarez (1999) estos olivares se engloban dentro de los intensivos, puesto que se trata de explotaciones más o menos tradicionales en las que se ejecutan las labores según calendario (Figura 3.5).

Figura 3.5: Vista de una parcela convencional en la comarca de La Vega.

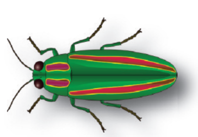
Figura 3.6: Vista de una parcela ecológica en la comarca de Los Montes.

Como en la provincia de Córdoba, nueve parcelas fueron muestreadas bajo los tres tipos de manejo (Figura 3.6).

Los municipios a los que pertenecen las parcelas son Albolote (comarca de La Vega) y Deifontes (comarca de Los Montes), las nueve parcelas se nombraron de la J a la R (Tabla 3.2), nomenclatura que se utilizó en todos los apartados y están situadas geográficamente como muestra la Figura 3.7.

Tabla 3.2: Parcelas muestreadas en Granada, indicando prácticas agronómicas en cada manejo, coordenadas geográficas y características generales en cada parcela.

Parcela	Tipo de Manejo	Riego	Arado	Insecticidas	Herbicidas	Cubierta vegetal	Setos	Coordenadas geográficas	Altura (m)	Pendiente media (%)	Superficie total (Ha)	Nº total de olivos	Variedad
j	Convencional	Sí	Sí	Sí	No	No	Sí	438986,15E 4130127,82N	715	4,10	11,36	1352	Picual
K	Integrado	Sí	No	Sí	Sí	Sí	No	441190,07E 4129513,54N	745	6,11	256,48	19457	Picual
L	Integrado	Sí	Sí	Sí	No	No	Sí	442864,06E 4132384,84N	751	4,58	57,02	4362	Picual
M	Ecológico	Sí	No	No	Sí	No	No	446692,69E 4132239,70N	821	27,60	2,38	235	Picual
N	Integrado	No	Sí	No	No	No	Sí	447575,81E 4132355,94N	751	26,86	0,61	81	Picual
O	Convencional	Sí	Sí	Sí	No	No	Sí	449981,29E 4131990,40N	1028	24,72	2,04	231	Picual
P	Ecológico	Sí	No	No	Sí	Sí	No	450388,71E 4132048,45N	1026	6,80	0,97	141	Picual
Q	Convencional	Sí	Sí	Sí	Sí	No	Sí	450238,18E 4132114,73N	1013	7,90	2,04	309	Picual
R	Ecológico	Sí	No	No	Sí	SÍ	No	449549,72E 4130741,18N	1035	9,30	1,44	265	Picual



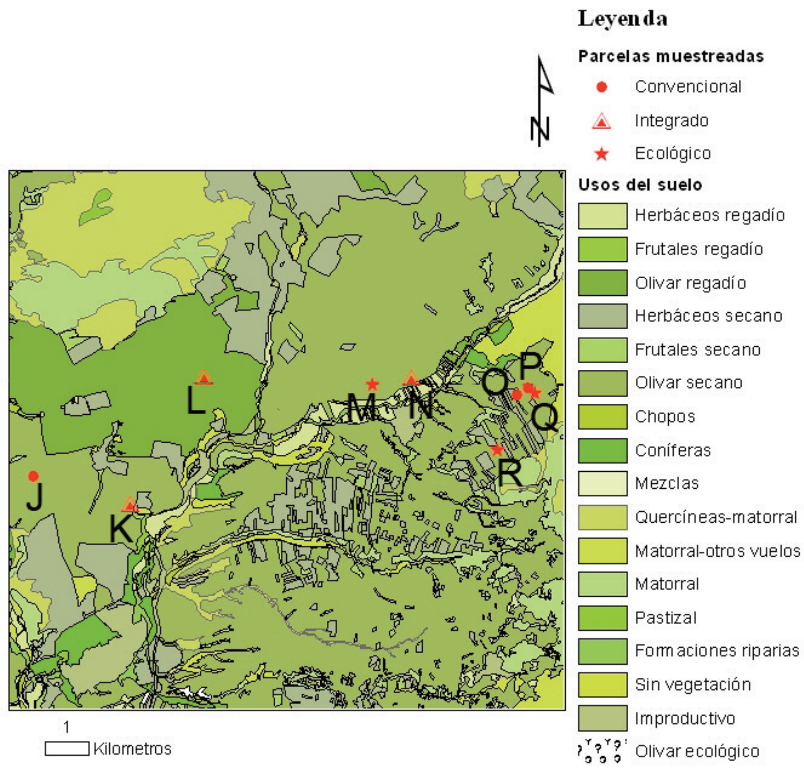


Figura 3.7: Localización de las parcelas muestreadas en la provincia de Granada indicando las características del paisaje.

3.1.3 Provincia de Jaén

El estudio, sobre la incidencia de la eliminación de las cubiertas vegetales sobre las familias de coleópteros del suelo, se llevó a cabo en una parcela perteneciente a la provincia de Jaén, la cual está situada en el término municipal de Mancha Real (443391E 4190638N). El municipio cuenta con una población de 10.616 habitantes, limita al este con el municipio de Jaén, hacia el norte con el río Guadalquivir, donde se encuentra la campiña olivarera de este municipio y al sur limita con las estribaciones de Sierra Mágina, donde se encuentran los terrenos forestales del municipio. El clima es mediterráneo continentalizado, frío en invierno, con temperaturas mínimas por debajo de -3°C y abundantes heladas, mientras que el verano es caluroso con máximas que alcanzan los 40 °C. Las precipitaciones son muy escasas en verano, se concentran en los meses invernales, final del otoño y principio de primavera. En cuanto a la actividad económica de la zona se reparte entre la olivicultura y la industria oleícola, muy desarrolladas, la industria del mueble de madera, en fuerte crecimiento, la industria de aperos y maquinaria agrícola y la fabricación de ordenadores que, en conjunto, hacen de esta localidad una de las más ricas y dinámicas de la provincia de Jaén.

La finca muestreada es un olivar de variedad Picual manejado bajo agricultura ecológica desde el año 2002. La plantación abarca unas 25 ha conteniendo la parcela unos 156 olivos (Figura 3.8), siendo los usos del suelo en las parcelas adyacentes en su mayoría olivar ecológico en regadío y matorral (Figura 3.9).

Figura 3.8: Vista parcial de la parcela ecológica en Mancha Real.

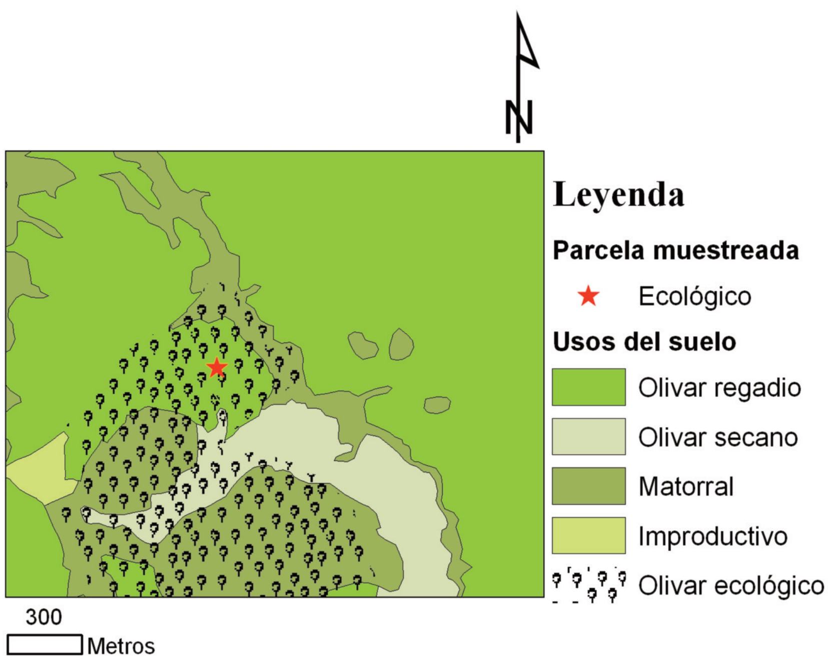


Figura 3.9: Localización de la parcela muestreada en la provincia de Jaén indicando las características del paisaje.

3.2 Diseño de muestreo

Una vez elegido al azar el primer árbol a muestrear se siguió en el campo el diseño mostrado en la figura 3.10. Se muestrearon cinco árboles por cada fila, separados entre sí por un árbol no muestreado, así la distancia entre dos árboles muestreados fue de 20 metros. Cada grupo de cinco árboles muestreados representó la unidad muestral de este estudio (*bloque*). El tamaño de cada parcela era lo suficientemente grande como para garantizar que cada unidad muestral fuera considerada una auténtica réplica, ya que la distancia mínima entre dos unidades muestrales (un mínimo de 0,5 km) aseguraba su independencia (Cárdenas, 2008).

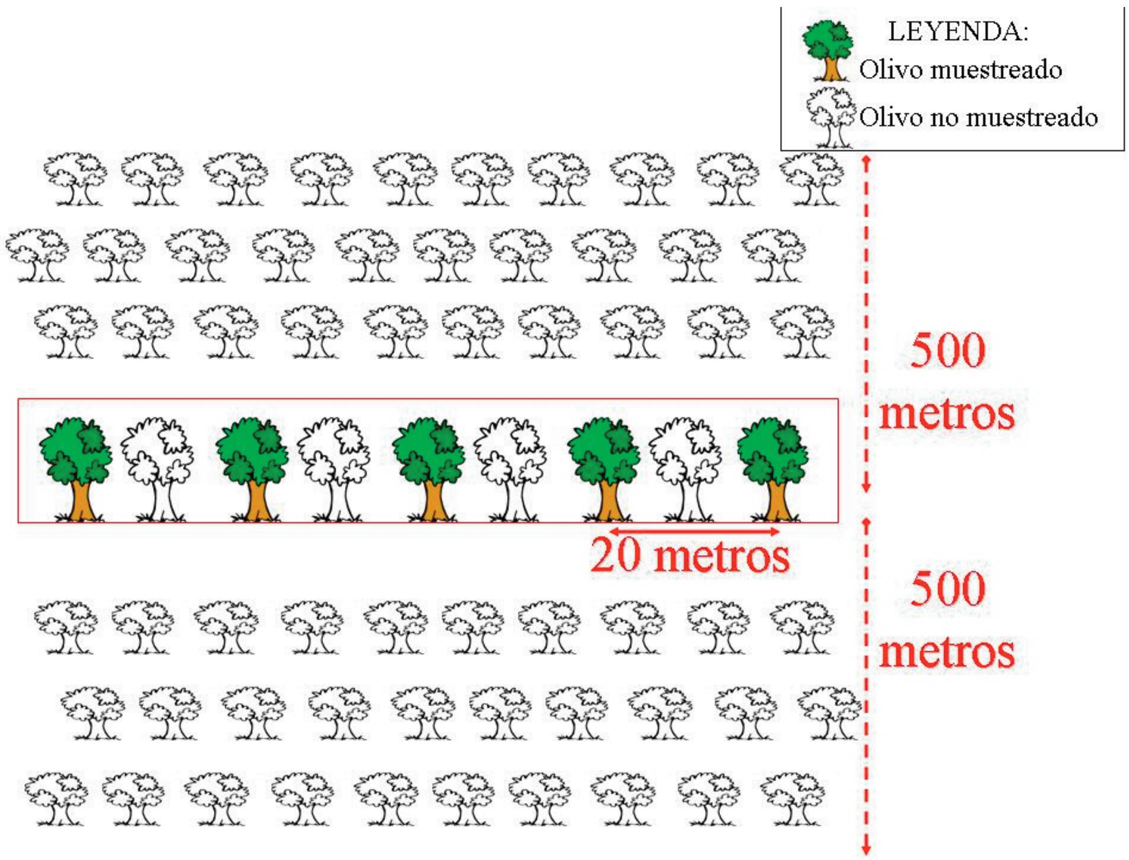


Figura 3.10: Diseño experimental seguido en las parcelas muestreadas.

El número de unidades muestrales tomadas en cada parcela varió a lo largo de los años, en 1999 se comenzó con seis unidades (30 árboles), siguiendo con cinco unidades (25 árboles) en 2000 y finalmente cuatro unidades en 2003

(20 árboles). Esta variación en el número de unidades muestrales es resultado de los cálculos realizados para mantener el esfuerzo de muestreo, disminuyendo el número de muestras sin disminuir significativamente la precisión. Sin embargo, en algunos ensayos de esta Tesis se ha prescindido justificadamente de algunas unidades, a fin de homogeneizar el tamaño de muestra con fines comparativos.

3.3 Técnicas de muestreo

3.3.1 Vareo en la copa de los olivos

Esta técnica de muestreo consistió en la elección de un grupo de ramas al azar situadas a una altura aproximada de 1,5 - 1,75 m sobre el suelo, las cuales fueron agitadas cinco veces dentro de una bolsa de plástico (Figura 3.11). Este proceso se repitió en cada árbol cuatro veces, una por orientación. Los insectos recogidos en la bolsa de plástico fueron llevados al laboratorio. Para impedir durante el traslado la interacción entre los artrópodos y evitar la huida de aquellos más esquivos y la posible depredación, se colocó en el interior de la bolsa un ¼ de pastilla de DDVP Strips ® (Diclorovos), un insecticida de alta tasa de evaporación.

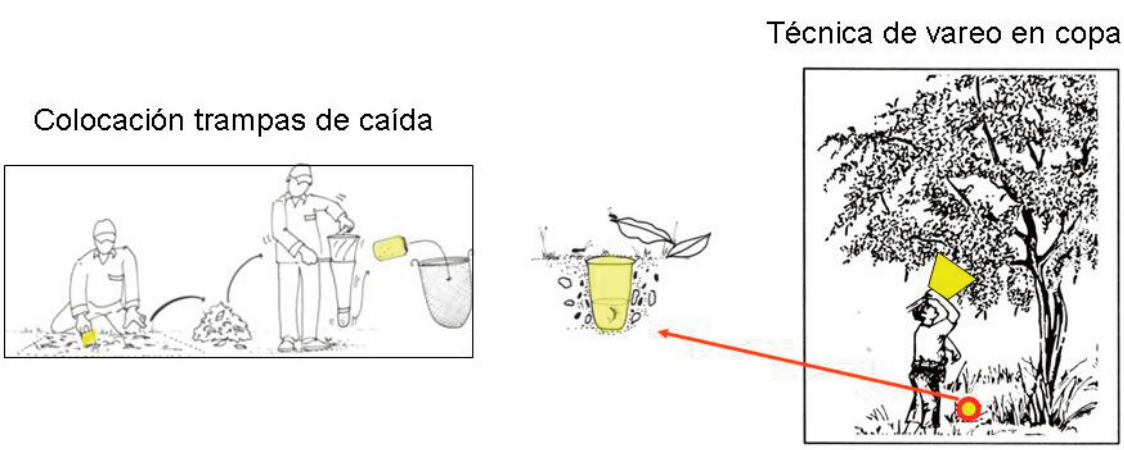


Figura 3.11: Colocación de trampas de caída en suelo y técnica de vareo en copa.

3.3.2 Trampas de caída

Esta técnica desarrollada para recolectar insectos epígeos, consistió en la inserción en el suelo de recipientes de plástico de 7 cm de diámetro y una capacidad aproximada de 200 ml, los cuales eran rellenados hasta la mitad de su capacidad con una mezcla de detergente y agua.

La colocación se realizó en la orientación norte en la base de los árboles bajo copa (a 30 cm del tronco). Las trampas permanecieron en el suelo durante 24 horas antes de ser recogidas (Figura 3.11).

Excepcionalmente, para evaluar la incidencia de la eliminación de las cubiertas vegetales sobre los coleópteros del suelo, las trampas de caída presentaron otro diseño: el diámetro del vaso fue de 11 cm, fueron rellenadas líquido Scheerpeltz (60 % de alcohol de 96º, 39 % de agua destilada, 1% de ácido acético y 1% de glicerina) y además, permanecieron colocadas durante 48 horas.

La recogida y vaciado de las trampas de caída se realizó mediante la filtración del contenido con gasa de tamaño de malla de 0,2 mm, suficiente para recoger incluso los microartrópodos del suelo, la cual fue posteriormente introducida en un recipiente de plástico y transportada al laboratorio.

3.4 Procesado de las muestras en laboratorio

En el menor tiempo posible (unas horas) las muestras recogidas fueron debidamente etiquetadas y conservadas en arcones congeladores a -20 ºC, hasta el momento de su limpieza y posterior identificación.

Mediante el uso de un estereomicroscopio (Stemi SV8, Zeiss) y claves entomológicas se identificaron los insectos hasta el nivel taxonómico de orden, los coleópteros hasta el nivel de familia, los coccinélidos a nivel de especie y finalmente el resto de familias de coleópteros se identificaron a nivel de morfoespecie. Los especímenes una vez identificados fueron conservados en alcohol de 70 º y clasificados de acuerdo con su taxonomía en viales apropiados.

3.5 Análisis estadísticos

A continuación se resumen los métodos estadísticos aplicados en cada uno de los diferentes apartados.

3.5.1 Estadística univariante

En primer lugar, y previo a cualquier análisis, se estudió la distribución de los datos, que en la mayoría de los casos no presentaron distribuciones normales. A fin de conseguir la normalización de los mismos, se realizaron diversas transformaciones. Para comprobar la normalidad de los datos se calculó el estadístico de Kolmogorov-Smirnov, y en caso de no normalidad se ensayaron varias transformaciones, de las cuales la más usual fue la aplicación de la transformación logarítmica log10 (y+1). Cuando no fue posible normalizar los datos se aplicaron técnicas estadísticas no paramétricas. Como técnicas para el contraste de medias se usaron los tests clásicos t-Student en el caso paramétrico o para muestras grandes, y los contrastes U de Mann-Whitney (o su equivalente de suma de rangos de Wilcoxon) en el caso no paramétrico. Para el contraste de más de dos grupos, se consideró el modelo de Análisis de la Varianza (ANOVA) de efectos fijos en el caso paramétrico o de muestras grandes, y la prueba de Kruskal-Wallis en el caso no paramétrico. Para el modelo ANOVA, además de comprobar las hipótesis de independecia y normalidad, se comprobó la hipótesis de homoscedasticidad por medio de del test de Levene. Todos los contrastes fueron realizados con un nivel de significación del 95%.

A modo de resumen, los diversos tipos de contrastes mencionados se han aplicado con el objeto de encontrar en su caso diferencias entre los tres tipos de manejo: ecológico, integrado y convencional, o particularmente entre dos tipos: ecológico y no ecológico (integrado y convencional). Se han utilizado distintos análisis según el tipo de ensayo y la distribución de los datos (Tabla 3.3).

Tabla 3.3: Tipos de análisis estadísticos paramétricos y no paramétricos

Tipo de análisis	Paramétrico	No paramétrico
Describir un grupo	Media, desviación, coeficiente de variación	Mediana, rango intercuartil
Comparar medias para dos muestras independientes	t-Student	Mann-Whitney
Comparar medias para tres o más muestras independientes	ANOVA	Kruskal-Wallis

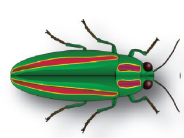
3.5.2 Estadística multivariante

Los análisis multivariantes o multivariados, a diferencia de los univariados, permitieron analizar los datos sobre la distribución de grupos de insectos mediante la observación del grado de asociación entre especies, entre especies y variables y el nivel de similitud entre muestras.

Los métodos de análisis de composición de especies se pueden dividir en análisis de ordenación y de clasificación y fueron aplicados en los diferentes apartados de esta Tesis doctoral como se señala en la Tabla 3.4.

Tabla 3.4: Modelo de decisión de análisis multivariados aplicados.

<table>
<tr><td>¿Qué pretendemos con los datos?</td><td colspan="5">Respuesta de las especies a las variables ambientales</td></tr>
<tr><td rowspan="4">1. Conocer la distribución de entidades en grados continuos: ORDENACIÓN</td><td>1.1 de una sola especie</td><td colspan="4">1.2 más de una especie</td></tr>
<tr><td rowspan="3">1.1.1 Modelos lienales generales (MLG) MANOVA de medidas repetidas (apartado 9)</td><td colspan="2">1.2.1 sólo datos de especies (métodos indirectos)</td><td colspan="2">1.2.2 especies y datos ambientales (métodos directos)</td></tr>
<tr><td>1.2.1.1 LINEAL</td><td>1.2.1.2 UNIMODAL</td><td>1.2.2.1 LINEAL</td><td>1.2.2.2 UNIMODAL</td></tr>
<tr><td>PCA (apartado 9)</td><td>CA (apartado 6)</td><td>RDA (apartado 5 y 8)</td><td>CCA (apartado 5)</td></tr>
<tr><td rowspan="3">2. Separar las entidades en diferentes categorías: CLASIFICACIÓN</td><td colspan="2" rowspan="3">2.1 No jerarquizada</td><td colspan="3">2.2 Jerarquizada</td></tr>
<tr><td rowspan="2">2.2.1 Aglomerativa (apartado 4)</td><td colspan="2">2.2.2 Divisiva</td></tr>
<tr><td>2.2.2.1 Monotético</td><td>2.2.2.2 Politético TWINSPAN (apartado 7)</td></tr>
<tr><td colspan="6">CA: análisis de correspondencias; CCA: análisis canónico de correspondencias; MANOVA: análisis múltiple de varianza; NLDA: análisis discriminante no lineal; PCA: análisis de componentes principales; RDA: análisis de redundancias; TWINSPAN: análisis de especies indicadoras de dos vías.</td></tr>
</table>



3.5.2.1 Métodos de ordenación

- **Métodos indirectos (o de reducción de la dimensión)**

Los métodos indirectos como el análisis de correspondencias (Correspondence Analysis CA), y el análisis de componentes principales (Principal Component Analysis PCA) buscan relaciones entre las distintas parcelas muestreadas sobre la base de los taxones encontrados sin mediar datos ambientales, aunque las mismas se infieren a partir de dicha variación espacial de las especies. Estos métodos se basan fundamentalmente en la obtención de un espacio de dimensión reducida, que sea capaz de proyectar los datos originales con la menor pérdida de variación posible. Es decir, se trata de resumir en pocos ejes la variación que originalmente es n-dimensional, siendo n el número de especies (o variables) o el número de sitios (o atributos de las variables), según interese reconocer grupos de especies o grupos de sitios asociados. Por tanto, sólo después de realizar el análisis, pueden encontrarse correlaciones entre la distribución de los organismos y las variables ambientales. Dado que, con estos métodos se asume que la variación espacial de las especies se debe a la variación de variables ambientales (factores bióticos o abióticos), estos factores pueden ser evaluados a posteriori una vez que se ha obtenido el patrón de distribución de las especies.

- **Métodos directos**

Sin duda, la primera aproximación y seguramente la más sencilla se puede hacer con técnicas de regresión, las cuales describen la función que mejor ajusta los valores de abundancia de un taxón (variable dependiente) frente a una variable ambiental (variable independiente) en relación con un modelo concreto; éste sería el caso de una regresión simple.

Otra alternativa más elaborada se basa en la utilización de técnicas de regresión múltiple. Los modelos de regresión múltiple permiten extraer un modelo de dependencia y una variable respuesta sobre dos o más variables predictoras. Por ejemplo el análisis de redudancias (Redundancy Analysis RDA) y el análisis canónico de correspondencias (Canonical Correspondence Analysis CCA), son utilizados para determinar la variación de los taxones en relación a variables ambientales (prácticas agronómicas, tipos de uso del suelo, etc.).

Otros modelos de regresión múltiple utilizados en este trabajo son también:

- El modelo lineal general

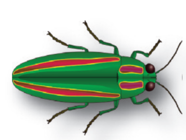
Dentro de los métodos de regresión éste es uno de los más importantes, entre los que se encuentran los llamados ANOVA y MANOVA de medidas repetidas. A diferencia del modelo tradicional, el modelo lineal general introduce tanto variables cuantitativas como cualitativas para ser usadas como predictoras.

- Los modelos lineales generalizados (Generalized Linear Models GLM)

Estos modelos son una generalización de los modelos anteriores, ya que extienden el modelo lineal general en dos importantes y relacionados aspectos. Primero, no se supone que los valores esperados de la variable respuesta vayan a ser directamente una combinación lineal de las variables predictoras. Segundo, los modelos lineales generalizados no tienen suposiciones específicas sobre la parte estocástica de los modelos lineales generales. A modo de ejemplo, entre los distintos modelos de regresión, el conocido modelo de regresión de Poisson (o log-Poisson) es una forma de regresión usada para modelar datos de conteo y tablas de contingencia. Este tipo de regresión asume que la variable de respuesta tiene una distribución de Poisson y que el logaritmo de su valor esperado puede ser modelado por una combinación lineal de parámetros desconocidos.

3.5.2.2 Métodos de clasificación

Los métodos de clasificación se basan en la obtención de grupos de objetos (unidades muestrales, grupos taxonómicos) internamente homogéneos y distintos unos de otros. Cuando las especies son clasificadas, entonces la homogeneidad se puede interpretar como un comportamiento ecológico parecido, puesto de manifiesto mediante la similitud distribucional.



Los métodos de clasificación generalmente se dividen en:

• **Clasificación no jerarquizada** (K-means clustering)

• **Clasificación jerarquizada aglomerativa** ("classical" cluster analysis)

Se inicia con los objetos individuales y se van uniendo en grupos de mayor tamaño. La similitud local prevalece sobre las diferencias grandes. Los métodos aglomerativos requieren de dos decisiones, escoger una medida de similitud (Jaccard, distancia Euclidiana, coeficiente de correlación de Pearson, entre otras) o escoger un método de aglomeración (agrupación del vecino más cercano, agrupación con centroides, etc.). Un método de clasificación jerarquizada aglomerativa utilizada en esta Tesis es el **Análisis Discriminante Lineal** (Linear discriminant analysis LDA), cuyo objetivo es encontrar la combinación lineal de las variables independientes (abundancia total de los distintos grupos taxonómicos) que mejor permite diferenciar (discriminar) a los grupos de interés (tipos de manejo agronómico). Una vez encontrada esa combinación (la función discriminante) podrá ser utilizada para clasificar nuevos casos. Se trata de una técnica de análisis multivariado, capaz de aprovechar las relaciones existentes entre una gran cantidad de variables independientes para maximizar la capacidad de discriminación. Su propósito es el mismo que el del análisis de regresión logística, pero a diferencia de él, sólo admite variables cuantitativas. Sin embargo, el análisis discriminante no paramétrico (Non-Parametric Linear Discriminant Analysis NPLDA), aplicado en el apartado 3, se basa en el modelo del algoritmo de los k-vecinos más próximos (k-Nearest Neighbour kNN), definidos a su vez considerando la distancia de Mahalanobis de cada caso a los centroides de los casos (Lachenbruch, 1975).

• **Clasificación jerarquizada divisiva**

Se inicia con todos los objetos (sitios, especies, variables) y se va dividiendo en grupos menores. Estos métodos enfatizan las diferencias grandes sobre las pequeñas, y pueden ser de dos tipos:

- o Monotético: basado en un solo carácter.
- o Politético: basado en varios caracteres, como el análisis de especies indicadoras de dos vías (Two-way Indicator Species Analysis TWINSPAN).

Finalmente, conviene señalar que existe una gran variedad de técnicas de análisis multivariado disponibles con diferentes suposiciones. Entre las principales suposiciones se encuentran la de si las especies responden de manera lineal a los gradientes (respuesta lineal) o si responden a un óptimo ambiental (respuesta unimodal).

3.5.3 Medidas de la diversidad

3.5.3.1 Diversidad biológica

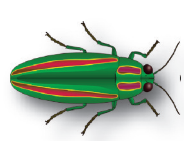
Las medidas de diversidad aplicadas en este estudio han tenido como objetivo, cuantificar la diversidad de una comunidad de individuos y comparar estadísticamente la diversidad de las comunidades entre distintas zonas.

Por un lado la riqueza de diferentes taxones, se utiliza como el indicador más natural de riqueza de taxones en la comunidad (Colwell, 2000). Por otro lado los índices de diversidad utilizados en esta Tesis se describen a continuación:

- *Índices de dominancia:* son parámetros inversos al concepto de uniformidad o equidad de la comunidad. Tienen en cuenta la representatividad de las especies o unidades taxonómicas con mayor valor de importancia sin evaluar la contribución del resto de las especies o unidades taxonómicas (Moreno, 2001). La dominancia es simplemente la fracción de la colección que está representada por la unidad taxonómica más común (Colwell, 2000). Se expresa como D = 1 – índice de Simpson, y varía entre 0, cuando todos los taxones están presentes en la misma proporción y 1, cuando un taxón domina la comunidad completamente.
- *Índice de probabilidad de encuentro interespecífico de Hurlbert (índice de PIE de Hurlbert o Hurlbert's PIE):* este índice calcula la probabilidad de que dos individuos muestreados al azar de una comunidad puedan representar a dos unidades taxonómicas diferentes. Se calcula mediante la fórmula:

$$PIE = \left(\frac{N}{N-1}\right)\left(1-\sum_{i-1}^{s} p_i^2\right)$$

en donde N es el número de especies en la comunidad, y p (i) corresponde a la proporción de la muestra completa representada por la especie o unidad taxonómica i.



- *Índice de Shannon*: es uno de los más conocidos y aplicados en ecología. Se calcula mediante la fórmula:

$$H' = -\sum_{i-1}^{s} p_i \ln p_i$$

en donde *p* (i) es la proporción de la muestra representada por la especie i y ln es el logaritmo neperiano. Varía entre 0 para comunidades con únicamente un taxón a valores más altos (raramente superior a 5) para comunidades con muchos taxones, cada uno con algunos individuos.

3.5.3.2 Diversidad paisajística

El término Hemerobia procede del griego *hemeros* que significa cultivado o domesticado. El *índice de Hemerobia* (*M* Hemeroby) fue introducido en ecología para describir el gradiente de influencia humana sobre el paisaje y la flora (Jalas, 1955) teniendo en cuenta las plantas autóctonas e introducidas. Otra de sus aplicaciones posteriores propuesta por ecólogos centroeuropeos (Blume & Sukopp, 1976; Bornkamm, 1980; Sukopp, 1972; Sukopp, 1976), menos extendida pero de gran utilidad, integra parámetros que describen el impacto humano en los ecosistemas tales como los usos del suelo, las comunidades de plantas y los suelos. De acuerdo con Sukopp (1976) el grado de hemerobia es "*una medida integrada para los impactos de todas las intervenciones humanas sobre los ecosistemas, tanto si son intencionadas como si no*". Su cálculo y uso en esta tesis han servido para incorporar cuantitativamente el efecto de la composición de paisaje y para conocer su influencia sobre la entomofauna del olivo, algo que hasta ahora no había sido evaluado en los estudios de diversidad en el olivar. Los niveles de hemerobia fueron asignados según la fórmula propuesta por Steinhardt (1999):

$$M = 100 \sum_{h=1}^{m} \left(\frac{f_m}{m} \right) h$$

en donde m es el número de categorías de hemerobia, f_m la proporción del área de la categoría m y finalmente *h*, es el factor de hemerobia.

Para medir el estado de conservación o el grado de la influencia humana en los ecosistemas, la hemerobia puede ser usado como sustituto de intensidad en los usos de suelo y como índice de medida de la sostenibilidad de los ecosistemas agrarios (Fu *et al.*, 2006). Tanto el manejo agronómico como las características del paisaje deben ser observadas en los estudios de paisajes agrícolas, puesto que éstas actúan sobre la diversidad de los mismos (Weibull *et al.*, 2003).

3.6 Bibliografía

Álvarez Guzmán, J. R. (1999). Olivar y ecología: estado de la cuestión en España. *Olivae*, **78**, 41-49.

Blume, H.-P. & Sukopp, H. (1976). Ökologische bedeutung anthropogener Bodenveränderungen. *Schriftenreihe für Vegetationskunde*, **10**, 75-89.

Bornkamm, R. (1980). Hemerobie und Landschaftsplanung. *Landschaft und Stadt*, **12**, 49-55.

Cárdenas, M. (2008). Análisis de la actividad ecológica de las arañas en el agroecosistema del olivar, Universidad de Granada. Granada, pp. 312.

Colwell, R. K. (2000). EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples (Software and User's Guide). Version 6.

Fu, B.-J., Hu, C.-X., Chen, L.-D., Honnay, O. & Gulinck, H. (2006). Evaluating change in agricultural landscape pattern between 1980 and 2000 in the Loess hilly region of Ansai County, China. *Agriculture, Ecosystems & Environment*, **114**, 387-396.

Jalas, J. (1955). Hemerobe und hemerochore Pflanzenarten. Ein terminologischer Reformversuch. *Acta Societatia Pro Fauna et Flora Fennica*, **72**, 1- 15.

Lachenbruch, P. A. (1975). *Discriminant analysis*. Hafner, New York, 128 pp.

Moreno, C. E. (2001). *Métodos para medir la biodiversidad.* M&T-Manuales y Tesis SEA, Zaragoza, 84 pp.

Steinhardt, U., Herzog, F., Lausch, A., Müller, E. & Lehmann, S. (1999). Hemeroby index for landscape monitoring and evaluation. In *Enviromental Indices - System Analysis Approach*, eds. Y. A. Pykh, D. E. Hyatt & R. J. Lenz, EOLSS Publ. Oxford, pp. 237-254.

Sukopp, H. (1972). Wandel von Flora und Vegetation in Mitteleuropa unter dem Einfluss des Menschen. *Berichte über Landwirtschaft*, **50**, 112-139.

Sukopp, H. (1976). Dynamik und Konstanz in der Flora der Bundesrepublik Deutschland. *Schriftenreihe Vegetationskunde*, **10**, 9-26.

Weibull, A. C., Östman, Ö. & Granqvist, A. (2003). Species richness in agroecosystems: The effect of landscape, habitat and farm management. *Biodiversity and Conservation*, **12**, 1335-1355.

4. Using higher insect taxa as indicators for olive farming systems in southern Spain

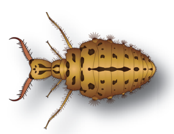
Using higher insect taxa as indicators for olive farming systems in southern Spain

Submitted to Agricultural and Forest Entomology

4.1 Abstract

Previous surveys have established methods based on insect groups as possible tools for detecting the absence of pesticide application and determining friendlier environmental practices in olive farming in the Granada province of southern Spain. Following those first approaches, the present study covered a greater area in Andalusia (Córdoba and Granada provinces) in an attempt to validate the use of certain orders of insects as indicators for organic and non-organic olive farming systems. Canopies were sampled using the technique of branch-beating during preblooming and postblooming periods over three years in Granada (1999, 2000 and 2003) and one year in Córdoba (2003). Using a Non-parametric Linear Discriminant Analysis (NPLDA) method, based on the k-Nearest Neighbour (kNN) algorithm, several discriminant functions were constructed. A first discriminant model took into account interannual variability in the Granada province and the second one focused especially on environmental heterogeneity between the two provinces. Cross validation techniques (leave-one-out and split-sample) were applied to the associated discriminant functions for each model to check their performance. In spite of the differences in insect composition between regions, the second model correctly classified 78.10% of the sampled blocks under the non-organic and organic farming systems, taking into account two orders: Coleoptera and Hemiptera (excluding the Heteroptera suborder and *Euphyllura olivina* pest) during the postblooming developmental stage. High abundances of these groups, especially coleopterans, seemed to indicate more sustainable practices. However, most of the misclassifications were found in blocks of organic orchards with low abundances of captured beetles.

Keywords: canopies, high taxonomic groups, olive orchards, organic vs non-organic farming, preblooming and postblooming period.



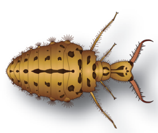
4.2 Introduction

The intensification of olive production methods in southern Spain, involving a widespread use of chemicals and the progressive loss of many Mediterranean forest patches have led to an impoverished arthropod fauna in olive agroecosystems (Ruano *et al.*, 2004; Santos *et al.*, 2007). In Andalusian landscapes natural and seminatural vegetation has been removed to enlarge the olive growing size, leading to a decrease and a fragmentation of the original landscape leading to a decrease of the original landscape (de Graaff & Eppink, 1999; Milgroom *et al.*, 2007; Parra López & Calatrava Requena, 2006). This situation along with less friendly environmental practices impoverished biodiversity in agroecosystems (Biaggini *et al.*, 2007).

The Common Agricultural Policy (CAP) reform of the European Union (EU) recently introduced several new concepts and management activities for environmental protection, taking into account landscapes and environmental care (Yli-Viikaria *et al.*, 2007). Agri-environmental indicators (AEIs) are one of the tools intended to achieve an easily understood picture about the current state of agroecosystems. To manage sustainable agroecosystems in the Mediterranean basin, it is necessary to know, among other features, the biodiversity in each ecosystem (Labrador & Altieri, 2001). Among living organisms from all agroecosystems, arthropods, the most diverse inhabitants of terrestrial ecosystems, occupy a tremendous variety of functional niches across a wide array of spatial and temporal scales (Kremen *et al.*, 1993; McGeoch, 1998).

Since changes in several animal and plant groups are assumed to be associated with the changes in agricultural practices and land use (Büchs, 2003; Büchs *et al.*, 2003; Heyer *et al.*, 2003; Muramoto & Gliessman, 2006; Paoletti, 1999; Perner & Malt, 2003), and previous surveys have validated the use of certain insects groups as indicators of olive farming systems (Ruano *et al.*, 2004); the goal of this study was, on the one hand, to determine which higher-taxa insect groups could be used to correctly discriminate the type of farming system practiced in olive orchards, and on the other hand, to describe common insect groups in olive agroecosystems in the southern provinces of Spain.

The resulting information will hopefully lighten the workload for

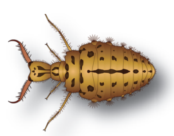


non-taxonomists, who require a rapid and cheap methodology of certification for the organic olive farming system. Even though this is a recent approach (Balmford *et al.*, 1996; Williams & Gaston, 1994), some other studies have begun to be accepted as a shortcut for comparing the biodiversity levels of agricultural landscapes, at least as a first phase of investigation (Biaggini *et al.*, 2007). The novel aspects of the current study are, first, the consideration of interannual variation, and second, the use of a greater environmental heterogeneity, including new areas and different traditions of land use intensity over a long period (Burel *et al.*, 1998; Duelli & Obrist, 2003).

4.3 Materials and methods

4.3.1 Study zones and sampling periods

The study area covers some regions of two provinces in Spain extending about 104 km from north to south and 117 km at its widest point from east to west, with the experimental fields located at an altitude 400 to 1100 m above sea level. Córdoba and Granada provinces are two of the largest commercial olive producing areas in southern Spain, but natural surroundings and the land use traditions make the olive landscape diverse. In Córdoba the sampling was carried out in Los Pedroches Valley, which is the largest organic producing region in Andalusia. Though there are some non-organic farmers in this valley, the organic olive farming system is extensive. This region is close to the Cardeña and Montoro natural park, and contains a semi-natural olive landscape with Mediterranean forest patches. Olive orchards from Granada are located near mountain oak stands; however, in Granada the surrounding olive orchards are cultivated under conventional and intensive farming systems and the patches of natural vegetation are smaller than in Córdoba (Figure 4.1). The 2000 crops and land-use maps of Andalusia (Consejería de Agricultura y Pesca, Junta de Andalucia) provided us information about the land-use around the fields, using the ArcGIS 9.1 software (ESRI, 2006).



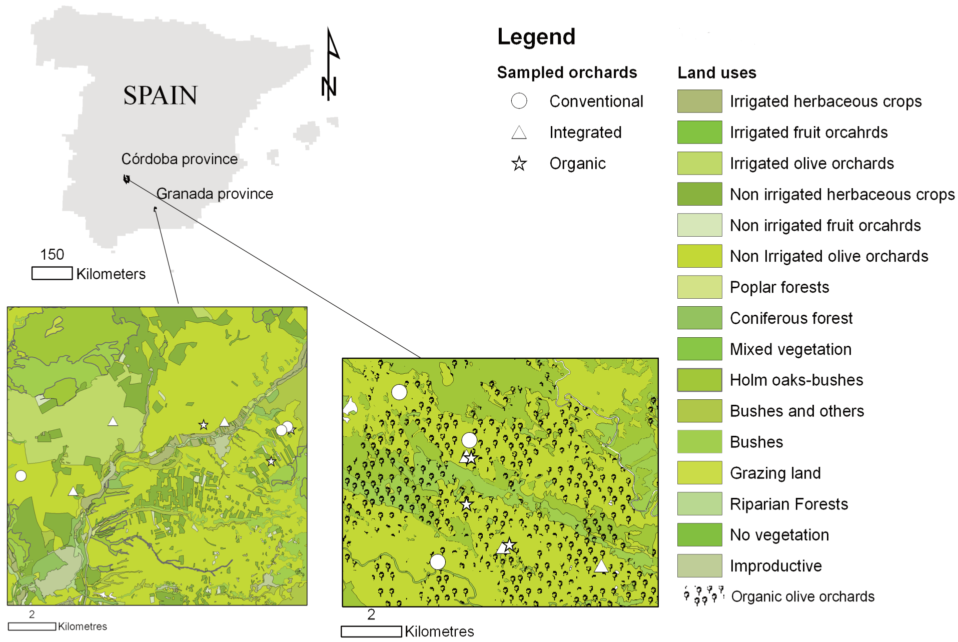


Figure 4.1: Location of the conventional, integrated and organic orchards with surrounding land-uses in the two provinces.

First, three olive orchards from Granada under organic, integrated and conventional farming systems were sampled in 1999, 2000 and 2003, in order to include interannual variability of insect abundances. Additionally, six other orchards (two per farming system) were sampled in 2003 as well. Thus, a total of nine orchards were investigated in Granada, and some of them during a three year period (Figure 4.1). The 2003 sampling pattern from Granada was applied in the Córdoba province, where nine orchards (three per management) were sampled in the same year. Altogether, a total of 18 orchards were sampled in 2003. Following previous researchers' observations (Ruano *et al.*, 2004), preblooming (May) and postblooming (June) time are the most appropriate periods to take samples, because arthropod abundance shows the strongest differences among farming managements during these periods.

4.3.2 Collection of arthropods

The sampling unit was a block consisting of a row of five sampled trees separated by two rows of unsampled trees. The distance between sampled trees was 20 metres. The total number of sampled blocks was 105 (35 per management) over the three years. Six blocks were sampled in 1999; the number of samples was reduced to five blocks in 2000 and to four blocks in 2003 in order to reduce the sampling effort while maintaining a sufficient degree of accuracy. The canopies of the olive trees were sampled by beating with an insect net 50 cm in diameter five times at four branches per tree (one branch per compass orientation) that were chosen at random.

Samples from canopies were frozen and, subsequently, the insects were separated from vegetal and non-organic remains. Adults and juveniles were identified to the taxonomic level of order, and the total number of each taxon was recorded. Some taxonomic considerations such as *Euphyllura olivina* (Costa 1839) (Hemiptera: Psyllidae), suborder Heteroptera (Hemiptera) and Family Formicidae (Hymenoptera), were identified to a lower-taxonomic level because of the high number of captured specimens. Thus, when we refer to other Hemiptera, we exclude Heteroptera suborder and *E. olivina* species.

4.3.3 Statistical analysis

Due to the non-normality of data even after several transformations, the different captured orders were monthly compared among management regimes (conventional, integrated and organic) province by province and in both provinces by Kruskal-Wallis test. Finally, the lack of correlation between observations over time was evaluated by applying the Durbin-Watson test.

Because the data were not assumed to have multivariate normality, a Non-parametric Linear Discriminant Analysis (NPLDA) model based on the k-Nearest Neighbour (kNN) algorithm was applied; this is a non-parametric method based on the Mahalanobis distance of each case to each of the groups' centroids (Lachenbruch, 1975). The taxonomic groups selected to perform the canonical functions were obtained using a stepwise variable selection procedure (Muñoz Serrano, 1996; McGarigal *et al*., 2000). Two procedures for validating canonical functions were carried out. The two discriminant functions (preblooming and postblooming) from Granada in 1999, 2000 and 2003 were performed and validated using the leave-one-out (LOO) cross validation, because this procedure is recommended when the sampling size is small. However, when the sampling size is larger, the split-sample validation method is recommended (McGarigal *et al.*, 2000). This last method was applied to the data from the Córdoba province in 2003 along with data from the Granada province over the three years (1999, 2000 and 2003), they were included to increase the heterogeneity of the landscapes; for that reason the number of orchards was increased to 18. As the number of considered blocks changed each year, this procedure resulted in a dataset compounded by 105 blocks. Randomly selecting two groups from a full data set, the first group was used to perform the function and the second was used to validate it. These analyses were carried out with SPSS 17.0 for Windows.

4.4 Results

4.4.1 Comparing farming systems

In 2003, 2,780 individuals were captured in the Granada province during preblooming time; 63.20% were *E. olivina*, 8% Diptera, 7.60% Hemiptera, 6% Lepidoptera, and the remaining 15% were Coleoptera, Heteroptera, Dermaptera, Hymenoptera, Formicidae, Neuroptera, Orthoptera, Psocoptera, Trichoptera, Thysanoptera and Zygentoma (Table 4.1). The highest abundance was observed in organic orchards, while integrated orchards followed by conventional orchards showed lower values. The greatest number of specimens, 8317 individuals, were captured during the postblooming period in Granada; 72.50% were *E. olivina*, 8.10% Heteroptera, 7.30% Hemiptera, 3.60% Hymenoptera and the remaining 8.50% were Coleoptera, Diptera, Thysanoptera, Dermaptera, Dictyoptera, Formicidae, Lepidoptera, Neuroptera, Orthoptera, Psocoptera and Trichoptera (Table 4.2). The increase of *E. olivina* species meant that integrated orchards showed the highest abundances, followed by organic orchards and finally conventional orchards.

Table 4.1: Mean and standard deviation (SD) for each total captured insect group (arranged by their relative abundance) per block in conventional (C), integrated (I) and organic (O) orchards from Granada and Córdoba provinces in 2003, preblooming period. Significant values per management in each province and both provinces.

	GRANADA								CÓRDOBA								KW-test (gl=2)	
	C		I		O		KW-test (gl=2)		C		I		O		KW-test (gl=2)			
Preblooming	Mean	SD	Mean	SD	Mean	SD	χ2	*p*	Mean	SD	Mean	SD	Mean	SD	χ2	*p*	χ2	*p*
E. olivina	16.83	13.22	53.00	62.82	76.67	70.73	9.40	**	3.25	5.55	1	1.71	19.33	12.32	17	***	13.30	*
HEMIPTERA	1.92	3.99	7.67	10.29	8.00	11.24	NS		2.75	2.99	1.50	1.17	12.42	6.86	18.50	***	15.70	***
DIPTERA	5.25	4.07	2.25	2.45	11.08	9.93	11.60	**	1.92	1.62	2.58	2.27	5.08	5.11	NS		NS	
LEPIDOPTERA	2.50	3.32	1.25	1.48	10.25	14.35	NS		0.67	0.89	0.42	0.51	0.58	0.67	NS		NS	
Formicidae	0.17	0.39	3.42	4.14	5.58	13.12	9.50	**	1.00	1.60	2.00	2.49	2.33	2.15	10.80	**	17	***
Heteroptera	1.08	1.56	1.75	2.53	6.50	4.36	14.80	***	0.50	0.52	0.83	1.34	3.83	1.85	11.20	**	18.50	***
HYMENOPTERA	1.92	1.83	1.75	1.22	2.42	1.56	NS		0.92	1.44	1.75	1.48	5.50	3.53	9.30	*	6.30	*
COLEOPTERA	1.50	1.51	0.83	1.27	1.08	0.67	NS		1.50	1.31	1.00	0.95	4.83	3.30	13.2	*	NS	
NEUROPTERA	1.67	1.56	0.92	1.16	0.92	1.38	NS		0.83	1.03	0.83	0.83	3.17	2.52	8.50	*	NS	
THYSANOPTERA	1.00	1.04	0.92	1.51	0.50	0.90	NS		1.17	1.19	0.92	1.24	1.33	0.89	8.90	*	8.50	*
PSOCOPTERA	0.08	0.29	0.25	0.62	0.08	0.29	NS		0.50	1.17	0.17	0.39	0.83	1.34	NS		NS	
DICTYOPTERA	0	0	0	0	0	0	NS		0	0	0	0	1.00	1.41	NS		NS	
DERMAPTERA	0.08	0.29	0.08	0.29	0	0	NS		0.08	0.29	0.42	0.67	0.08	0.29	NS		NS	
ORTHOPTERA	0	0	0.08	0.29	0.08	0.29	NS		0.08	0.29	0	0	0	0	NS		NS	
TRICHOPTERA	0	0	0.25	0.45	0	0	6.40	*	0	0	0	0	0	0	NS		NS	
ODONATA	0	0	0	0	0	0	NS		0	0	0	0	0.08	0.29	NS		NS	
ZYGENTOMA	0.08	0.29	0	0	0	0	NS		0	0	0	0	0	0	NS		NS	
TOTAL	409		893		1478				182		161		725					

P values are: *, < 0.05; **, < 0.01; ***,<0.005; NS, not significant (> 0.05)

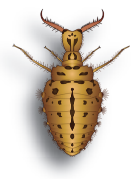
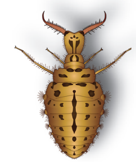


Table 4.2: Mean and standard deviation (SD) of each total captured insect group (arranged by their relative abundance) per block in conventional (C), integrated (I) and organic (O) orchards from Granada and Córdoba provinces in 2003, postblooming period. Significant values per management in each province and both provinces.

	GRANADA								CÓRDOBA								KW-test (gl=2)	
	C		I		O		KW-test (gl=2)		C		I		O		KW-test (gl=2)			
Postblooming	Mean	SD	Mean	SD	Mean	SD	χ2	p	Mean	SD	Mean	SD	Mean	SD	χ2	p	χ2	p
E. olivina	64.17	52.00	290.08	228.61	148.50	68.61	NS		12.08	12.70	3.67	2.84	36.67	13.96	21.80	***	NS	
HEMIPTERA	3.92	4.68	29.42	27.31	17.33	17.13	NS		9.17	6.83	3.00	2.83	12.92	11.90	11.50	***	NS	
Heteroptera	12.42	18.96	38.00	25.70	5.67	4.50	NS		4.33	7.25	3.25	6.22	2.75	4.45	NS		NS	
HYMENOPTERA	5.92	5.37	5.83	5.42	13.08	15.29	7.40	*	2.83	1.75	1.67	2.27	2.00	1.54	NS		NS	
COLEOPTERA	0.42	0.67	1.17	1.03	2.83	3.51	6.40	*	9.42	9.70	5.42	5.58	9.25	6.61	NS		NS	
LEPIDOPTERA	6.33	7.18	1.92	2.19	15.58	12.72	8.40	*	0.17	0.39	0	0	0.25	0.62	NS		NS	
NEUROPTERA	3.83	2.59	2.50	1.93	7.17	3.90	NS		1.75	2.34	2.75	2.80	2.42	2.11	NS		NS	
Formicidae	0.67	0.89	5.50	5.52	1.08	1.78	NS		4.42	7.76	2.58	2.75	3.83	2.66	NS		6.50	*
DIPTERA	0.83	0.83	1.17	0.94	2.92	2.47	NS		0.50	0.67	0.17	0.39	0.25	0.62	NS		NS	
PSOCOPTERA	0.42	0.67	0.25	0.62	1.67	1.92	NS		0.58	0.90	0.58	1.08	0.92	2.11	NS		NS	
THYSANOPTERA	0.33	0.65	0.42	0.90	0.67	0.98	NS		0.08	0.29	0.08	0.29	0.08	0.29	NS		NS	
ORTHOPTERA	0.25	0.62	0	0	0.17	0.58	6.40	*	0.25	0.45	0.17	0.58	0.25	0.87	NS		NS	
DERMAPTERA	0	0	0.17	0.39	0.08	0.29	NS		0	0	0.25	0.62	0	0	NS		NS	
DICTYOPTERA	0	0	0.25	0.45	0	0	NS		0	0	0	0	0.08	0.29	NS		NS	
TRICHOPTERA	0	0	0.17	0.58	0	0	NS		0	0	0	0	0	0	NS		NS	
ODONATA	0	0	0	0	0	0	NS		0	0	0	0	0.08	0.29	NS		NS	
TOTAL	1194		4522		2601				547		283		861					

P values are: *, < 0.05; **, < 0.01; ***,<0.005; NS, not significant (> 0.05)



In Córdoba canopies, 1,068 specimens were captured during the preblooming period, of which 29.50% were *E. olivina*, 17.80% Hemiptera, 10.80% Diptera, 9.20% Hymenoptera, 8.20% Coleoptera, and the remaining 26.60% were the orders Dermaptera, Dictyoptera, Formicidae, Heteroptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Psocoptera and Thysanoptera (Table 1). Organic orchards showed the richest number of captured specimens, while integrated and conventional orchards were similar regarding insect abundance.

The postblooming developmental stage showed a higher abundance of specimens than the preblooming stage; of the 1691 total number of captured individuals, 37.20% belonged to *E. olivina* species, followed by Hemiptera (17.80%), Coleoptera (17.10%), Formicidae (7.70%), Heteroptera (7.30%), and the final 12.50% represented by Diptera, Dermaptera, Dictyoptera, Hymenoptera, Neuroptera, Odonata, Orthoptera, Psocoptera and Thysanoptera. Organic orchards, followed by conventional and integrated orchards, produced the highest number of insects.

4.4.2 Discriminant function with interannual variation

The first approach attempted to discriminate organic and non-organic orchards from the Granada province. The three resampled orchards showed to be independient over the time (three years) applying the Durbin-Watson test. The two discriminant functions (preblooming and postblooming) were performed using a dataset from the Granada province in 1999, 2000 and 2003, and the cross validation of these discriminant functions was performed using LOO. On the one hand, in the preblooming period the selected taxonomic groups included in the discriminant function were the Hymenoptera, Lepidoptera and Hemiptera orders, the rates of well-classified non-organic and organic blocks were 95.70% and 56.50%, respectively, such as in the discriminant function as well as in the validation (82.60% of the total blocks). On the other one hand, the postblooming period function showed a correct classification rate of 97.80% for non-organic blocks and 87% for organic blocks (94.20% of the total blocks), having taken into account all the Hemiptera (including in this case Heteroptera suborder and *E. olivina* species) Lepidoptera and Formicidae. LOO model correctly discriminated

92.80% of the blocks (95.70% of non-organic and 87% of organic blocks). Even when the correct classification rates of the LOO validation were lightly lower than the rate from the full data set, a higher number of organic blocks were well-discriminated in postblooming (Table 4.3).

Table 4.3: Percent of correct classification of the full data set for each farming system and period, using the leave-one-out cross validation (LOOCV) method in the Granada province.

		Farming system	Full data set	LOOCV
Percent of correct classification	Preblooming	Non-organic	95.70	95.70
		Organic	56.50	56.50
	Postblooming	Non-organic	97.80	95.70
		Organic	87	87

4.4.3 Discriminant function with environmental heterogeneity

After applying the discriminant coefficients obtained from Granada province to Córdoba blocks, no more than a 25% of the Córdoba organic blocks could be well-discriminated in both periods. Looking for a better approach, a second procedure was applied. Due to the sample size was large enough, the split-sample validation was used to validate the functions. The total sample of entities was randomly divided into two groups; half of the sampled blocks from each orchard were randomly selected and two sub-data sets were created. First, the initial subset made up of 53 blocks was used to derive the discriminant functions. Then, the second dataset with 52 blocks was used to validate the functions (split-sample validation). The preblooming function was performed using the hemipterans (Table 4.4), resulting in a correct classification rate of 70.40% for the blocks (Table 4.5). The obtained unstandardised coefficients were used to classify samples from the second data set, resulting in a 52.90% correct classification rate for the blocks, as compared to a rate of 71.04% for the full data set. The postblooming function (Table 4.4) included as variables coleopterans (with the highest coefficient in the function) and hemipterans, and resulted in a correct classification rate of 77.80%. After validating the function with the second data set, 78.40% of the blocks were observed to be correctly classified. Therefore, the resulting correct classification rate of the full data set (78.10%) was similar to both first and second data set (Table 4.5).

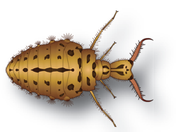


Table 4.4: Unstandardised coefficients of the canonical discriminant function obtained from Granada and Córdoba in the preblooming and postblooming periods.

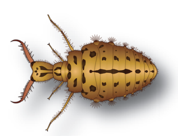
	Preblooming Function	Postblooming Function
	Hemiptera 0.050	Coleoptera 0.170
		Hemiptera -0.017
	Constant -0.608	Constant -0.474

Table 4.5: Percent of correct classification of the first sampling, second sampling and full data set for each farming system and period, using the split-sample validation method in Granada and Córdoba provinces.

		Farming system	First data set	Resampling data set	Full dataset
Percent of correct classification	Preblooming	Non-organic	86.10	55.90	85.70
		Organic	38.90	47.10	42.80
	Postblooming	Non-organic	88.90	85.30	87.10
		Organic	55.60	64.70	60

Correct classification rates for the preblooming and postblooming periods were different; in the preblooming period a low number of organic blocks could be correctly classified before and after the split-sample validation, whereas in the postblooming period the resulting correct validation was similar to or higher than the correct rate of the full data set (Table 4.5). However, most of the organic blocks, especially from Granada, were misclassified due to a low overall abundance of coleopterans.

Finally, to demonstrate the difficulties found to discriminate between Granada and Córdoba orchards, a discriminant map containing three groups (non-organic and organic blocks of Granada and all blocks of Córdoba) showed a clear spatial distribution. The 100% of Córdoba blocks were well discriminated, while the 83.30% of organic and 75% of non-organic blocks from Granada were also correctly classified (Figure 4.2).



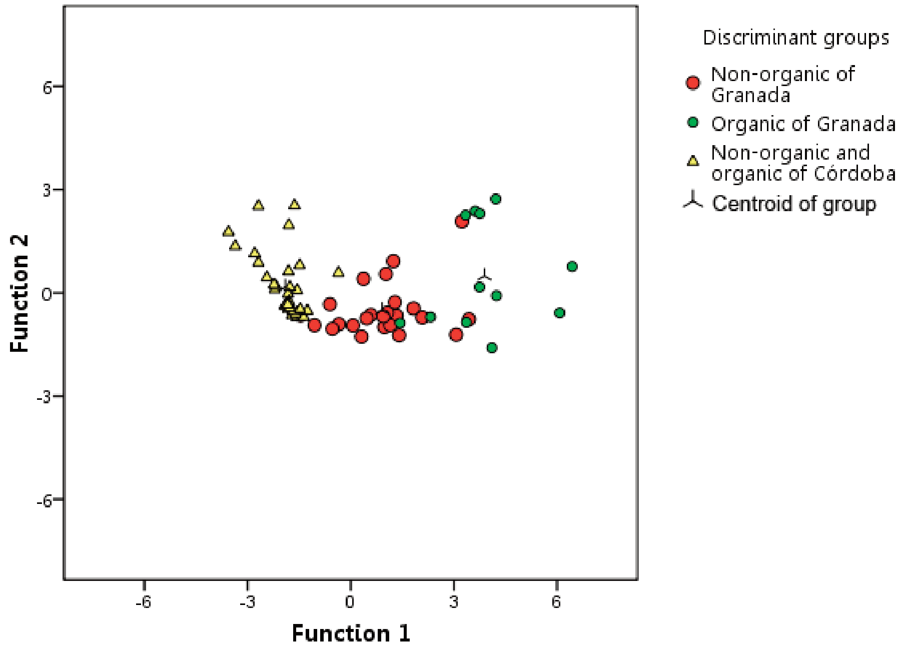
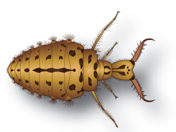


Figure 4.2: Distribution of the non-organic and organic blocks from Granada and all blocks from Córdoba, in accordance with the values from the canonical discriminant function.

4.5 Discussion

Regarding the 2003 sampling, the total abundance of insects was higher in Granada than in Córdoba, which was a result of the *E. olivina* pest. This species was the most abundant captured group in almost all organic orchards and principally in Granada (Ruano *et al.*, 2004), but the highest abundance was found in Granada integrated orchards in the postblooming period.

The percentage and total abundance of the different taxonomic groups varied from one province to another, potentially due to the proportion of species depending on semi-natural habitats in agricultural landscapes (Duelli & Obrist, 2003). The Córdoba zone presented a higher frequency of Mediterranean forest patches, giving more opportunities for dispersal of species and functional groups of insects from relatively undisturbed habitats into agricultural production areas (Altieri, 1999; Duelli & Obrist, 2003). The percentage varied in the same regions on a monthly and yearly basis (Ruano *et al.*, 2004), with the greatest differences observed in the postblooming period. Different farming practices have also been correlated with changes in diversity and composition of species (Burel *et al.*, 1998);



organic olive orchards showed the highest number of captures, following by integrated orchards in Granada and conventional orchards in Córdoba. These data indicated that integrated intensity of farming practices is variable between provinces as well as among individual olive growers.

The highly variable abundance of the higher taxa among farming systems, provinces, months and years made it difficult to design a linear discriminant function that would be useful and reliable anywhere and anytime. Two models were studied that focused on the sample interannual and environmental variability; the first one showed high accuracy, even when the same orchards were evaluated over the time. Some difficulties in classifying orchards over time could be due to not only weather changes, but also due to changes in the intensity of the agronomic practices from farmer to farmer and in the same orchard from year to year. However, after increasing the sample size, and even including a new province with different landscape features, the postblooming period may be a reliable period to classify organic and non-organic orchards, using the coleopterans and hemipterans. Coleopterans had the strongest contribution to the discriminant function, which could mean that higher beetle abundances are related to more sustainable practices. However, most of the misclassifications were produced by blocks that belonged to organic orchards with low abundances of captured beetles in the postblooming period, especially in the Granada province. Those two groups could indicate a greater heterogeneity of organic farming practices, such as vegetal cover and soil management regime or type of irrigation, besides the importance of landscape features from one province to another, since organic and non-organic blocks in Granada and blocks in Córdoba could clearly be separated using a discriminant analysis.

4.6 Conclusion

The postblooming period was the most favourable time to sample when using higher taxa of insects in highly heterogeneous landscapes to discriminate organic *vs.* non-organic orchards. Our results have shown that better approaches were achieved when only one region with some resampled years is analysed, more than when a greater environmental heterogeneity was included. Córdoba orchards demonstrated to be quite different to non-organic and organic orchards of Granada in insect composition, however, from all identified higher insect taxa, Coleoptera and Hemiptera were able to best discriminate among organic and non-organic farming systems in olive orchards in both provinces, although the conventional, integrated and organic farming systems could not be discriminated from each other based only on higher insect taxa.

To be able to conclude, in order to decide if either several functions for local accuracy assessment or a general function are reliable, longitudinal studies should be devoted. They would (re-)validate the obtained discriminant functions and to verify if high abundances of coleopterans and hemipterans are favoured by organic practices, focusing on organic orchards in Granada and new replicated years sampled in Córdoba province.

4.7 References

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment*, **74**, 19-31.

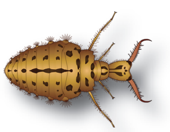
Balmford, A., Green, M. J. B. & Murray, M. G. (1996). Using higher taxa richness as a surrogate for species richness. I. *Regional tests,* Vol. 263, Proceedings of the Royal Society. London, pp. 1267–1274.

Biaggini, M., Consorti, R., Dapporto, L., Dellacasa, M., Paggetti, E. & Corti, C. (2007). The taxonomic level order as a possible tool for rapid assessment of Arthropod diversity in agricultural landscapes *Agriculture, Ecosystems & Environment*, **122**, 183-191

Büchs, W. (2003). Biodiversity and agri-environmental indicators-general scopes and skills with special reference to the habitat level. *Agriculture, Ecosystems & Environment*, **98**, 35-78.

Büchs, W., Harenberg, A., Zimmermann, J. & Weiß, B. (2003). Biodiversity, the ultimate agri-environmental indicator? Potential and limits for the application of faunistic elements as gradual indicators in agroecosystems. *Agriculture, Ecosystems & Environment*, **98**, 99-123.

Burel, F., Baudry, J., Butet, A., Clergeau, P., Delettre, Y., Le Couer, D., Dubs, F., Morvan, N., Paillat, G., Petit, S., Thenail, C., Brunel, E. & Lefeuvre, J. C. (1998). Comparative biodiversity along a gradient of agricultural landscapes. *Acta Oecologica*, **19**, 47-60.



de Graaff, J. & Eppink, L. A. A. J. (1999). Olive oil production and soil conservation in southern Spain, in relation to EU subsidy policies. *Land Use Policy*, **16**, 259-267.

Duelli, P. & Obrist, M. K. (2003). Regional biodiversity in an agricultural landscape: the contribution of semi-natural habitat islands. B*asic and Applied Ecology* **4**, 129-138.

Heyer, W., Hülsbergen, K. J., Wittman, C., Papaja, S. & Christen, O. (2003). Field related organisms as possible indicators for evaluation of land use intensity. *Agriculture, Ecosystems & Environment*, **98**, 453-461.

Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R. F. & Sanjayan, M. A. (1993). Terrestrial arthropod assemblages: their use in conservation planning. *Conservation Biology*, **7**, 796-808.

Labrador, J. & Altieri, M. A. (2001). Agroecología y desarrollo. Aproximación a los fundamentos agroecológicos para la gestión sustentable de agrosistemas mediterráneos. Universidad de Extremadura. Ediciones Mundi-Prensa, Cáceres-Madrid.

Lachenbruch, P. A. (1975). *Discriminant analysis*. Hafner, New York, 128 pp.

McGarigal, K., Cushman, S. & Stafford, S. (2000). M*ultivariate Statistics for Wildlife and Ecology Research*. Springer-Verlag, New York. 283 pp.

McGeoch, M. A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, **73**, 181-201.

Milgroom, J., Soriano, M. A., Garrido, J. M., Gómez, J. A. & Fereres, E. (2007). The influence of a shift from conventional to organic olive farming on soil management and erosion risk in southern Spain. *Renewable Agriculture and Food Systems*, **22**, 1-10.

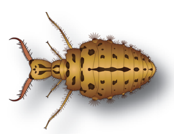
Muñoz Serrano, A. (1996). *Estadística aplicada uni y multivariante* (Tomos I e II). Junta de Andalucía, Consejería de Agricultura y Pesca. 390 pp.

Muramoto, J. & Gliessman, S. R. (2006). Bioindicators: Use for Assessing Sustainability of Farming Practices. In *Encyclopedia of Pest Management*, Taylor & Francis, pp. 1-5.

Paoletti, M. G. (1999). Using bioindicators based on biodiversity to assess landscape sustainability. *Agriculture, Ecosystems & Environment*, **74**, 1-18.

Parra López, C. & Calatrava Requena, J. (2006). Comparison of farming techniques actually implemented and their rationality in organic and conventional olive groves in Andalusia, Spain. *Biological Agriculture & Horticulture*, **24**, 35-59.

Perner, J. & Malt, S. (2003). Assessment of changing agricultural land use: response of vegetation, ground-dwelling spiders and beetles to the conversion



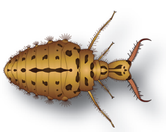
of arable land into grassland. *Agriculture, Ecosystems & Environment,* **98**, 169-181.

Ruano, F., Lozano, C., García, P., Peña, A., Tinaut, A., Pascual, F. & Campos, M. (2004). Use of artrhopods for the evaluation of the olive-orchard management regimes. *Agriculture and Forest Entomology,* **6**, 111-114.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007). Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pests in olive groves from north-east of Portugal. *Chemosphere*, **67**, 131-139.

Williams, P. H. & Gaston, K. J. (1994). Measuring more of biodiversity: can higher-taxon richness predict wholesale species richness? *Biological Conservation*, **67**, 211-217.

Yli-Viikaria, A., Hietala-Koivub, R., Huusela-Veistolaa, E., Hyvönena, T., Peräläa, P. & Turtolaa, E. (2007). Evaluating agri-environmental indicators (AEIs)-Use and limitations of international indicators at national level. *Ecological Indicators*, **7**, 150-163.



5. Selecting Coleopteran families as indicators of olive farming systems in southern Spain

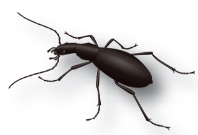
Selecting Coleopteran families as indicators of olive farming systems in southern Spain

Submitted to Ecological Indicators

5.1 Abstract

Coleopterans are one of the best represented arthropod orders in olive agreocosystems, and they could be considered as indicators of farming management. Cost and time necessary to identify pollutants or non-organic practices might justify the investigation of indicators. Moreover the use of higher taxa as surrogates for species supports this approach as a rapid, cheap and effective tool for shortcut to detect organic and non-organic olive farming at a local scale. Describing some ecological traits of coleopteran assemblages from olive canopies (abundance and diversity), different farming systems (conventional, integrated and organic) have been characterized in Granada province in a two-year study (from March to October in 1999 and 2000). An extending the sampling was conducted during May and June 2003 in a broad number of locations (two different provinces: Granada and Córdoba) with different land use tradition and landscape features. In most of cases, coleopteran abundances and diversity were higher in organic orchards, especially in Granada, where coccinellids and scraptiids seemed to indicate organic farming management, but it had not been observed in Córdoba, where differences were hardly found between organic and non-organic farming systems. Through multivariate statistics, agricultural practices, along with landscape features, and coleopteran families, could distinguish among organic and non-organic farmings, principally in June with a higher total explained variance (75.80%). A highest number of families were positively correlated with more sustainable practices (presence of vegetal covers), while herbicide and insecticide application were negatively correlated with most of beetle families. Finally, anthicids and staphylinids seemed to be favoured by non-organic practices. The landscape configuration and the land-use tradition are definitively acting on the coleopteran populations.

Key words: Coleopteran families, Hemeroby and Shannon indexes, indicator taxa.



5.2 Introduction

In searching for an indicator of farming systems in olive agroecosystems, studies have successfully shown differences among farming regimes, e.g., through distinctions in leaf features of olive trees (Ruano *et al.*, 2003), in biochemical variability of soils (Benítez *et al.*, 2006) or insect assemblages (Cotes *et al.*, 2009; Ruano *et al.*, 2004; Santos *et al.*, 2007). All these surveys are supported by the premise that the cost and time necessary to identify pollutants justifies the use of indicators. In the same way, the use of higher taxa as surrogates for species, such as order, family and even morphospecies, supports this approach as a rapid, cheap and effective tool for shortcuts to different goals (Derraik *et al.*, 2002; Krell, 2004; Kremen *et al.*, 1993; Woodcock *et al.*, 2006).

To manage sustainable agroecosystems in the Mediterranean basin, it is necessary to know, among other features, the biodiversity in each ecosystem (Labrador & Altieri, 2001). Among living organisms from all agroecosystems, arthropods, the most diverse inhabitants of terrestrial ecosystems, occupy a tremendous variety of functional niches across a wide array of spatial and temporal scales (Kremen *et al.*, 1993; McGeoch, 1998). However, the relative complexity of arthropod communities associated with crops is determined by biological, socio-cultural and environmental factors (Liss *et al.*, 1986). As a group of arthropods, beetles (Coleoptera) are one of the best represented orders in agroecosystems, due to their contribution to pest control (Iperti, 1999; Kromp, 1999) and being an important food source for farmland birds (Holland & Luff, 2000). On the one hand, as a result of their sensitivity, their reactions can be used to detect and identify the nature of disturbances or changes in environmental quality (Çilgi, 1994) or to predict the impact of disturbances on biodiversity (Bohac, 1999) when they are used as indicators (McGeoch, 1998). On the other hand, the coleopteran assemblages in olive orchards, one of the principal crops in the Mediterranean area, differ between localities (Belcari & Dagnino, 1995; Morris *et al.*, 2000; Petacchi & Minnocci, 1994; Raspi & Malfatti, 1985) and vary in abundance in the canopy and soil depending on the zone and the year (Ruano *et al.*, 2004). Previous studies have observed that the most abundant predatory coleopteran family in the canopy is Coccinellidae, whereas in the soil, it is Carabidae (Cotes *et al.*, 2009; Morris & Campos, 1999).

In this survey, three approaches are followed: i) some ecological traits of coleopteran assemblages from olive canopies (abundance, the Shannon diversity measure at the morphospecies level, and family richness) are used to characterise farming systems in the Granada province in a seasonal pattern; ii) coleopteran families more representative of each farming system are identified; and finally, iii) a second region (Córdoba province) with extremely different traditions of land use and landscape features, is compared to the Granada province and investigated in order to evaluate the suitability of coleopteran families in olive agroecosystems with different land-use practices. The evaluation of these practices was made using the concept of "hemerobiotic state" or "hemeroby" (Jalas, 1955) that describes human impacts on ecosystems such as land-use types, plant communities and soils (Blume & Sukopp, 1976; Bornkamm, 1980; Sukopp, 1972; Sukopp, 1976). As a measure for naturalness or, conversely, the human influence on ecosystems, hemeroby can be used as a surrogate for land-use intensity and a sustainability measure index for agricultural landscapes (Fu *et al.*, 2006). Both management and landscape features have to be observed in biodiversity studies in the agricultural landscape, since they affect diversity (Weibull *et al.*, 2003).

5.3 Materials and methods

5.3.1 Study zones and sampling periods

The study area covers a region spanning two provinces in Spain extending about 104 km from north to south and 117 km at its widest point from east to west, with the experimental fields located at an altitude of 400 to 1100 m above sea level. The provinces of Córdoba and Granada are two of the largest commercial olive producing areas in southern Spain, but natural surroundings and land-use traditions make the olive landscape diverse. In Córdoba, the sampling was carried out in the Los Pedroches Valley, which is the largest organic producing region in Andalusia. Though there are some non-organic farmers in this valley, the organic olive farming system is extensive. This region is close to the Cardeña and Montoro natural park, and it contains a semi-natural olive landscape with Mediterranean forest patches. Olive orchards from Granada are located near mountain oak stands; however, in Granada, the surrounding olive orchards are cultivated under intensive farming systems, and the patches of natural vegetation are smaller than in Córdoba (Figure 5.1). First, three large olive orchards in Granada using organic, integrated and conventional farming systems were sampled from March to October in 1999 and 2000, in order to include interannual variability of beetle abundances and the distribution patterns of beetle families over time. Additionally, nine large orchards (three per farming system) were sampled in Granada and nine other orchards in Córdoba in May and June 2003; altogether, a total of 18 orchards were sampled in 2003. Then we undertook a temporal variability study in Granada (1999 and 2000) in three large olive orchards and another study at a high scale level in 18 olive orchards (nine per province) at the same time in 2003.

The different farming systems were performed according to the current legislation enforced at that time; the farming practices of each type are summarised in Table 5.1.

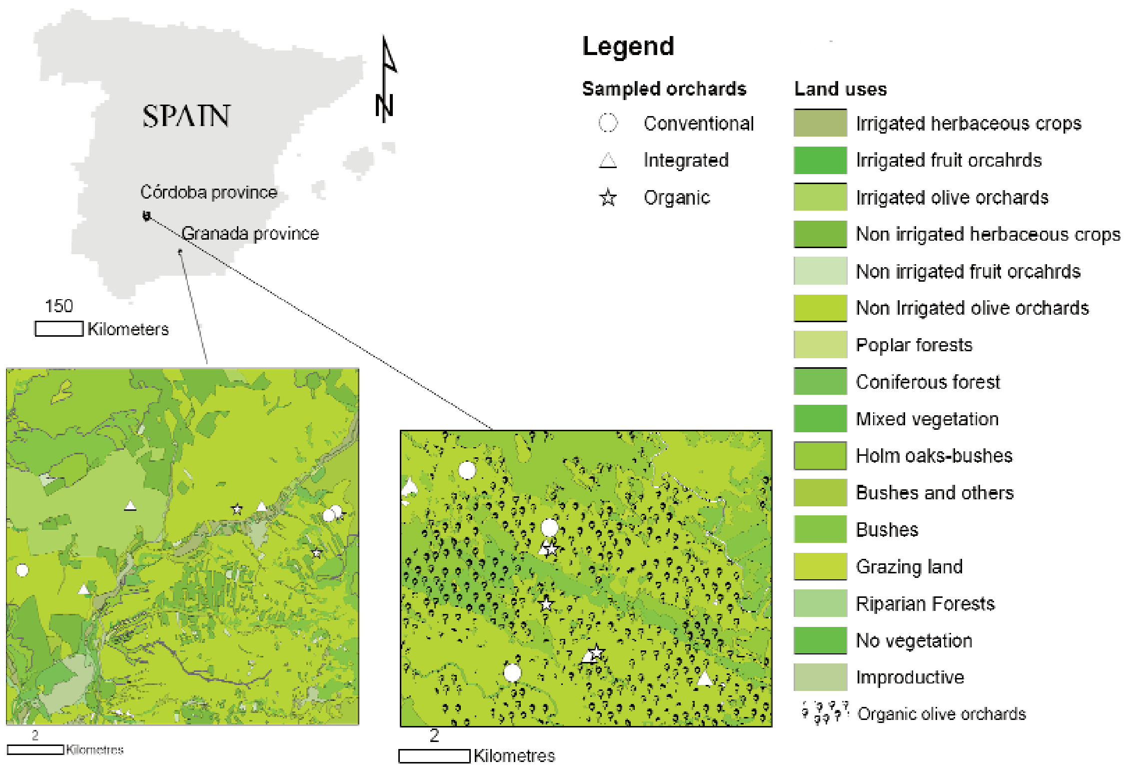
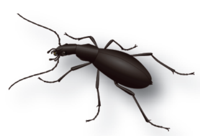


Figure 5.1: Locations, type of farming systems and agronomic practices, months and and years of the sampled olive orchards.

Table 5.1: Type of farming systems, sampling year, hemerobiotic index at different buffers and agronomic practices of the sampled olive orchards (Córdoba: A to I and Granada: J to R)

Province		Farming system	Sampling year	Hemeroby index				Irrigation	Plough	Insecticides	Herbicides	Vegetal Cover	Hedge row
				2000 m	1500 m	1000 m	500 m						
Córdoba	A	Conventional	2003	24.42	35.25	36.25	37	No	No	Yes	Yes	No	No
	B	Integrated	2003	38.44	40.50	31.70	34.08	No	No	Yes	Yes	Yes	No
	C	Organic	2003	38.45	40.50	31.79	34.08	No	Yes	No	No	Yes	No
	D	Conventional	2003	39.09	31.33	33.21	35.15	No	Yes	Yes	Yes	Yes	Yes
	E	Organic	2003	38.44	53.50	54.78	59.24	Yes	No	No	No	Yes	No
	F	Conventional	2003	51.35	51.41	56.88	56.17	No	Yes	Yes	Yes	No	Yes
	G	Integrated	2003	58.07	58.98	58.66	54.55	No	No	Yes	No	Yes	No
	H	Organic	2003	58.94	60.32	58.69	55.74	No	Yes	No	No	Yes	Yes
	I	Integrated	2003	60.22	61.72	58.46	61.17	No	No	Yes	Yes	No	No
Granada	J	Conventional	1999, 2000, 2003	66.33	66.39	67.06	67.38	Yes	Yes	Yes	Yes	No	No
	K	Integrated	2003	70.75	71.35	73.31	74.30	Yes	No	No	Yes	Yes	Yes
	L	Intengrated	1999, 2000 2003	30.41	66.41	70.40	71.04	Yes	Yes	Yes	Yes No	No	No
	M	Organic	2003	63.19	66.63	66.79	66.56	Yes	Yes	No	No	Yes	No
	N	Integrated	2003	69.76	63.61	66.70	66.86	No	Yes	Yes	No	No	No
	O	Conventional	2003	60.44	56.77	60.59	66.19	Yes	No	Yes	Yes	No	No
	P	Organic	1999, 2000, 2003	59.98	56.77	56.88	61.19	Yes	Yes	No	No	Yes	Yes
	Q	Conventional	2003	44.87	56.65	60.59	61.50	Yes	No	Yes	Yes	Yes	No
	R	Organic	2003	63.87	59.93	60.80	61.05	Yes	Yes	No	No	Yes	Yes



5.3.2 Collection of coleopterans

In each olive orchard, four blocks were sampled, and each block consisted of a row of five trees. Two sampled trees in the block were separated by an unsampled tree, so that the distance between sampled trees was 20 metres. Each block was considered a true replication because of the large size of the olive zones studied, and the distance between blocks (a minimum of 0.5 km) ensures independence between them. The canopies of these olive trees were sampled by five beatings of four randomly chosen branches per tree (one per compass orientation), over an insect net 50 cm in diameter with a pile of insecticide to avoid predation among individuals.

Samples from canopies were frozen, and, subsequently, the beetles were separated from vegetal and inorganic remains. Adults and juveniles were identified to the taxonomic level of families and morphospecies (Krell, 2004).

5.3.3 Hemeroby index

In order to evaluate the landscape features and the traditions of land use, the "Hemeroby" concept was considered as an environmental variable in the multivariate analysis. A polygon layer was designed from UTM coordinates of the certified organic orchards in three provinces. The land uses and the land cover types around the fields were obtained from the crops and land-use maps of Andalusia (Junta de Andalucía, 2001). The overlay of these two layers is an output layer containing hemerobiotic categories that we took into account. Levels of hemeroby were assigned to the different land uses according to Table 5.2. From the total area belonging to the different hemerobiotic levels, an hemeroby index (M) was calculated (Steinhardt *et al.*, 1999) for each olive grove at different distances and was buffered at 500, 1000, 1500 and 2000 metres (Table 5.1). The cartographical information was managed using ArcGIS 9.3 software.

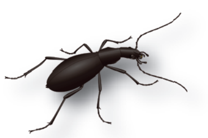
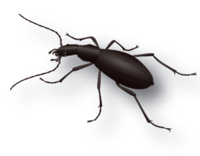


Table 5.2: Land use types according to the human impact on ecosystems and corresponding hemerobiotic degrees.

Land use types	Hemeroby-factor	Degree of hemeroby
None	0	Ahemerobe: natural
Mixed and riparian forest	1	Oligohemerobe: Natural vegetation (limited removal of wood, pastorilism, imissions through air and water)
Coniferous forest, tree nurse.	2	Mesohemerobe: semi-natural vegetation (clearing and ocasional ploughing, clear cut, ocasional slight fertilization)
Permanent grassland, fruit tree alley.	3	
Organic olive orchards	4	β-mesohemerobe: Relatively far from natural (application of fertilizers, lime and pesticides, ditch drainage)
Non-irrigated fruit orchards and herbaceous crops	5	
Non-irrigated olive orchards	6	
Irrigated fruit and olive orchards and herbaceous crops	7	α-mesohemerobe: Far from natural (deep plughingh, drainage, application of pesticides and intensive fertilization)
Without vegetation	8	Polyhemerobe: Strange to natural (single destruction of the biocenosis and covering of the biotope with external material at the same time)
Purely artificial	9	Metahemerobe: artificial (biocenosis destroyed)

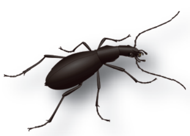


5.3.4 Univariate statistical analysis

In order to distinguish some differences between management regimes, the mean abundance of the families and the mean of the Shannon index at the morphospecies level per block were compared monthly among farming systems in 1999, 2000 and 2003 by non-parametric tests. They were used because of the non-normality of data even after several transformations. These analyses were carried out with SPSS 17.0 for Windows, while the Shannon index was generated using Robert Colwell's Estimates Program (Colwell, 2004).

5.3.5 Multivariate statistical analysis

Ordination methods were performed in order to characterise the coleopteran assemblages from canopies of the Andalusian olive orchards under organic and non-organic farming regimes from Granada and Córdoba during pre-blooming (May) and post-blooming (June) in 2003. The multivariate approach was chosen to determine relationships among coleopteran families with farming practices (insecticide and herbicide use, existence of vegetal cover and hedge rows, irrigation and plough) and land-use heterogeneity (Hemeroby Index). Direct gradient analyses were performed to extract patterns from the explained variation by explanatory variables (farming practices and land-use heterogeneity) with respect to the most abundant families. First of all, a Detrended Canonical Correspondence Analysis (DCCA) was used to determine the approach (unimodal or linear) that fit best with the data set (Leps & Smilauer, 2003). The significant level of the analyses was assessed by a Monte-Carlo permutation test with 499 randomisations because this number of permutations is proposed by Leps & Smilauer (1999) to test the hypothesis that the effect of all the explanatory variables is zero. The total abundance of coleopteran families and the environmental variables were transformed by a log transformation (log10 (y+1)). Calculations and resulting biplots are performed using XLStat (Addinsoft, 2004).



5.4 Results

5.4.1 Local and seasonal patterns of abundance and richness of coleopteran families

A total of 26 families of coleopterans were captured in the canopy of the olive trees from March to October in the 1999-2000 sampling period, 25 in 1999 and 19 in 2000 (Table 5.3). The integrated and organic orchards showed the highest family richness (20), while the conventional orchard was far poorer (14). Nevertheless, only 16 and 10 families, respectively, represented 7% of the total captured coleopterans in 1999 and 2000. Also, seven of the most abundant families were the same in both years of study: Coccinellidae, Scraptiidae, Apionidae, Anthicidae, Curculionidae Staphilinidae and Bruchidae. During both sampling years, 905 individuals were collected (554 in 1999 and 351 in 2000). Neither the total abundance of coleopterans nor the abundance of the seven most abundant families separately showed significant differences between years when applying the Kruskal-Wallis test.

The most abundant family was Coccinellidae in the two years, appearing in all farms, but especially abundant in the organic olive orchards.

Scraptiidae were practically exclusive to the organic olive orchard and appeared in the olive canopy only in July. This family presented high variability for number of individuals per block, as shown by its large SD in both sampled years.

The third most abundant group was the chrysomelid beetle family, which showed an erratic pattern during both years in the three kinds of farming systems. The highest number of captures appeared in the organic orchard in May 1999 and October 2000. Significant differences were observed in June 1999 (χ^2 = 7.20; df=2; p<0.05), May (χ^2 = 7.20; df=2; p<0.05) and August 2000 (χ^2 = 6.41; df=2; p<0.05), and in each case, integrated, organic and conventional farming systems had the highest abundance.

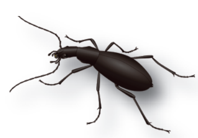
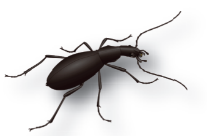


Table 5.3: Mean and SD of coleopteran families ordered decreasingly and captured in each management regimes in during 1999 and 2000.

	1999						2000					
	Conv		Int		Org		Conv		Int		Org	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Scraptiidae	0	0	0.03	0.18	5.91	19.03	0	0	0	0	1.78	8.85
Coccinellidae	1.03	2.44	0.78	1.21	3.94	4.21	0.63	1.10	1.19	2.88	1.34	1.89
Chryrsomelidae	0.28	0.58	0.44	0.67	0.59	0.76	0.63	0.79	0.44	1.05	1.28	1.40
Anthicidae	0.56	1.46	0.28	0.63	0.13	0.34	0.16	0.51	0.28	0.77	0.06	0.25
Staphylinidae	0.31	0.90	0.06	0.25	0.22	0.55	0.13	0.34	0.09	0.30	0.19	0.54
Apionidae	0.03	0.18	0	0	0.44	1.41	0.09	0.30	0.09	0.39	0.31	0.78
Curculionidae	0.09	0.30	0.19	0.40	0.16	0.51	0.06	0.25	0.16	0.37	0.53	2.09
Malachiidae	0	0	0.03	0.18	0.34	1.07	0	0	0.06	0.25	0.09	0.39
Cucujidae	0.13	0.42	0	0	0.09	0.30	0.03	0.18	0.06	0.25	0	0
Phalacridae	0	0	0.03	0.18	0.16	0.45	0	0	0	0	0.09	0.39
Cantharidae	0	0	0.09	0.30	0.06	0.35	0.03	0.18	0.03	0.18	0.09	0.30
Nitidulidae	0.03	0.18	0.03	0.18	0.06	0.25	0	0	0	0	0	0
Tenebrionidae	0	0	0	0	0.13	0.34	0	0	0.06	0.25	0.28	1.28
Rhynchitidae	0	0	0.03	0.18	0.06	0.25	0	0	0.28	0.81	0.09	0.30
Anobiidae	0	0	0.09	0.30	0	0	0	0	0	0	0.06	0.25
Mycetophagidae	0.06	0.35	0	0	0.03	0.18	0	0	0	0	0	0
Elateridae	0.03	0.18	0.03	0.18	0	0	0.03	0.18	0	0	0	0
Scarabaeidae	0	0	0	0	0.06	0.25	0	0	0	0	0.06	0.25
Cryptophagidae	0.06	0.35	0	0	0	0	0.03	0.18	0.06	0.25	0	0
Dascillidae	0	0	0.03	0.18	0	0	0	0	0	0	0.03	0.18
Carabidae	0	0	0.03	0.18	0	0	0	0	0	0	0	0
Melyridae	0.03	0.18	0	0	0	0	0	0	0	0	0	0
Bostrichidae	0.03	0.18	0	0	0	0	0	0	0	0	0	0
Melandryidae	0	0	0	0	0.03	0.18	0	0	0	0	0	0
Dermestidae	0	0	0	0	0.03	0.18	0	0	0	0	0	0
Dasytidae	0	0	0	0	0	0	0	0	0.03	0.18	0	0
Total average	2.69	5.03	2.19	1.75	12.44	21.14	1.81	1.38	2.88	4.39	6.28	11.48



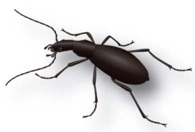
The anthicid family seemed to be more related to non-organic farming because it was more abundant in the integrated olive orchard and in the conventional orchard in May of both sampling years. Abundance peaked in May and June of both years of the study, except for October of 1999, when abundance was highest in the conventional olive orchard. In organic orchards, this family was practically absent.

Curculionidae presented a different abundance pattern in 1999 and 2000, appearing in the conventional orchard in April 1999 and in the organic orchard in May 1999, while peaks occurred in the organic orchard in May 2000.

With regard to Staphylinidae, no pattern was observed between years; in April of both years, they were more abundant in the organic orchard, while the highest abundance was computed in the conventional orchard during October of 1999.

Finally, the integrated orchard lacked apionid individuals in 1999, and only a few of them were collected in April 1999 in the conventional orchard. Some specimens were found in March, July and August 1999 in organic orchards, achieving a peak in September 1999, and they were absent in May, June and October in all the orchards. The situation changed in 2000 because individuals were collected only in the organic orchard from May to September, showing the maximal abundance in June and August. In the months when no individuals were collected in the organic orchard, the highest abundances occurred in March in the integrated orchard and in April in the conventional orchard. Only apionids were captured in the conventional orchard in October.

The mean of the Shannon Diversity Index varied between months and years in the Granada province (Figure 5.2 A and B). Significant differences were observed in 1999, the highest diversity was achieved in organic orchards in March, August and September, while the integrated orchard achieved the greatest diversity in June and July. In 2000, the organic orchard showed the greatest diversity in May, June, August and September, and the integrated orchard showed significant differences only in March, with similar diversity in the organic and integrated orchards in July.



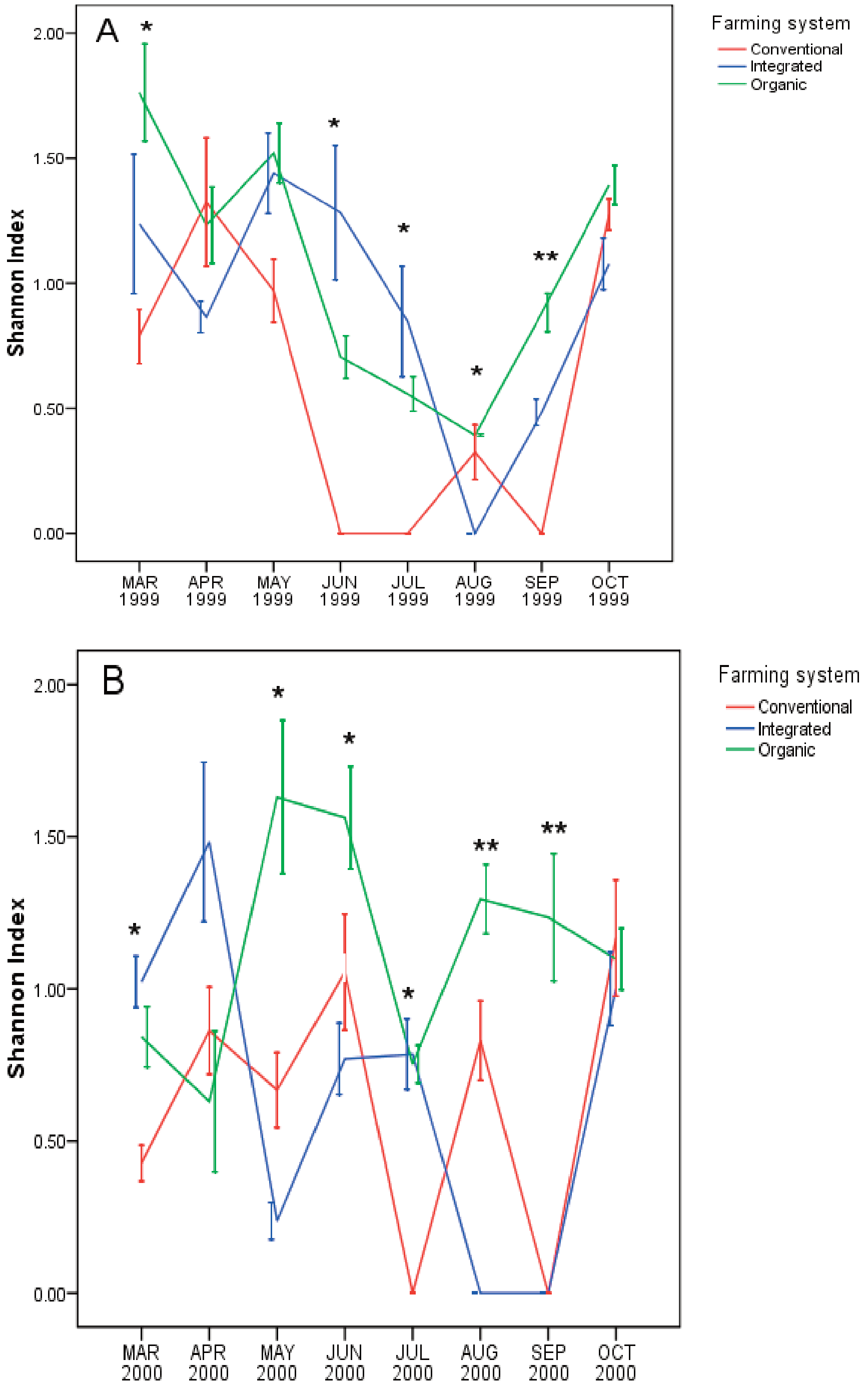


Figure 5.2: Mean of Shannon index per block (mean ± SE). Bars mean SE. Stars show significant differences among farming systems in Granada 1999 (A) and Granada 2000 (B): * $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$

5.4.2 Pre-blooming and post-blooming patterns of abundance and richness of coleopteran families

The next sampling period (2003) covered the two provinces under different olive farming systems (three orchards per management system). A total of 23 coleopteran families and 471 specimens were captured between May and June in eighteen olive orchards, which were randomly selected in Córdoba and Granada provinces (Figure 5.1). A greater number of beetles (19 families and 377 specimens) were collected in Córdoba than in Granada (14 families and 95 specimens). The total mean abundance of beetles varied between provinces independently of the kind of farming system. On the one hand, significant differences were observed among regimes in May in the Córdoba province (χ^2 = 18.76; df=2; p<0.005), with the organic orchards showing the greatest abundance of beetles, followed by conventional and integrated orchards. The increase of captures in the three farming systems made the abundances of the organic and conventional orchards in June equal, while the integrated orchards showed lower abundances. On the other hand, the conventional, followed by the organic and finally the integrated orchards, showed a low mean of beetle abundances in May in Granada. These values grew significantly in June (χ^2 = 7.25; df=2; p<0.05), with the lowest abundance in the conventional orchard, followed by the integrated and organic orchards. The scraptiid, coccinellid and chrysomelid families represented 67.80%, with the remaining 20 families making up the other 32.20%. Scraptiid beetles were absent in May, and their presence was higher in Córdoba than in Granada during June, and they were more abundant in Córdoba integrated orchards than in Granada organic orchards. Coccinellids were practically absent in May in both Granada and Córdoba provinces, but they were captured in high numbers in June in conventional and organic orchards in Córdoba, while coccinellids in Granada in the same period showed similar abundances for the different farming systems. Finally, chrysomelid beetles differed between provinces without showing similar patterns.

When the three farming systems from the different provinces were taken into account in 2003, May as well as June showed significant differences, with the highest diversity in the organic orchards (Table 5.4).

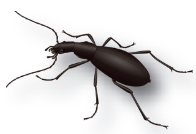
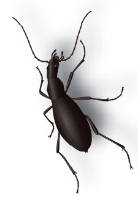


Table 5.4: Mean and SD of coleopteran families ordered decreasingly captured in conventional, integrated and organic farmings in Córdoba and Granada during 2003.

Farming system	Córdoba May						Granada May						Córdoba June						Granada June					
	Conv		Int		Org		Conv		Int		Org		Conv		Int		Org		Conv		Int		Org	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	0	0	0	0	0	0	0	0	0.08	0.29	0	0	2		3.67	5.63	3	3.19	0	0	0.17	0.39	0.83	1.75
Coccinellidae	0	0	0.08	0.29	0.17	0.39	0.08	0.29	0.08	0.29	0.17	0.58	3.50	5.60	0.42	0.51	3.92	4.89	0.42	0.67	0.50	0.52	0.33	0.49
Chrysomelidae	0.42	0.51	0.25	0.62	1.17	1.27	0.92	1.24	0.08	0.29	0.33	0.49	1.75	2.73	0.67	1.15	1.33	1.78	0	0	0.17	0.58	0.17	0.39
Phalacridae	0	0	0	0	0.08	0.29	0	0	0	0	0	0	1.50	3.45	0	0	0.42	0.67	0	0	0	0	0.25	0.45
Malachiidae	0.17	0.39	0	0	0.08	0.29	0	0	0.42	0.90	0	0	0.42	0.67	0.08	0.29	0.17	0.58	0	0	0.08	0.29	0.75	1.14
Curculionidae	0.25	0.87	0.08	0.29	0.58	0.79	0	0	0.08	0.29	0.33	0.65	0	0	0.08	0.29	0	0	0	0	0.08	0.29	0.25	0.87
Cantharidae	0.25	0.45	0	0	0.58	1.00	0.25	0.45	0	0	0.17	0.39	0	0	0.33	0.89	0	0	0	0	0	0	0	0
Melandryidae	0	0	0.25	0.45	1.08	1.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchitidae	0	0	0.08	0.29	0.42	0.51	0	0	0	0	0	0	0	0	0	0	0.25	0.45	0	0	0	0	0	0
Carabidae	0.08	0.29	0	0	0.08	0.29	0	0	0	0	0	0	0.25	0.62	0.17	0.39	0.08	0.29	0	0	0	0	0	0
Tenebrionidae	0.25	0.62	0	0	0	0	0.08	0.29	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0	0
Staphylinidae	0	0	0	0	0	0	0.17	0.39	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.29	0	0
Anthicidae	0	0	0	0	0	0	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0.08	0.29	0	0
Apionidae	0	0	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.29
Elateridae	0	0	0.17	0.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dermestidae	0	0	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.29
Cucujidae	0	0	0	0	0.17	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dasytidae	0	0	0	0	0.17	0.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitidulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.29	0	0	0	0	0	0
Cerambycidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.29
Anobiidae	0	0	0	0	0	0	0	0	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0	0
Cryptophagidae	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oedemeridae	0	0	0	0	0.08	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total average	1.50	1.31	1.00	0.95	4.83	3.30	1.50	1.51	0.83	1.27	1.08	0.67	9.42	9.70	5.42	5.58	9.25	6.61	0.42	0.67	1.17	1.03	2.83	3.51



5.4.3 Multivariate analysis

In order to find a better representation of agricultural practices, environmental variables and biological data, a DCCA indicated that a linear ordination model would be appropriate, so two Redundancy Analyses (RDA) were performed to establish the relationship between these data and the olive orchard sites in May and June 2003. Through the forward selection procedure, the Hemeroby indexes at different distances were selected in order to find a distance of the Hemeroby index that a higher variability of coleopteran abundance explained. The results indicated that the Hemeroby index at distances of 2000 and 1500 metres explained a higher variability in May and June, respectively.

In May 2003, the total explained variance was 72.50% (Figure 5.3.A) (Axis 1: 54.10% of the variance), while in June, it was 75.80% (Figure 5.3.B) (Axis 1: 47.40% of the variance). The first and second axes represent environmental stress, with organic orchards from Granada and Córdoba in the right corners and integrated and conventional orchards in the left corners in both months, but some integrated and conventional orchards from Córdoba and Granada appeared beside organic orchards or were located far away from these two groups. Irrigated orchards and the application of herbicides and pesticides seemed to favour the presence of anthicids and staphylinids in non-organic orchards. High hemerobiotic values are also related to non-organic orchards. However, ploughed soils and the presence of hedge rows increased the abundance of beetle families, such as malachiids and tenebrionids in May and cerambycids, nitidulids and dermestids in June. Finally, vegetal covers also had a positive influence on phalacriids, chrysomelids, coccinellids and carabids. Melandryds and coccinellids seemed to be related to organic orchards in May and to scraptiids and apionids in June. The presence of the remaining coleopteran families varied among the months.

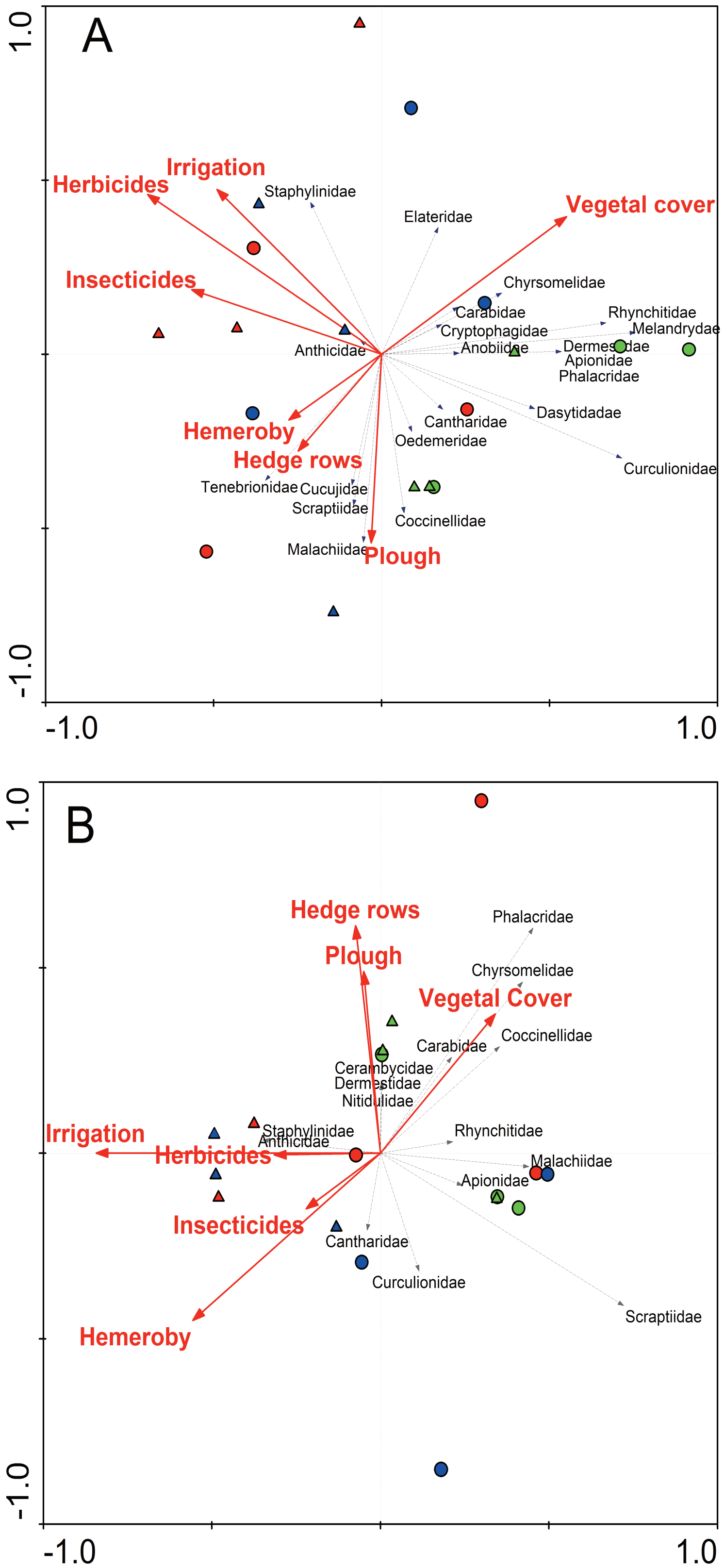
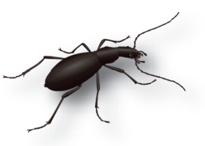


Figure 5.3: Redundancy analysis (RDA) of farming practices, hemerobiotic index and coleopteran families with sampling sites (olive orchards) in Granada (triangle) and Córdoba (circle) in May (A) and June (B) 2003. The red, blue and green colours represent respectively the conventional, integrated and organic farming.

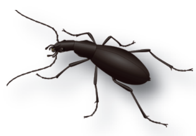


5.5 Discussion

It has already been observed that the arthropod assemblages can be representative of a range of agronomic practices (Clough *et al.*, 2007; Hadjicharalampous *et al.*, 2002; Letourneau & Goldstein, 2001; Purtauf *et al.*, 2005; Ruano *et al.*, 2004; Shah *et al.*, 2003). Coleopteran fauna living in the canopy of olive orchards was found to be very abundant, showing a high number of families represented, especially Coccinellidae, Scraptiidae, Chrysomelidae, Curculionidae and Apionidae. The total abundance of coleopterans was higher in organic olive orchards than in other farming systems (Menalled *et al.*, 1999) in Granada during the entire year of field activity (March to October), although several months, specially in 1999, showed low values of biodiversity in organic orchards.

After extending the samplings in these two regions, both provinces followed the previous pattern showing higher values in organic orchards, except for June in Córdoba, where conventional and organic orchards had similar abundances of coleopterans. From the results, it can be said that organic orchards had higher coleopteran abundances and diversity can be confirmed in the Granada province, but not the same affirmation can be made in the case of Córdoba organic orchards. A lower intensity of land use, higher heterogeneity of the landscape, and more sustainable olive culture in the Córdoba region compared with Granada could be the reason why conventional orchards are more similar in coleopteran assemblages. It is known that the relative complexity of arthropod communities associated with crops is determined by biological, socio-cultural and environmental factors (Liss *et al.*, 1986).

Thus, coleopteran populations in olive orchards differ among regions (Belcari & Dagnino, 1995; Morris *et al.*, 1999; Petacchi & Minnocci, 1994; Raspi & Malfatti, 1985; Ruano *et al.*, 2004). Scraptiids showed the highest abundances in the two provinces in 2003; however, their abundance differed between non-organic and organic orchards in Granada, but not in Córdoba, where the abundance of the scraptiid family was similar between different orchards in June. Although morphospecies diversity was shown to be higher in organic orchards in the two studied provinces, coleopteran families did not indicate non-organic or organic farming systems in the same way.



In May and June, the RDAs summarised farming practices and land-use heterogeneity as explanatory variables and families as response variables of sampled orchards and finally resulted in separated groups of organic and non-organic orchards. The highest numbers of families were positively correlated with more sustainable practices (presence of vegetal covers) in May and June, while herbicide and insecticide applications were negatively correlated with most of the beetle families. In spite of the highest abundance of scraptiids in organic orchards in Granada and integrated orchards in Córdoba, they could not be associated with any farming system. Finally, anthicids and staphylinids seemed to be associated more with non-organic practices.

The study of beetle assemblages in southern Spain under different farming systems could not be interpreted if, as Bartel (2000) proposed, the pattern of land use is not taken into account (e.g., site conditions, preferring traditional cultivation, regional techniques, social development, economic forces) (Bartel, 2000). The hemeroby concept has been analysed in order to include whether landscape structure can modify coleopteran assemblages from a variety of land-use traditions and combinations of practices. Many studies have found a positive correlation between environmental heterogeneity and biodiversity (Omer *et al.*, 2007), but human influence can modify this tendency in many different ways (Moreno-Rueda & Pizarro, 2007).

5.6 Conclusion

Allowing for the fact that spatial variability can determine coleopteran assemblages in olive agroecosystems, coccinellids and scraptiids seemed to behave as possible indicators of organic farming in most of the sampling months in Granada, but the same conclusion could not be confirmed in the Córdoba samplings. Non-organic and organic orchards did not show significant differences among the most abundant coleopteran families. Agricultural practices and their relationship with beetle families could be better explained in June, separating organic and non-organic orchards from both provinces. However, farming systems in olive orchards in Andalusia cannot be identified with certain kind of practices because each farming system allows a large range of practices, which can be more or less friendly to insects in olive orchards. Therefore, landscape configuration and land-use traditions are definitively acting on the insect populations. More investigations should be made on coccinellid and scraptiid species because some of them may be used as bioindicators, at least in the Granada province, where companies might guarantee the organic origin of produce and for public administrations that promote sustainable agriculture through incentives or rewards on a regional scale.

5.7 References

Addinsoft. (2004). XLstat for excel, version 7.5. 7.5 ed, Addinsoft. New York.

Bartel, A. (2000). Analysis of landscape pattern: towards a 'top down' indicator for evaluation of landuse. *Ecological Modelling*, **130**, 87-94.

Belcari, A. & Dagnino, A. (1995). Preliminary analysis of the insects caught by a "malaise" trap in an olive grove in northern Tuscany. *Agricoltura Meditteranea*, **125**, 184-192.

Benítez, E., Nogales, R., Campos, M. & Ruano, F. (2006). Biochemical variability of olive-orchard soils under different management systems. *Applied Soil Ecology*, **32**, 221-231.

Blume, H.-P. & Sukopp, H. (1976). Ökologische bedeutung anthropogener Bodenveränderungen. *Schriftenreihe für Vegetationskunde*, **10**, 75-89.

Bohac, J. (1999). Staphylinid beetles as bioindicators. *Agriculture, Ecosystems & Environment*, **74**, 357-372.

Bornkamm, R. (1980). Hemerobie und Landschaftsplanung. *Landschaft und Stadt*, **12**, 49-55.

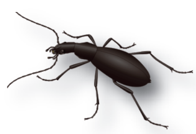
Çilgi, T. (1994). Selecting arthropod "indicator species" for environmental impact assessment of pesticides in field studies. *Aspects of Applied Biology*, **37**, 131-140.

Clough, Y., Kruess, A. & Tscharntke, T. (2007). Organic versus conventional arable farming systems: Functional grouping helps understand staphylinid response. *Agriculture, Ecosystems & Environment*, **118**, 285-290.

Colwell, R. K. (2004). ESTIMATES: Statistical Estimation of Species Richness and Shared Species from Samples. 7.5 ed.

Cotes, B., Ruano, F., García, P. A., Pascual, F. & Campos, M. (2009). Coccinellid morphospecies as an alternative method for differentiating management regimes in olive orchards. *Ecological Indicators*, **9**, 548-555.

Derraik, J., Closs, G., Dickinson, K., Sirvid, P., Barratt, B. & Patrick, B. (2002). Arthropod morphospecies versus taxonomic species: a case study with



Araneae, Coleoptera, and Lepidoptera. *Conservation Biology*, **16**, 1015-1023.

Fu, B.-J., Hu, C.-X., Chen, L.-D., Honnay, O. & Gulinck, H. (2006). Evaluating change in agricultural landscape pattern between 1980 and 2000 in the Loess hilly region of Ansai County, China. *Agriculture, Ecosystems & Environment*, 114, 387-396.

Hadjicharalampous, E., Kalburtji, K. L. & Mamolos, A. P. (2002). Soil Arthropods (Coleoptera, Isopoda) in Organic and Conventional Agroecosystems. *Environmental Management*, **29**, 683-690.

Holland, J. M. & Luff, M. L. (2000). The Effects of Agricultural Practices on Carabidae in Temperate Agroecosystems. *Integrated Pest Management Reviews*, **5**, 109-129.

Iperti, G. (1999). Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture, Ecosystems & Environment,* **74**, 323-342.

Jalas, J. (1955). Hemerobe und hemerochore Pflanzenarten. Ein terminologischer Reformversuch. *Acta Societatia Pro Fauna et Flora Fennica*, **72**, 1- 15.

Junta de Andalucía (2001) REDIAM: Red Medioambiental de Andalucía, Junta de Andalucía. Sevilla.

Krell, F. T. (2004). Parataxonomy vs. taxonomy in biodiversity studies-pitfalls and applicability of "morphospecies" sorting. *Biodiversity and Conservation*, **13**, 795-812.

Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R. F. & Sanjayan, M. A. (1993). Terrestrial arthropod assemblages: their use in conservation planning. *Conservation Biology*, **7**, 796-808.

Kromp, B. (1999). Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems & Environment*, **74**, 187-228.

Labrador, J. & Altieri, M. A. (2001). *Agroecología y desarrollo. Aproximación a los fundamentos agroecológicos para la gestión sustentable de agrosistemas mediterráneos.* Universidad de Extremadura. Ediciones Mundi-Prensa, Cáceres-Madrid.

Leps, J. & Smilauer, P. (1999). *Multivariate analysis of ecological data*. Faculty of Biological Sciences, University of South Bohemia., Ceske Budejovice, 110 pp.

Leps, J. & Smilauer, P. (2003). *Multivariate analysis of ecological data using CANOCO*, Cambridge, UK, 269 pp.

Letourneau, D. K. & Goldstein, B. (2001). Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology*, **38**, 557-570.

Liss, W. J., Gut, L. J., Westigard, P. H. & Warren, C. E. (1986). Perspectives on arthropod community structure, organization, and development in agriculture crops. *Annual Review of Entomology*, **31**, 455-478.

McGeoch, M. A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, **73**, 181-201.

Menalled, F. D., Lee, J. C. & Landis, D. A. (1999). Manipulating carabid beetle abundance alters prey removal rates in corn fields. *BioControl*, **43**, 441-456.

Moreno-Rueda, G. & Pizarro, M. (2007). The relative influence of climate, environmental heterogeneity, and human population on the distribution of vertebrate species richness in south-eastern Spain. *Acta Oecologica*, **32**, 50-58.

Morris, T. I. & Campos, M. (1999). Entomofauna depredadora del suelo del olivar. *Zoologia baetica*, **10**, 149-160.

Morris, T. I., Campos, M., Kidd, N. A. C., Jervis, M. & Symondson, W. O. C. (1999). Dynamic of the predatory arthropod community in Spanish olive groves. *Agricultural and Forest Entomology*, **1**, 219-228.

Morris, T. I., Symondson, W. O. C., Kidd, N. A. C. & Campos, M. (2000). Coleópteros depredadores y su incidencia sobre *Prays oleae* (Lepidóptera, Plutellidae) en el olivar. *Phytoma*, **118**, 43-52.

Omer, A., Pascual, U. & Russell, N. P. (2007). Biodiversity conservation and productivity in intensive agricultural systems. *Journal of Agricultural Economics*, **58** 308-329.

Petacchi, R. & Minnocci, A. (1994). Impact of different *Bactrocera oleae* (Gmel.) control strategies on olive grove entomofauna. *Acta Horticulturae*, **356**, 399-402.

Purtauf, T., Roschewitz, I., Dauber, J., Thies, C., Tscharntke, T. & Wolters, V. (2005). Landscape context of organic and conventional farms: influences on carabid beetle diversity. *Agriculture, Ecosystems & Environment*, **108**, 165-174.

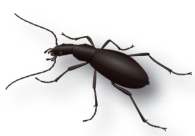
Raspi, A. & Malfatti, P. (1985). The use of yellow chromotropic traps for monitoring *Dacus oleae* (Gmel.) adults. In: Integrated pest control in olive groves. In *Proc. CEC/FAO/IOBC*, Cavalloro, R., Crovetti, A. Int. Joint Meet. Pisa, pp. 428-444.

Ruano, F., Campos, M. & Soler, J. J. (2003). Differences in leaves of olive trees under organic, integrated, and conventional pest management. *Agriculture, Ecosystems & Environment*, **97**, 353-357.

Ruano, F., Lozano, C., García, P., Peña, A., Tinaut, A., Pascual, F. & Campos, M. (2004). Use of artrhopods for the evaluation of the olive-orchard management regimes. *Agriculture and Forest Entomology*, **6**, 111-114.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007). Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pests in olive groves from north-east of Portugal. *Chemosphere*, **67**, 131-139.

Shah, P. A., Brooks, D. R., Ashby, J. E., Perry, J. N. & Woiwod, I. P. (2003). Diversity and abundance of the coleopteran fauna from organic and conventional management systems in southern England. *Agriculture and Forest Entomology*, **5**, 51-60.



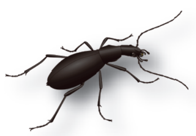
Steinhardt, U., Herzog, F., Lausch, A., Müller, E. & Lehmann, S. (1999). Hemeroby index for landscape monitoring and evaluation. In *Enviromental Indices - System Analysis Approach*, eds. Y. A. Pykh, D. E. Hyatt & R. J. Lenz, EOLSS Publ. Oxford, pp. 237-254.

Sukopp, H. (1972). Wandel von Flora und Vegetation in Mitteleuropa unter dem Einfluss des Menschen. *Berichte über Landwirtschaft*, **50**, 112-139.

Sukopp, H. (1976). Dynamik und Konstanz in der Flora der Bundesrepublik Deutschland. *Schriftenreihe Vegetationskunde*, **10**, 9-26.

Weibull, A. C., Östman, Ö. & Granqvist, A. (2003). Species richness in agroecosystems: The effect of landscape, habitat and farm management. *Biodiversity and Conservation*, **12**, 1335-1355.

Woodcock, B. A., Lawson, C. S., Mann, D. J. & McDonald, A. W. (2006). Effects of grazing management on beetle and plant assemblages during the re-creation of a flood-plain meadow. *Agriculture, Ecosystems & Environment*, **116**, 225-234.



6. Coccinellid morphospecies as an alternative method for differentiating management regimes in olive orchards

Coccinellid morphospecies as an alternative method for differentiating management regimes in olive orchards

Ecological Indicators Volume 9, Issue 3, May 2009 Pages 548 – 555

6.1 Abstract

Morphospecies, also known as morphotypes, recognizable taxonomic units (RTUs) and parataxonomic units (PUs) have been used for rapid biodiversity assessment (RBA) in invertebrate diversity studies worldwide. Their utilization might lighten taxonomists' workload when rapidly evaluating the richness and diversity of arthropods for conservation or biological assessment. To validate morphospecies, as opposed to taxonomic species, ladybird beetles (Coleoptera, Coccinellidae) were chosen in order to differentiate organic and non-organic management regimes (integrated and conventional) in olive orchards in southern Spain. Ladybird beetle specimens collected over two years (1999 and 2000) from three locations were sorted by morphospecies, and then identified by Coleopteran specialists according to taxonomic species. Thus, two different datasets were created, independently analyzed and compared to measure the accuracy at the morphospecies level. The comparison of morphospecies and species datasets showed an accuracy of 62.18% (one morphospecies to one taxonomic species), with the identifying error principally made when one species was identified as two different morphospecies (32.74%). Although two Coccinellid species (*Scymnus mediterraneus* Iablokoff-Khnzorian, 1972 and *Coccinella septempunctata* Linnaeus, 1758) showed significant differences among regimes during the June–August period in spite of small errors, we suggest that the most abundant morphospecies of Coccinellidae and the June–August period could be adopted as a rapid and useful tool for evaluating the impacts of non-organic vs. organic management regimes in olive orchards.

Keywords: Coccinellidae, indicator species, lumping, morphospecies, olive orchard rapid biodiversity assessment (RBA), splitting.

6.2 Introduction

The importance of olive agroecosystems in Andalusia (southern Spain) has grown considerably in recent decades despite the fact that olives have been an important crop in this region for a long time. With the present concern for the negative environmental impacts of large-scale olive monocultures, coupled with the growing demand for organic olive oil, a need to develop useful indicators of agroecosystem health in olive-growing regions has emerged. One key indicator of such health, or sustainability, is the abundance and biodiversity of invertebrates, especially arthropod fauna (Paoletti & Bressan, 1996; van Straalen, 1997; van Straalen & Verhoef, 1997). According to Moreno *et al.* (2007), invertebrates are the most commonly studied biological groups as biodiversity shortcuts. More specifically, arthropod diversity has been used to indicate the impacts of habitat modification (Andersen, 1990; Kremen *et al.*, 1993; Lawton *et al.*, 1998; Platen *et al.*, 2001), to measure the effects of human disturbance (Kimberling *et al.*, 2001), and even for conservation monitoring (Brown, 1997). Past studies of invertebrate fauna have also been used to compare organic and non-organic farming systems (Álvarez *et al.*, 2000; Clough *et al.*, 2007; Hadjicharalampous *et al.*, 2002; Letourneau & Goldstein, 2001; Purtauf *et al.*, 2005; Ruano *et al.*, 2004; Shah *et al.*, 2003), reporting significant differences between agroecosystem management and faunal diversity. Since the number of arthropod species is considerably large in olive agroecosystems (Arambourg, 1986; Campos & Civantos, 2000; de Andrés Cantero, 1991; Ruíz & Montiel, 2000; Varela & González, 1999), they can be used to distinguish organic, conventional and integrated farming systems.

Previous studies have proposed the Coleoptera and Lepidoptera orders as possible indicators of the impacts of conventional management systems in olive orchards (Ruano *et al.*, 2004). The criteria for selecting and testing terrestrial insects as indicators and their later application have been extensively described and defined in literature (Altieri & Nicholls, 2004; Çilgi, 1994; McGeoch, 1998; Moreno *et al.*, 2007; Nordén & Appelqvist, 2001; Smith *et al.*, 1999). However, the use of the Coleoptera order is complicated by having a large number of families with different life histories, biology, and environmental requirements. Different Coleopteran families have been proposed as indicators, in some cases together with other groups like Araneae (Pearce & Venier, 2006) or Isopoda (Hadjicharalampous *et al.*, 2002). The most common groups are the epigeal beetles (Buck *et al.*, 1992), more precisely staphylinids (Bohac, 1999; Melke & Gutowski, 1995) and carabid beetles (Kampichler & Platen, 2004; Luka, 1996; Michaels & McQuillan, 1995; Rainio & Niemelä, 2003). Coccinellidae is an abundant family in the olive canopy (Santos *et al.*, 2007; Varela & González, 1999), the place where insecticide treatments are applied, and has been studied for its predator function in this agroecosystem (Morris *et al.*, 1999). About 90% of the species of this family are beneficial predators (Iperti, 1999; Varela & González, 1999). Due to their beneficial role, the impact of pesticides on coccinellid species has been analyzed in olive agroecosystems (Ba M'hamed & Chemseddine, 2002; Cirio, 1997; Ruano *et al.*, 2004; Santos *et al.*, 2007), and synthetic pyrethroid insecticides (cypermethrin, alfa-cypermethrin) are one of the most toxic products (Ba M'hamed & Chemseddine, 2002), causing rapid mortality with a ratio that exceeded 60% after 24 h on *Scymnus mediterraneus* Iablokoff-Khnzorian, 1972 when applied in conventional olive orchards. In the same way, although with a more moderate effect, dimethoathe was also observed to cause mortality in *Sc. mediterraneus* and other coccinellids (Iperti, 1999). Furthermore, ladybirds are taxonomically one of the best known families of beetles because of their ubiquity and their presence around the world. This is a group with a vast number of species that are difficult to identify only on the basis of color pattern, which is extremely variable in most species (Iperti, 1999). However, the distinctive coccinellid appearance facilitates the recognition of specimens at the family level (Iperti, 1999). The current scarcity of taxonomists, the difficulty in identifying separate species, especially invertebrates (Ward & Stanley, 2004), and the long experience necessary to be able to recognize the vast number of species, obligates agroecologists to appeal to other systems for evaluating diversity.

Taxonomic surrogacy is one of the four categories of rapid biodiversity assessment (RBA) proposed by Oliver & Beattie (1996a). RBA approaches have been developed to meet the short-term needs of providing scientific advice for resource managers and policy makers (Boone *et al.*, 2005). For example, Oliver & Beattie (1993) developed RBAs for invertebrates. RBAs aim to reduce the time and effort for the identification process, greatly reducing dependence on specialist

taxonomists (Wilkie *et al.*, 2003) and allowing more ambitious sampling designs. The family Coccinellidae, identified at the morphospecies taxonomic level, can be used as a recognizable taxonomic unit (RTU). This term refers to the identification of unifying characteristics according to morphological similarities, without considering taxonomic literature or taxonomic standards (Krell, 2004). The precision of identifying morphospecies is quite variable for different arthropod groups, and therefore, it should be established based on the taxonomic morphospecies–species relationship for each group. According to Lawton *et al.* (1998), a large proportion of morphospecies cannot be assigned to named species, and the number of "scientist-hours" required to process samples increases dramatically for smaller-bodied taxa. Derraik *et al.* (2002), based on arguments in Lawton *et al.* (1998), suggested that the mistakes in ladybirds are made when several coccinelid species are very small. We have carried out this study in order to test the proposal that the use of coccinellid morphospecies (as a surrogate for coccinellid species) could be a possible "indicator" of the different management regimes for olive agroecosystems.

6.3 Materials and methods

6.3.1 Study zones

The study was conducted between 1999 and 2000 in three commercial olive orchards (Colomera, Arenales and Deifontes) 20 km north of Granada in southern Spain. These three sites were in an area of large olive orchards ranging between 200 and 500 ha. They were approximately 4 km apart from each other, located at similar altitudes and with similar environmental characteristics, but were under different management regimes. In one with intensive conventional management, a dimethoate spray occurred in March or April (against *Prays oleae* (Bernard, 1788)), in June there was an alpha-cypermethrin spray (against *P. oleae*), and finally, in October, a dimethoate spray (against *Bactrocera oleae* (Gmelin, 1790)) was applied. The orchard under integrated pest management (IPM) received only one treatment with dimethoate (against *P. oleae*) in June 2000. Finally, in the organic management, neither *Bacillus thuringiensis* Berliner used in other organic systems nor other permitted insecticides were applied during our study. Regarding the vegetal cover, weeds on the fields were totally eliminated in both integrated and conventional orchards; the conventional one was frequently ploughed deeply and treated with the herbicide simazine (4 L/ ha of the formulation at 50%), while the same herbicide was applied twice a year in the integrated orchard. Finally, the organic olive orchard was ploughed only to a shallow depth (10 cm) from the end of May to the beginning of June.

6.3.2 Collection of Coccinellidae

The canopies of olive trees were sampled by beating, five times, four branches per tree (one per compass orientation) that were chosen at random, over an insect net of 50 cm in diameter. Coccinellid specimens collected from these olive canopies were frozen and later separated from vegetal and inorganic remains. Adults and juvenile beetles were identified under a stereomicroscope (Stemi SV8, Zeiss) to the taxonomic level of order and family. The adults of coccinellids were separated from the other coleopterans in order to be identified by a parataxonomist in accordance with their morphological differences, avoiding the use of taxonomic keys as recommended by Basset *et al.* (2004). A taxonomist (F. Rei) examined the coccinellid morphospecies and, at the same time, trained the parataxonomist to recognize the coccinellid species. In this way, it was possible to determine the degree of "splitting" and "lumping" (Oliver & Beattie, 1996b) committed by the untrained parataxonomist. These terms mean that a taxonomic species is divided into several different morphospecies (splitting) or two or more taxonomic species are combined into a single morphospecies (lumping). The identification of ladybird species was carried out using the review of Coccinellidae from Portugal elaborated by Raimundo & Alves (1986); however, the polymorphism and the range in length (from about 1 mm to about 10 mm depending upon species) of the family, in some cases, forced the extraction of male and/or female genitalia to differentiate between species. The scientific nomenclature was updated according to the Fauna Europaea inventory (Fauna Europaea Web Service, 2004).

6.3.3 Statistical analysis

The experimental sampling design was established as follows: three large olive grove zones, one per management (even orchards of different owner per zone). In each olive orchard, six blocks were sampled in 1999, each block consisting of a row of five trees separated by unsampled one, so the distance between sampled trees was 20 m, though only five blocks were considered in 2000. Each block was considered a true replication because of the large size of the studied olive zones and because the distance between blocks (a minimum of 0.5 km) ensures independence between them. Thus, the three sites with different management were sampled on sixteen occasions (monthly from March to October in 1999 and 2000), and the blocks were sampled by beating. Coccinellid family count data were analyzed by applying a principal effects quasi-Poisson (overdispersion parameters took values much greater than 1) log-linear model (Cunningham & Lindenmayer, 2005) in which the design factors are block (1–6 in 1999 and 1–5 in 2000), management (organic and non-organic) and year (1999 and 2000). The coefficients and associated p-values for the factors for each model were calculated using R-statistical software (R Development Core Team 2005). As an additional check, a Mann–Whitney U-test was used to compare both databases (species vs. morphospecies) monthly over the duration of the study with SPSS 14.0 for Windows.

Correspondence analysis (CA) was performed for the most abundant morphospecies and species (Hammer *et al.*, 2001) to check the similarity graphically among regimes using PAST program.

6.4 Results

6.4.1 Splitting and lumping

From a total number of 1253 coleopteran specimens, the parataxonomist was able to identify 394 individuals by coccinellid family over the two years of study, according to the general morphological features of the family. Following the morphospecies definition, the parataxonomist sorted the individuals into 16 morphospecies. After examination by the taxonomist, the number of coccinellid specimens was 375 individuals (19 individuals less than in the morphospecies dataset), and they belonged to 12 taxonomic Coccinellidae species (Table 6.1). The total number of specimens was different in the two dataset, because three specimens were lost or could not be identified due to their poor state of preservation. The remaining 16 specimens belonged to phalacrid species (ten individuals) and cucujid species (six individuals), because even though they are not in the coccinellid family, their body size, color pattern, and other features fit the morphological concept that the parataxonimst had been taught for small ladybirds. Finally, for these reasons, we consider that the total number of taxonomic species was 14 (12 coccinellids and two belonging to other families).

Table 6.1: Coccinellid morphospecies and species dataset and total abundance in integrated (I), conventional (C) and organic (O) management regime over the two years, with type of identification error and general body size of species.

Morphospe-cies dataset	I	C	O	Species dataset	I	C	O	Correspondence sp-msp	Error	Body length (mm)
msp. 1	1	0	3	Family Phalacridae	–	–	–	1:02	Splitting	–
msp. 2	1	4	2	*R. chrysomeloides*	3	10	1	1:01	Correct	–
msp. 3	73	10	36	*Sc. mediterraneus*	73	48	174	1:02	Splitting	1–1.50
msp. 4	3	44	140						Splitting	1–1.50
				Sc. subvillosus	0	0	2	2:01	Lumping	1.90–2.50
msp. 5	4	10	21	*C. septempunctata*	4	10	22	1:01	Correct	5.50–8
msp. 6	0	1	1	*H. variegata var. carpini*	0	1	1	1:02	Splitting	3–5.50
msp. 7	0	0	8	*A. decempunctata*	0	0	8	1:01	Correct	3–5.50
msp. 8	0	0	8	Family Phalacridae	–	–	–	1:02	Splitting	–
msp. 9	0	0	5	*Sc. apetzi*	1	0	4	1:01	Correct	2–3
msp. 10	0	0	3	*A. bipunctata*	0	0	3	1:01	Correct	3.50–5
msp. 11	2	4	0	Family Cucujidae	–	–	–	1:01	Correct	–
msp. 12	1	0	0	*H. variegata var. constellate*	1	0	0	1:02	Splitting	3–5.50
msp. 13	0	2	4	*Sc. punctillum*	0	2	4	1:01	Correct	1.20–1.50
msp. 14	0	0	1	*H. reppensis*	0	0	1	1:01	Correct	2.50–4.50
msp. 15	0	0	1	*M.octodecimguttata*	0	0	1	1:01	Correct	3.50–5.50
msp. 16	0	0	1	*P. luteorubra*	0	1	0	1:01	Correct	2.50–3.50
Total	85	75	234	Total	82	72	221			
Richness of msp.	7	7	14	Richness of sp.	5	6	11			

On one hand, following the formula proposed by Oliver & Beattie (1993) to calculate the relation between identified morphospecies and verified taxonomic species, we obtained a 14.20% error rate (error % = 100 * [No. of taxonomic species (14) - No. ofmorphospecies (16)]/No. of taxonomic species (14)).
On the other one hand, from the 394 individuals of the morphospecies dataset, the proportion of correctly assigned morphospecies to taxonomic species was 62.18% (245 * 100/ 394). However, during the identification, a 32.74% lumping (129 * 100/394) and a 5.08% splitting (20 * 100/394) error occurred. *Sc. mediterraneus* one of the species causing splitting errors and assigned to msp. 3, was the most abundant species (294 individuals), but a total of 89 individuals were assigned to msp. 4 (Table 6.1). However, this species was the smallest of the captured ladybirds, and the extraction of genital apparatus was necessary to identify it correctly. Another splitting error occurred when *Hippodamia variegata* (Goeze, 1777) was identified as two different morphospecies, but verified by the taxonomist as two varieties of one species (*H. variegata carpini* and *H. variegata constellata*). Regarding the non-coccinellids in the sample, msp. 1 and msp. 8 were identified by the taxonomist as one unique phalacrid species; for that reason, a splitting error was committed. On the other hand, only one lumping case occurred with *Scymnus subvillosus* (Goeze, 1777), of which only two specimens were found and included as *Sc. mediterraneus*, due to the small size of its body length (Table 6.1).

Mistakes were not made with the other species, since each taxonomic species was identified as a morphospecies: *Coccinella septempunctata* Linnaeus, 1758, the second most abundant species, *Adalia decempunctata* (Linnaeus, 1758), *Adalia bipunctata* (Linnaeus, 1758), and *Myrrha octodecimguttata* (Linnaeus, 1758) could be identified on the basis of their particular coloration. There was no error in identification of *Rhyzobius chrysomeloides* (Herbst, 1792), *Stethorus punctillum* Weise, 1891, *Scymnus apetzi* Mulsant, 1846, *Hyperaspis reppensis* (Herbst, 1783) and *Platynaspis luteorubra* (Goeze, 1777).

6.4.2 Coccinellid abundance and species–morphospecies richness

The total numbers of individuals assigned to coccinellid morphospecies over the two years of study in the integrated, conventional and organic orchards were 85, 75 and 234, respectively, giving a total of 394 individuals (Table 6.1). The mean abundance of ladybird specimens found in organic, integrated and conventional olive orchards did not show a similar pattern over the two years, but the greatest number of individuals was achieved between June to September in 1999 and June and July 2000. In the non-organic orchards, a repeating pattern was not observed during the two years. The integrated orchard showed low values from July to October in 1999; however, the mean abundance increased in March 2000, but decreased again from April to June, and dimethoate was applied in July 2000, which is perhaps the cause of absence of ladybirds until October 2000. The mean abundance in the conventional orchard also had an irregular pattern, where March and April 1999 showed a low abundance, and there were no captures until October, when the mean number of caught individuals was highest in the conventional orchard. From March to June 2000, the mean abundance decreased and no individuals were captured until October, probably corresponding to the three applications of chemical products (alpha-cypermethrin and dimethoate). The total number of individuals identified as coccinellid morphospecies was greater than the number identified as coccinellid species, corresponding 82, 72 and 221 in the integrated, conventional and organic orchards, respectively, with 375 individuals altogether over the two years of study (Table 6.1). The patterns of mean abundance of ladybird species did not differ statistically from the patterns of morphospecies over the time. Both species and morphospecies datasets showed significant differences in March 1999 (Mann–Whitney test: $p < 0.05$). However, the mean abundance was very low for this month. In the morphospecies dataset, a total of 16 morphospecies were identified, while in the species dataset, 12 species were identified. The correspondence among species and morphospecies is represented in Table 6.1. The numbers of morphospecies for the two years were 7, 7 and 14 on the integrated, conventional and organic orchards, respectively while the numbers of species were 5, 6 and 11. This indicates that the richness and abundance of ladybirds were higher in the organic than the non-organic orchards, with respect to morphospecies as well as species.

6.4.3 Comparison among management regimes

In the canopies of the olive trees in the organic orchard, the months with the highest number of individuals were June, July and August, and for this reason this period over the two years was chosen for analyzing the statistical differences between organic and non-organic farming systems. In spite of the significant differences observed among the years for this period (Table 6.2), the Box-and-Whisker diagram (Figure 6.1 A and B) shows that the abundance of coccinellids was highest in organic orchards, such as in 1999 as well as in 2000. Several quasi-Poisson log-linear models without interactions between factors were considered to analyze and compare both the morphospecies and species datasets. The respective coefficients of the adjusted models show that we can leave out the factor block (Table 6.2).

Table 6.2: t-student coefficients and associated significance p-values for the adjusted models of species and morphospecies, considering block, year and management regime factors.

Dependent variable	Year	Management regime	Block	Overdispersion parameter
	(t-value)	(t-value)	(t-value)	
Total species	-4.81 ***	8.19 ***	-0.64	2.04
Most abundant species	-5.27 ***	8.03 ***	-0.60	1.88
Total morphospecies	-4.75 ***	8.30 ***	-0.41	2.03
Most abundant morphospecies	-5.35 ***	8.14 ***	-0.24	1.81
*** *p*<0.001				

Results for the morphospecies dataset showed that there were significant differences among regimes, and this was also true for the species datasets (Table 6.2). This indicates that organic farming can be differentiated from non-organic farming (integrated and conventional) from June to August, using either morphospecies or species. For the same period, the proposed models were applied for the most abundant morphospecies and species. The abundances of morphospecies 3, 4 and 5 and for *Sc. mediterraneus* and *C. septempunctata* were significantly different among management regimes (Table 6.2). These results lead us to conclude that the most abundant species or morphospecies could be used to distinguish between organic and non-organic systems at first glance.

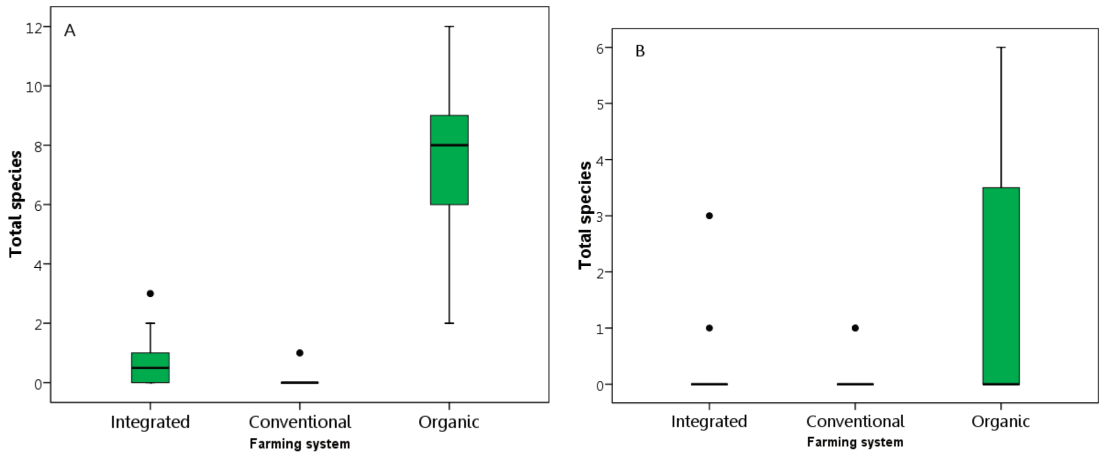


Figure 6.1: Box and Whisker diagram of the abundances of coccinellid species according to management regime in 1999 (A) and 2000 (B).

Furthermore, two correspondence analysis maps were elaborated for the visualization of the data for the four most abundant ladybird morphospecies: msp. 3, msp. 4, msp. 5 and msp. 7 (Figure 6.2), and for the three most abundant species: *Sc. mediterraneus*, *C. septempunctata* and *A. decempunctata* (Figure 6.3) during the June–August period. The CA plots display organic farming data in 1999 as more grouped and closer to msp. 3 and msp. 4, or *Sc. mediterraneus*, than integrated sites, while the non-organic data in 2000 were closer to msp. 5, or *C. septempunctata.* Organic orchards were closer to msp. 5 (*C. septempunctata*) and msp. 7 (*A. decempunctata*) in June and July 2000, respectively. In some summer months, none of the most abundant species or morphospecies were caught, and for this reason they do not appear on the CA maps (Figures 6.2 and 6.3).

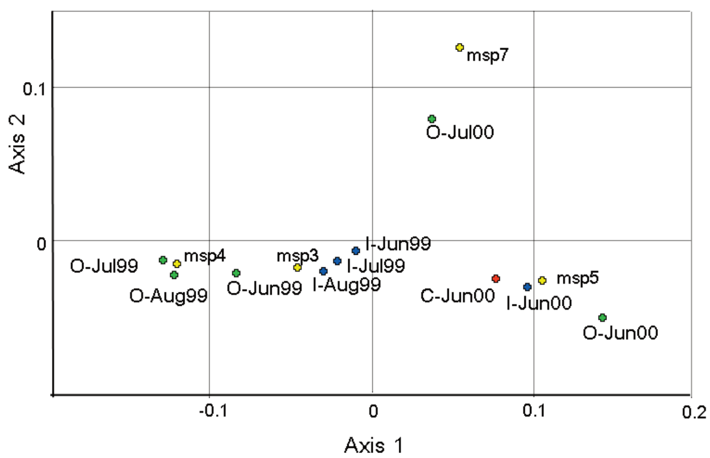


Figure 6.2: Correspondence analysis map for the organic (O), integrated (I) and conventional (C) olive orchards from June till August period in 1999 and 2000, using the most abundant morphospecies.

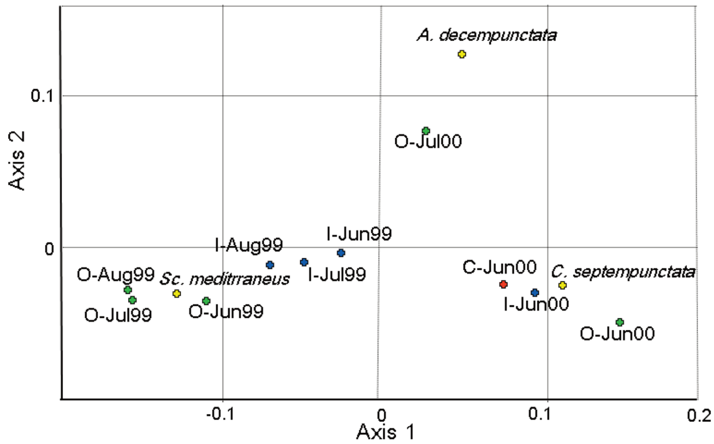


Figure 6.3: Correspondence analysis map for the organic (O), integrated (I) and conventional (C) olive orchards from June till August period in 1999 and 2000, using the most abundant species.

6.5 Discussion

Coccinellids were chosen because they are the most abundant family of coleopteran in the olive canopy and are abundantly present in the olive agroecosystem (Ba M'hamed & Chemseddine, 2002; Cirio, 1997; Ruano *et al.*, 2004; Santos *et al.*, 2007; Varela & González, 1999). Iperti (1999) suggested that the ladybeetle species found in different geographic areas of the world can be utilized as bioindicator insects due to their climatic and trophic characteristics. Regarding their sampling, the method seems to be most efficient during the June–August period because the average number of captured individuals is greatest in organic orchards (sampling surrogacy) (Ward & Larivière, 2004).

Species identification presents relative difficulty when based only on color patterns and is only possible by looking carefully at morphological characteristics, such as ventral size or by using genital apparatus extraction, especially for the small species (Derraik *et al.*, 2002) as *Sc. mediterraneus*. Because of this, it has been suggested that the number of scientist-hours to process samples is inversely related to each group's geometric mean body length (Lawton *et al.*, 1998). Even though the parataxonomist made a splitting error (one species to two morphospecies), this error was worthwhile, because an enormous amount of time was saved, which is very valuable if rapid biodiversity is being assessed.

Ladybirds met some of the requirements to be a good indicator group, since their predator condition, their biologies and their life cycles have been widely described in biological control (Iperti, 1999). Ladybird migration has been associated with short photoperiod, unfavorable temperatures, and changes in food availability and quality in ecosystems (Iperti, 1999). In southern Spain, olive landscapes cover large, continuous areas, and ladybirds can fly to nearby olive orchards under such uniform conditions while perturbation is occurring, and then after the perturbation they can return. It would be necessary to study adjacent lands to understand if the insects take shelter from perturbation there. As another requirement of an indicator group, Coccinellids in olive agroecosystems also suffer the effects of chemical products, and dimethoathe and alpha-cypermemethrin were applied in non-organic orchards, which might have caused the rapid mortality of *Sc. mediterraneus*, the most abundant species of sampled ladybirds in the organic orchard. Ladybirds fulfill all the requirements for a useful bioindicator, because they: (1) are a widely distributed and abundant species; (2) are relatively easy to sample and identify; (3) have well-known biologies and life cycles; (4) are relatively immobile; and finally (5) seem to be more abundant in organic farming from June to September, which has been shown in our study comparing organic and non-organic practices (i.e. use of agrochemical products).

6.6 Conclusion

From this study we conclude that coccinellid species could be used as bioindicators for organic vs. non-organic management systems in olive orchards, while coccinellid morphospecies could be also used as a RBA method when necessary. Moreover, statistical analysis has shown that the June–August period is optimal for sampling Coccinellids. It is also not necessary to take into account all morphospecies, only the most abundant, and despite some lumping errors, enough information can be provided.

6.7 References

Altieri, M. A. & Nicholls, C. I. (2004). *Biodiversity and pest management in agroecosystems.* Food Products Press, Binghamton NY, 256 pp.

Álvarez, T., Frampton, G. K. & Goulson, D. (2000). Epigeic Collembola in winter wheat under organic, integrated and conventional farm management regimes. *Agriculture, Ecosystems & Environment*, **83**, 95-110.

Andersen, A. N. (1990). The use of ant communities to evaluate change in Australian terrestrial ecosystems: a review and a recipe. *Proceedings of the Ecological Society of Australia*, **16**, 347-357.

Arambourg, Y. (1986). *Traite d'Entomologie Oleicole*. Consejo Oleícola Internacional, Madrid, 360 pp.

Ba M'hamed, T. & Chemseddine, M. (2002). Selective toxicity of some pesticides to *Pullus mediterraneus* Fabr. (Coleoptera: Coccinellidae), a predator of *Saissetia oleae* Bern. (Homoptera: Coccoidea). *Agricultural and Forest Entomology*, **4**, 173-178.

Basset, Y., Novotny, V., Miller, S. E., Weiblen, G. D., Missa, O. & Stewart, A. J. A. (2004). Conservation and biological monitoring of tropical forests: the role of parataxonomists. *Journal of Applied Ecology*, **41**, 163-174.

Bohac, J. (1999). Staphylinid beetles as bioindicators. *Agriculture, Ecosystems & Environment*, **74**, 357-372.

Boone, J. H., Mahan, C. G. & Kim, K. C. (2005). *Biodiversity inventory: approaches, analysis, and synthesis.* Technical Report NPS/NER/NRTR-2005/015 ed. N. P. S. Dept. Interior, Northeast Region, National Park Service. Philadelphia, PA, pp. 38.

Brown, K. S. (1997). Diversity, disturbance, and sustainable use of Neotropical forests: insects as indicators for conservation monitoring. *Journal of Insect Conservation*, **1**, 25-42.

Buck, H., Konzelmann, E. & Alf, A. (1992). *Käfer als Bioindikatoren zur Habitatcharakterisierung und -entwicklung*. Hohenheimer Umwelttagung, 24 Universität Hohenheim, Stuttgart.

Campos, M. & Civantos, M. (2000). Técnicas de cultivo del olivo y su incidencia sobre las plagas. *Olivae*, **84**, 40-46.

Çilgi, T. (1994). Selecting arthropod "indicator species" for environmental impact assessment of pesticides in field studies. *Aspects of Applied Biology*, **37**, 131-140.

Cirio, U. (1997). Productos agroquímicos e impacto ambiental en olivicultura. *Olivae*, **65**, 32-39.

Clough, Y., Kruess, A. & Tscharntke, T. (2007). Organic versus conventional arable farming systems: Functional grouping helps understand staphylinid response. *Agriculture, Ecosystems & Environment*, **118**, 285-290.

Cunningham, R. B. & Lindenmayer, D. B. (2005). Modeling count data of rare species: Some statistical issues. *Ecology*, **86**, 1135-1142.

de Andrés Cantero, F. (1991). *Enfermedades y Plagas del Olivo*. Riquelme y Vargas Ediciones S.L., Jaén, Spain, 646 pp.

Derraik, J., Closs, G., Dickinson, K., Sirvid, P., Barratt, B. & Patrick, B. (2002). Arthropod morphospecies versus taxonomic species: a case study with Araneae, Coleoptera, and Lepidoptera. *Conservation Biology*, **16**, 1015-1023.

Fauna Europaea Web Service (2004). Fauna Europaea version 1.1. Available online at: http://www.faunaeur.org.

Hadjicharalampous, E., Kalburtji, K. L. & Mamolos, A. P. (2002). Soil Arthropods (Coleoptera, Isopoda) in Organic and Conventional Agroecosystems. *Environmental Management*, **29**, 683-690.

Hammer, Ø., Harper, D. A. T. & Ryan, P. D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica. 4, 9. Available online at: http://palaeo-electronica.org/2001_2001/past/issue2001_2001.htm.

Iperti, G. (1999). Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture, Ecosystems & Environment*, **74**, 323-342.

Kampichler, C. & Platen, R. (2004). Ground beetle occurrence and moor degradation: modelling a bioindication system by automated decision-tree induction and fuzzy logic. *Ecological Indicators*, **4**, 99-109.

Kimberling, D. N., Karr, J. R. & Fore, L. S. (2001). Measuring human disturbance using terrestrial invertebrates in the shrub-steppe of eastern Washington (USA). *Ecological Indicators*, **1**, 63-81.

Krell, F. T. (2004). Parataxonomy vs. taxonomy in biodiversity studies-pitfalls and applicability of "morphospecies" sorting. *Biodiversity and Conservation*, **13**, 795-812.

Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R. F. & Sanjayan, M. A. (1993). Terrestrial arthropod assemblages: their use in conservation planning. *Conservation Biology*, **7**, 796-808.

Lawton, J. H., Bignell, D. E., Bolton, R., Bloemers, G. F., Eggleton, P., Hammond, P. M., Hodda, M., Holt, R. D., Larsen, T. B., Mawdsley, N. A., Stork, N. E., Srivastava, D. S. & Watt, A. D. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forests. *Nature*, **391**, 72-75.

Letourneau, D. K. & Goldstein, B. (2001). Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology*, **38**, 557-570.

Luka, H. (1996). Laufkäfer: Nützlinge und Bioindikatoren in der Landwirtschaft. *Agrarforschung*, **3**, 33-36.

McGeoch, M. A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, **73**, 181-201.

Melke, A. & Gutowski, J. M. (1995). Zmiany fauny kusakowatych (Coleoptera: Staphylinidae) œro-dowiska leœnego jako element monitoringu ekologicznego w pónocno-wschodniej Polsce. *Prace Inst. Bad. Leœn., A.*, **793**, 87-105.

Michaels, K. F. & McQuillan, P. B. (1995). Impact of commercial forest management on geophilous carabid beetles (Coleoptera: Carabidae) in tall, wet Eucalyptus obliqua forest in southern Tasmania. *Australian Journal of Entomology*, **20**, 316-323.

Moreno, C. E., Sanchez-Rojas, G., Pineda, E. & Escobar, F. (2007). Shortcuts for biodiversity evaluation: a review of terminology and recommendations for the use of target groups, bioindicators and surrogates. International *Journal of Environment and Health*, **1**, 71-86.

Morris, T. I., Campos, M., Kidd, N. A. C., Jervis, M. & Symondson, W. O. C. (1999). Dynamic of the predatory arthropod community in Spanish olive groves. *Agricultural and Forest Entomology*, **1**, 219-228.

Nordén, B. & Appelqvist, T. (2001). Conceptual problems of Ecological Continuity and its bioindicators. *Journal Biodiversity and Conservation*, **10**, 779-791.

Oliver, I. & Beattie, A. J. (1993). A possible method for the rapid assessment of biodiversity. *Conservation Biology*, **7**, 562-568.

Oliver, I. & Beattie, A. J. (1996a). Designing a cost-effective invertebrate survey: A test of methods for rapid assessment of biodiversity. *Ecological Applications*, **6**, 594-607.

Oliver, I. & Beattie, A. J. (1996b). Invertebrate morphospecies as surrogates for species: a case study. *Conservation Biology*, **10**, 99-109.

Paoletti, M. G. & Bressan, M. (1996). Soil Invertebrates as bioindicators of Human Disturbance. *Critical Reviews in Plant Sciences*, **15**, 21-62.

Pearce, J. L. & Venier, L. A. (2006). The use of ground beetles (Coleoptera: Carabidae) and spiders(Araneae) as bioindicators of sustainable forest management: A review. *Ecological Indicators*, **6**, 780-793.

Platen, R., Rademacher, J. & Schultz-Sternberg, R. (2001). Beurteilung des ökologischen Zustandes eines Niedermoores mit Hilfe von Arthropoden als Bioindikatoren. Naturschutz und Nandschaftsplanung. *Naturschutz und Landschaftspflege in Brandenburg*, **10**, 29-35.

Purtauf, T., Roschewitz, I., Dauber, J., Thies, C., Tscharntke, T. & Wolters, V. (2005). Landscape context of organic and conventional farms: influences on carabid beetle diversity. *Agriculture, Ecosystems & Environment*, **108**, 165-174.

Raimundo, A. A. C. & Alves, M. L. G. (1986). *Revisão dos Coccinelídeos de Portugal*. Universidade de Évora, Évora, 106 pp.

Rainio, J. & Niemelä, J. (2003). Ground Beetles (Coleoptera : Carabidae) as Bioindicators. *Biodiversity and Conservation*, **12**, 487-506.

Ruano, F., Lozano, C., García, P., Peña, A., Tinaut, A., Pascual, F. & Campos, M. (2004). Use of artrhopods for the evaluation of the olive-orchard management regimes. *Agriculture and Forest Entomology*, **6**, 111-114.

Ruíz, M. & Montiel, A. (2000). Introducción al conocimiento de la entomofauna del olivar en la provincia de Jaén. Aspectos cualitativos. *Boletin de Sanidad Vegetal y Plagas*, **26**, 129-147.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007). Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pests in olive groves from north-east of Portugal. *Chemosphere*, **67**, 131-139.

Shah, P. A., Brooks, D. R., Ashby, J. E., Perry, J. N. & Woiwod, I. P. (2003). Diversity and abundance of the coleopteran fauna from organic and conventional management systems in southern England. *Agriculture and Forest Entomology*, **5**, 51-60.

Smith, O. H., Petersen, G. W. & Needelman, B. A. (1999). Ecological indicators of agroecosystems. *Advances in Agronomy*, **69**, 76-97.

van Straalen, N. M. (1997). Community structure of soil arthropods as a bioindicator of soil health. In *Biology Indicators of Soil Health*, eds. C. E. Pankhurst, B. M. Doube & V. V. S. R. Gupta. CAB International, Wallingford, pp. 235-264.

van Straalen, N. M. & Verhoef, H. A. (1997). The development of a bioindicator system from soil acidity based on arthropod pH preferences. *Journal of Applied Ecology*, **34**, 217-232.

Varela, J. L. & González, R. (1999). Estudio sobre la entomofauna de un olivar en la provincia de Granada, durante el periodo de vuelo de la generación antófaga de *Prays oleae* (Lep. Yponomeutidae) *Phytoma España*, **111**, 42-55.

Ward, D. F. & Larivière, M.-C. (2004). Terrestrial invertebrate surveys and rapid biodiversity assessment in New Zealand: lessons from Australia. *New Zealand Journal of Ecology*, **28**, 151-159.

Ward, D. F. & Stanley, M. C. (2004). The value of RTUs and parataxonomy versus taxonomic species. *New Zealand Entomologist*, **27**, 3-9.

Wilkie, L., Cassis, G. & Gray, M. R. (2003). A quality control protocol for terrestrial invertebrate biodiversity assessment. *Biodiversity and Conservation*, **12**, 121-146.

7. The ladybeetle community (Coleoptera, Coccinellidae) in southern olive agroecosystems of Spain

The ladybeetle community (Coleoptera, Coccinellidae) in southern olive agroecosystems of Spain

Submitted to Environmental Entomology

7.1 Abstract

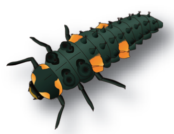
The aim of this survey is to faunistically describe the ladybeetle assemblages from the canopies of olive orchards in southern Spain, discerning all indicator ladybeetle species that are more representative of each region, taking into account: i) the ecological importance of the predatory ladybeetle species in olive orchards and ii) the variability in ladybeetle community composition in relation to landscape configuration.

First, three olive orchards from Granada under organic, integrated and conventional farming systems were sampled in 1999 and 2000, in order to study seasonal variation of ladybeetles. Secondly, a total of nine orchards (three per management system) in Granada and another nine in Córdoba were studied in 2003 in order to test ladybeetle similarities in different geographical locations, also taking into account the management system, using ordination and classification methods.

The total number of coccinellids collected was 481, and they belonged to nine genera and 13 species. The CCA showed a clear separation between orchards from Granada and Córdoba, taking into account ladybeetle species, environmental variables and sampled orchards. The land use types and the geographical location revealed that *Scymnus mediterraneus* Iablokoff-Khnzorian 1972 and *Platynaspis luteorubra* (Goeze, 1777) captured at higher latitudes benefited more by larger organic olive surfaces and by the presence of holm oak forests in the surrounding area. *Coccinella septempunctata* Linnaeus, 1758 and *Hippodamia variegata* (Goeze, 1777) were found at lower latitudes and at higher longitudes.

The ladybeetle assemblages can vary in response to the type of farming system, especially to pesticide use and landscape configuration. Nevertheless, the evaluation of the species composition might help identify the state of conservation of these agroecosystems. This knowledge could be used to improve the sustainability of agricultural landscapes, in order to increase the presence of coccinellids and their ecological function in olive pest control.

Key words: Coccinellidae, Córdoba and Granada provinces, Canonical Correspondence Analysis (CCA), Two-way Indicator Species Analysis (TWINSPAN).



7.2 Introduction

Ladybeetles (Col., Coccinellidae) belongs to the superfamily Cucujoidea (section Clavicornia), a total number of 111 coccinellid species belonged to 48 genera and seven families has been found and identified in the Iberian fauna (Alonso Zarazaga, 2007). The European literature of coccinellid species has been prolific (Duverger, 1990; Fürsch, 1966; Weise, 1885) and in other regions as well (Gordon, 1985; Pope, 1957; Xiong-Fei & Gordon, 1986), whereas coleopterists focused on Iberian coccinellids have unfortunately invested short interest (Alonso Zarazaga, 2007; Plaza, 1977; Plaza, 1986; Raimundo, 1992; Raimundo & Alves, 1986). This lack of a deep review of the coccinelid species contrasts with their role in agroecosystems (Iperti, 1999). Most ladybeetle species are carnivores; both adults and larvae are primarily predators of aphids, coccids and other insect pests (Chinery, 1993; Iperti, 1999), but a small number of species feed on plants (Majerus & Kearns, 1989).

They are found in many Mediterranean agroecosystems such as citrus (Marí *et al.*, 2002), olive (Castro Rodas *et al.*, 2006; Rei, 2004; Santos *et al.*, 2007a; Santos *et al.*, 2007b; Varela & González, 1999) or in weedy margins adjacent to crops (Burgio *et al.*, 2006). However, the abundance and distribution of many ladybeetle species in agroecosystem populations are decreasing because of habitat destruction (Burgio *et al.*, 2006; Dekoninck *et al.*, 2004) and the use of chemical pesticides (Ba M'hamed & Chemseddine, 2002; Castro Rodas *et al.*, 2006; Iperti, 1999; Santos *et al.*, 2007b). They have been used as indicators of organic farming regime in olive orchards in Granada province (southern Spain) (Cotes *et al.*, 2009). To extend the applicability of ladybeetles as indicators in other typology of oliviculture, it is necessary to know how vary the ladybeetle assemblages in other regions, taking into account landscape configuration and land use tradition in larger areas.

The aim of this survey is to faunistically describe the ladybeetle assemblages in olive orchards in Granada and Córdoba provinces, searching all those indicator ladybeetle species more representative of each region, taking into account: i) the ecological importance of the predatory ladybeetle species in olive orchards, and ii) the variability in ladybeetle community composition in relation to landscape configuration.

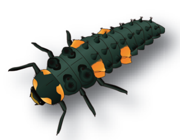
7.3 Materials and methods

7.3.1 Study zones

Population samples of the ladybeetle species were collected in two of the biggest commercial olive producer-areas in southern Spain, belonging to Granada and Córdoba provinces (Spanish government boundaries) of Andalusia. The study area covers a region spanning two provinces in Spain extending about 104 km from north to south and 117 km at its widest point from east to west, with the experimental fields located at an altitude of 400 to 1100 m above sea level.

The provinces of Córdoba and Granada are two of the largest commercial olive producing areas in southern Spain, but natural surroundings and land-use traditions make the olive landscape diverse. In Córdoba, the sampling was carried out in the Los Pedroches Valley, which is the largest organic producing region in Andalusia. Though there are some non-organic farmers in this valley, the organic olive farming system is extensive. This region is close to the Cardeña and Montoro natural park, and it contains a semi-natural olive landscape with Mediterranean forest patches. Olive orchards from Granada are located near mountain oak stands; however, in Granada, the surrounding olive orchards are cultivated under intensive farming systems, and the patches of natural vegetation are smaller than in Córdoba (Figure 7.1).

First, three olive orchards from Granada under organic, integrated and conventional farming systems were sampled in 1999 and 2000 (Table 7.1), in order to study ladybeetle richness, seasonal variation of abundance, and whether a relationship with the management system exists. First, three olive orchards from Granada under organic, integrated and conventional farming systems were sampled in 1999 and 2000 (Table 7.1), in order to study ladybeetle richness, and seasonal variation of abundance, and whether a relation with management system exists. Secondly, a total of nine orchards (three per management) were studied in Granada and other nine in Córdoba in 2003 (Table 7.1) in order to test whether abundance and richness of Coccinellidae present similarities in different geographical locations, also taking into account management system.



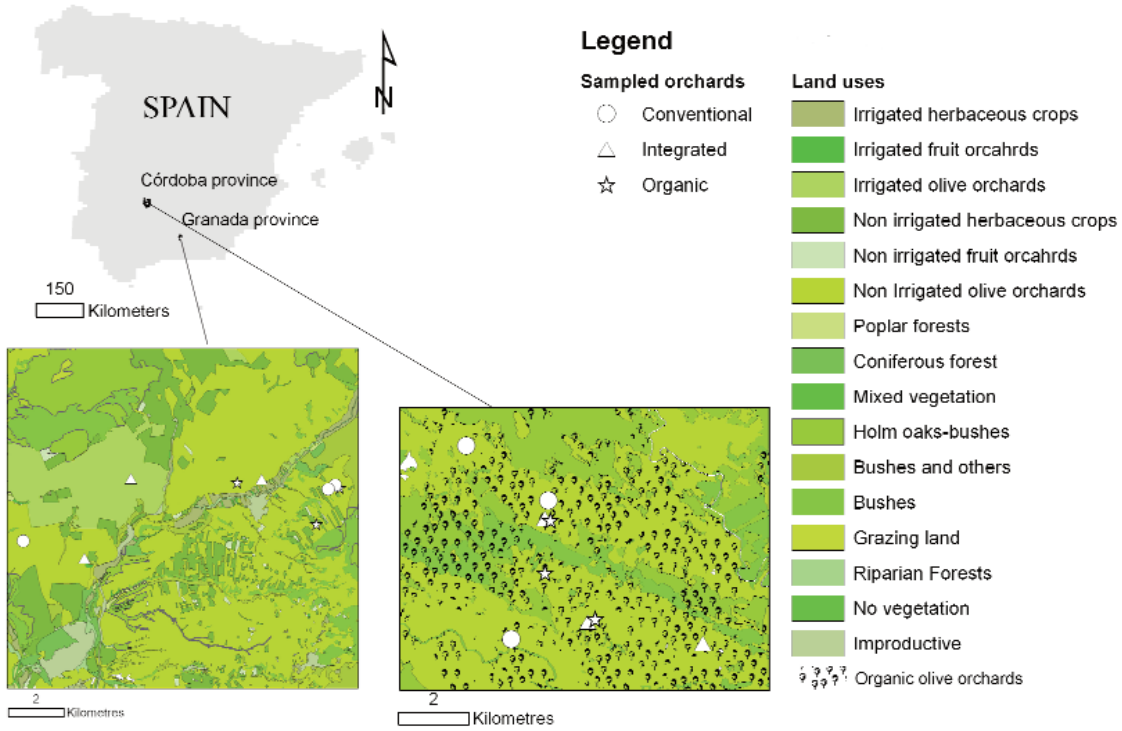


Figure 7.1: Locations and land-use types of the eighteen olive orchards in Granada and Córdoba provinces.

Following previous researchers' observations (Ruano *et al.*, 2004), preblooming (May) and postblooming (June) time are the most appropriate periods to take samples, because arthropod abundance shows the strongest differences among farming managements during these periods.

7.3.2 Collection of Coccinellidae

The total number of sampled blocks was 105 (35 per management system) over three years. Six blocks by location, management system and month were sampled in 1999; the number of samples was reduced to five blocks in 2000 and to four blocks in 2003 in order to reduce the sampling effort while maintaining a sufficient degree of accuracy (Ruano *et al.*, 2004). Each block consisted of a row of five trees, two sampled trees in the block were separated by an unsampled tree, so that the distance between sampled trees was 20 metres. Each block was considered a true replication because of the large size of the olive zones studied, and the distance between blocks (a minimum of 0.5 km) ensures independence

Table 7.1: Farming systems and sampling period in each Andalusian province. N. s. means not sampled period.

Province	Orchard	Farming system	1999	2000	2003
Córdoba	A	Conventional	N. s.	N. s.	May to June
	B	Integrated	N. s.	N. s.	May to June
	C	Organic	N. s.	N. s.	May to June
	D	Conventional	N. s.	N. s.	May to June
	E	Organic	N. s.	N. s.	May to June
	F	Conventional	N. s.	N. s.	May to June
	G	Integrated	N. s.	N. s.	May to June
	H	Organic	N. s.	N. s.	May to June
	I	Integrated	N. s.	N. s.	May to June
Granada	J	Conventional	March to November	March to November	May to June
	K	Integrated	N. s.	N. s.	May to June
	L	Intengrated	March to November	March to November	May to June
	M	Organic	N. s.	N. s.	May to June
	N	Integrated	N. s.	N. s.	May to June
	O	Conventional	N. s.	N. s.	May to June
	P	Organic	March to November	March to November	May to June
	Q	Conventional	N. s.	N. s.	May to June
	R	Organic	N. s.	N. s.	May to June

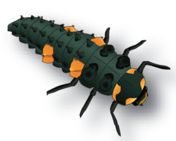
between them. The canopies of olive trees were sampled by fives beatings of four randomly chosen branches per tree (one per compass orientation), over an insect net 50 cm in diameter. Coccinellid specimens collected from these olive canopies were frozen and later separated from vegetal and inorganic remains. Adults and juvenile beetles were identified under a stereomicroscope (Stemi SV8, Zeiss) to the taxonomic level of species.

7.3.3 Data analysis

Ordination and classification methods were applied in order to characterise the ladybeetle community composition of the Andalusian olive orchards comparing data from Granada and Córdoba only during pre-blooming and post-blooming in 2003. The multivariate approach was chosen for the ordination methods to determine relationships between coccinellid species and environmental variables in olive orchards of two different regions, using R statistical software (R Development Core Team 2005). Both indirect and direct gradient analyses were performed because the aim of this study was to extract patterns from the variation explained by each environmental variable with respect to ladybeetle species data (indirect gradient analysis) and the variation explained by each environmental variation (direct gradient analysis). On the one hand, the indirect gradient method analyses all variance of biological data in relation to the variance of environmental data; on the other hand, the direct gradient analysis takes into account only the portion of biological data that are related to environmental variation. Thus, a Detrended Correspondence Analysis (DCA) for indirect gradient analysis and Detrended Canonical Correpondence Analysis (DCCA) for direct gradient analysis were used to determinate the adequate approach (unimodal or linear) that fit better with the data set (Leps & Smilauer, 2003). The significance level of the analyses was assessed by a Monte-Carlo permutation test with 499 randomisations. The environmental variables measured in percentages were arcSen transformed (Sqrt *y*/100), and the rest of the variables and the abundance of species were log transformed (log (*y*+1)).

As a classification method, a two-way indicator species analysis (TWINSPAN) was performed (Hill, 1979), using the computer programme Win TWINS, version 2.3 (Hill & Šmilauer, 2005). This divisive polythetic method was used to group orchards with similar ladybeetle assemblages.

Finally the geographical information was managed using the ArcGIS 9.3 software. In order to evaluate the landscape features and the tradition of land use, the cartographic information from the crops and land-use maps of Andalusia (Junta de Andalucía, 2001) was used to calculate the surface of each type of land use buffered at 500 metres around the polygonal orchards.



7.4 Results

7.4.1 Ladybeetle community composition

The total number of coccinellids collected was 481, and they belonged to nine genera and 13 species; they were collected in olive orchards in different periods and different regions and are taxonomically and ecologically described in Table 7.2.

On the one hand, a total of 375 individuals of 12 ladybeetle species were captured from March to October in 1999 and 2000 in Granada (Table 7.2). They were present in all the management systems but were especially abundant in the olive orchards using organic farming (Figure 7.2 A and B). Although ladybeetle species exhibited a different pattern of seasonal abundance in 1999 and 2000, in both cases they proved significantly more abundant in the organic olive orchard during the summer (July, August and September), showing a maximum abundance in July. In conventional orchards, this family was practically absent during months in which insecticides were applied (April to September), and it grew in abundance before and after spray seasons (March and October) in integrated and conventional orchards. In integrated orchards, the abundance was higher in 1999 (a year without insecticide application) than in 2000. *Sc. mediterraneus* and *C. septempunctata* were the most abundant species during the two years, with the remaining species rarely captured (Table 7.2). On the other hand, during May and June 2003 a total number of 16 individuals representing 6 species were captured in Granada, while 96 individuals representing 5 species were captured in Córdoba (Table 7.2). *Sc. mediterraneus* and *C. septempunctata* were also the most abundant species for this period in Granada, but only *Sc. mediterraneus* was predominant in Córdoba during the same period.

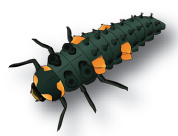


Table 7.2: Taxonomic status and feeding habits of ladybeetle species captured in Andalusian olive orchards and proportion of abundance of each ladybeetle species in the different sampling periods and provinces. Table continues in the next page.

Taxonomic status	Feeding habits	Granada 1999	Granada 2000	Córdoba 2003	Granada 2003
FAM. COCCINELLIDAE Latreille, 1807					
SUBFAM. CHILOCORINAE Mulsant, 1846					
Trib. Platynaspidini Mulsant, 1846					
Gen. *Platynaspis* Redtenbacher, 1843					
Platynaspis luteorubra (Goeze, 1777)	Highly specialized myrmecophilic ladybeetle (Majerus *et al.*, 2007; Völkl, 1995)	0%	0.85%	0%	0%
Trib. Hyperaspidini Mulsant, 1846					
Gen. Hyperaspis Dejean, 1835					
Hyperaspis reppensis (Herbst, 1783)	Myrmecophilics larvae on fulgorids in ants' nests (Silvestri, 1903)	0%	0.85%	0%	0%
Trib. Stethorini Dobzhansky, 1924					
Gen. Stethorus Weise, 1885					
Subgen. *Stethorus* Weise, 1885					
Stethorus punctillum Weise, 1891	Specialist predators of spider mites (Kapur, 1948)	1.17%	2.54%	0%	0%
Trib. Scymnini Mulsant, 1846					
Gen. Scymnus Kugelann, 1794					
Subgen. Scymnus Kugelann, 1794					
Scymnus apetzi Mulsant, 1846	Aphidophagous (Núñez-Pérez *et al.*, 1992)	1.17%	1.69%	0%	3.85%
Scymnus interruptus (Goeze, 1777)	Aphidophagous (Núñez-Pérez *et al.*, 1992)	0%	0%	0.53%	3.85%
Subgen. Mimopullus Fürsch, 1987					
Scymnus mediterraneus Iablokoff-Khnzorian 1972	Polyphagous predator (Panis, 1977)	84.05%	66.95%	0.53%	0%
Subgen. Pullus Mulsant, 1846					
Scymnus subvillosus (Goeze, 1777)	Polyphagous predator (Panis, 1977)	0.39%	1.00%	0.53%	0%

Table 7.2: Taxonomic status and feeding habits of ladybeetle species captured in Andalusian olive orchards and proportion of abundance of each ladybeetle species in the different sampling periods and provinces.

Taxonomic status	Feeding habits	Granada 1999	Granada 2000	Córdoba 2003	Granada 2003
SUBFAM. COCCIDULINAE Mulsant, 1846					
Trib. Coccidulini Mulsant, 1846					
Gen. Rhyzobius Stephens, 1829					
Rhyzobius chrysomeloides (Herbst, 1792)	Coccidiphagous (Toccafondi *et al.*, 1991)	5.45%	0%	51.87%	53.85%
SUBFAM. COCCINELLINAE Latreille, 1807					
Trib. Coccinellini Latreille, 1807					
Gen. Adalia Mulsant, 1846					
Subgen. Adalia Mulsant, 1846					
Adalia bipunctata (Linnaeus, 1758)	Aphidophagous (Núñez-Pérez *et al.*, 1992)	1.17%	0%	1.07%	7.69%
Adalia decempunctata (Linnaeus, 1758)	Aphidophagous (Núñez-Pérez *et al.*, 1992)	0.39%	5.93%	0%	7.69%
Gen. Coccinella Linnaeus, 1758					
Subgen. Coccinella Linnaeus, 1758					
Coccinella septempunctata Linnaeus, 1758	Aphidophagous (Bertolaccini *et al.*, 2008)	5.84%	17.80%	45.45%	15.38%
Gen. Myrrha Mulsant, 1846					
Myrrha octodecimguttata (Linnaeus, 1758)	Aphidophagous (Klausnitzer, 1968; Majerus, 1988)	0%	0.85%	0%	0%
Trib. Hippodamiini Mulsant, 1846					
Gen. Hippodamia Dejean, 1835					
Subgen. Adonia Mulsant 1846					
Hippodamia variegata (Goeze, 1777)	Aphidophagous (Bertolaccini *et al.*, 2008)	0.39%	1.69%	0%	7.69%

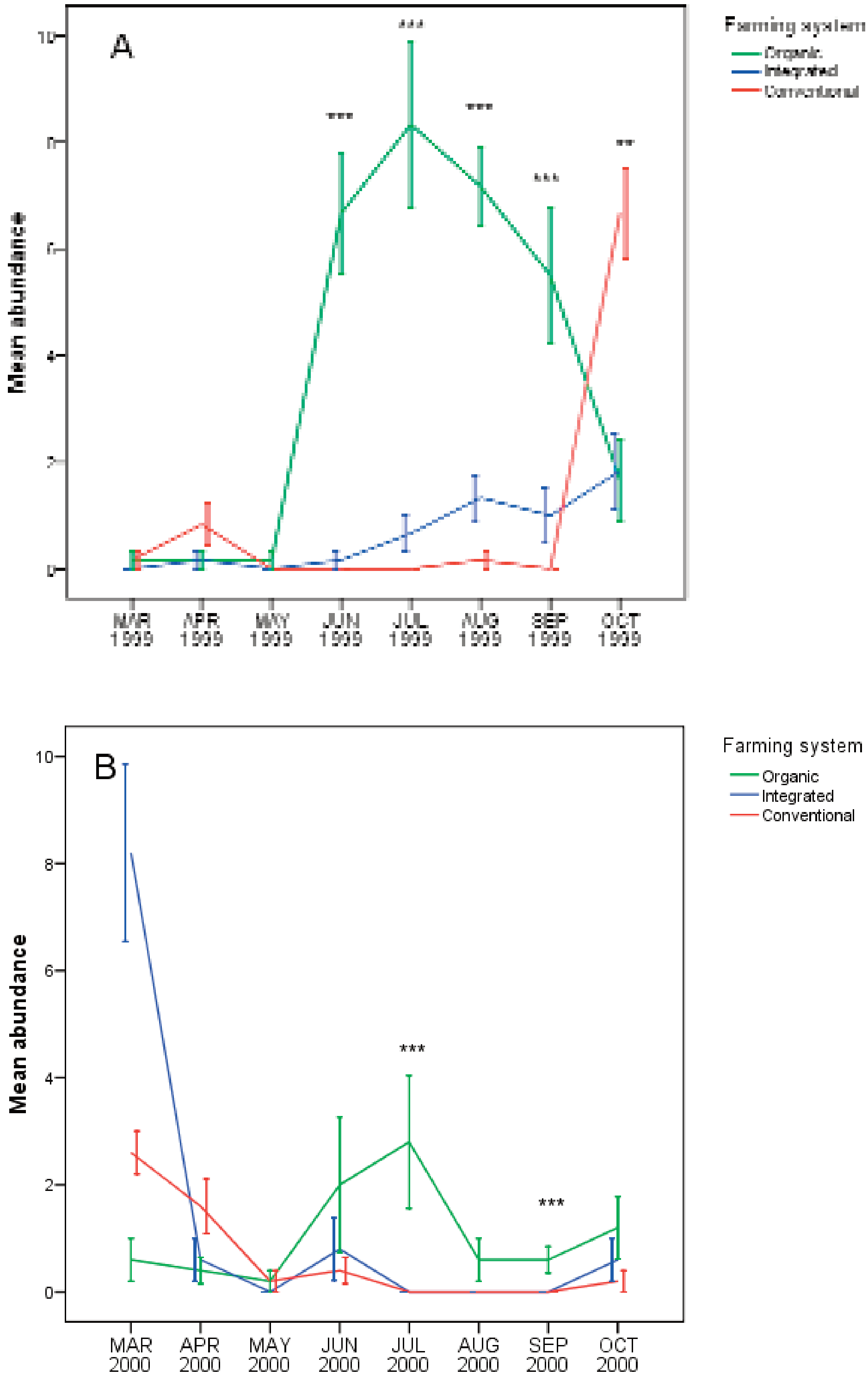


Figure 7.2: Seasonal variation of mean of Coccinellidae per block for A) 1999 and B) 2000 in three different management regimes. Monthly comparison was made among them (Kruskal-Wallis test; significance levels: * 0.05 > *P*=0.01; ** 0.01 > *P*=0.005; *** *P*<0.005).

7.4.2 Ordination methods

First, an indirect gradient was performed taking into account the relationship between species composition and environmental variables.

Table 7.3: Mean values and standard error of environmental variables and abbreviations used to describe the land use surroundings (at 500 meters diameter) of the olive orchards. * indicates the excluded variables in the multicollinearity analysis.

Variables	Abbreviation of variables	Mean	SE
Non-organic olive orchards	NOrgOlive	1.08	0.29
Organic olive orchards	OrgOlive	0.14	0.10
Holm oak forests	HOF	0.35	0.33
Bushes	Bu	0.12	0.14
No vegetation	NV	0.01	0.03
Coniferous forest	CF	0.01	0.02
Non-irrigated crops	NIC	0.04	0.11
Irrigated crops	IC	0	0.02
Non-irrigated fruit orchards	NIF	0	0.01
Irrigated fruit orchards*	IF	0	0.01
Grazing land*	GL	0	0
Riparian Forests*	RF	0.01	0.02
Poplar forests*	PF	0	0
Longitud	Long	5.57	0.06
Latitude	Lat	6.62	0

Indirect ordination (DCA) based on the ladybeetle species composition revealed that the length of the longest gradient was close to 4, meaning th at a unimodal ordination model is most suitable in this case (TerBraak, 1995). A Correspondence Analysis (CA) was selected as the most suitable method to summarise the ladybeetle variation (TerBraak & Smilauer, 2002). The first three axes explained 64% of the variability in species data (Table 7.4), and some groups of implied variables could be differentiated (Table 7.5).

Table 7.4: Eigenvalues and cumulative percentage variance of the canonical axes values in the indirect and direct analysis performed between ladybeetle species and environmental variables.

AXES	1	2	3	4
INDIRECT ANALYSIS				
Eigenvalues	0.73	0.55	0.54	0.45
Cumulative percentage variance	30.20	44.60	64.00	83.50
DIRECT ANALYSIS				
Eigenvalues	0.71	0.53	0.44	0.24
Cumulative percentage variance	31.90	56.10	75.90	86.80

The first axis included variables that were related to geographical location and organic olive surface. Longitude, latitude and organic olive surface appeared at the negative end of the axis, and non-irrigated fruit orchard surface and longitude at the positive end. The second axis did not have a strong correlation with any variable, while the third axis was negatively related to land without vegetation and poplar forest surfaces. Afterwards, a direct gradient analysis was carried out to detect significant effects of each environmental variable on the ladybeetle species. In the DCCA, the length of the greater gradient axis was over 3, and thus a unimodal ordination model, such a Canonical Correspondence Analysis (CCA), was appropriate to relate species abundance and environmental variables. The forward selection procedure indicates ranking and importance of

Table 7.5: Intraset correlation of environmental variables with the three axis of CA for ladybeetle species (environmental variables abbreviated according to Table 3)

	AXIS 1	AXIS 2	AXIS 3
NOrgOlive	0.45	0.13	-0.02
OrgOlive	-0.52	0.10	-0.08
HOF	-0.44	-0.04	0.11
Bu	0.08	-0.06	-0.44
NV	-0.22	-0.30	0.53
CF	0.47	0.11	0.07
NIC	0.11	-0.12	0.10
IC	-0.19	0.42	-0.50
NIF	0.72	-0.35	-0.28
IF	-0.28	0.02	0.12
GL	0.47	0.11	0.07
RF	-0.28	-0.04	0.19
PF	-0.19	-0.36	0.60
Long	0.59	-0.10	0.06
Lat	-0.58	0.10	-0.05

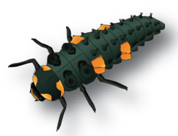
the environmental variables explaining ladybeetle abundance. Eigenvalues for the considered axes (first and second) explained 56.10% of the ladybeetle variability (Table 7.4). This analysis included eleven environmental variables, nine kinds of land use, and longitude and latitude that were obtained by Monte Carlo test, with non-irrigated fruit orchard surface (F= 2.64, *p*= 0.02), organic olive orchard surface (F= 1.86, *p*= 0.004), longitude (F= 2.11, *p*= 0.018) and latitude (F= 2.06, *p*= 0.042) being the most important in the model, they were obtained by Monte Carlo test.

The triplot among ladybeetle species, environmental variables and sampled orchards showed a clear separation between orchards from Granada and Córdoba, with the Córdoba orchards having a more homogeneous ladybeetle composition than Granada orchards (Figure 7.3), since the proximity among all the Córdoba orchards is closer, and a closer proximity among sampling sites means a more similar species composition. Moreover, in Córdoba, *Sc. mediterraneus* was the most representative ladybeetle species, while species compositions were less homogeneous in Granada orchards. *C. septempunctata* and *H. variegata* were representative in some Granada olive orchards.

Three olive orchards from Granada were located far away from a fourth orchard group; one orchard was close to Córdoba orchards, and the other two were located in the opposite left corners (Figure 7.3). These three orchards were the northernmost of the orchards sampled in Granada (Figure 7.1). With regard to the environmental variables, non-irrigated fruit orchard surfaces, non-organic olive orchard surfaces and an increase in longitude were related to orchards from Granada with *C. septempunctata* and *H. variegata*, while an increase in latitude, organic olive surfaces and the presence of holm oak forests favoured the presence of *Sc. mediterraneus* in Córdoba orchards.

7.4.3 Classification methods

The TWINSPAN procedure was used with cut-off levels of 0, 2, 5, 10, and 20% to construct pseudospecies, as proposed by Hill (1979). The results of the classification of olive orchards with indicator species abundance levels are presented in Table 7.6. The indicator species for olive orchards from Córdoba was *Sc. mediterraneus*, which is present in almost all these orchards, although one



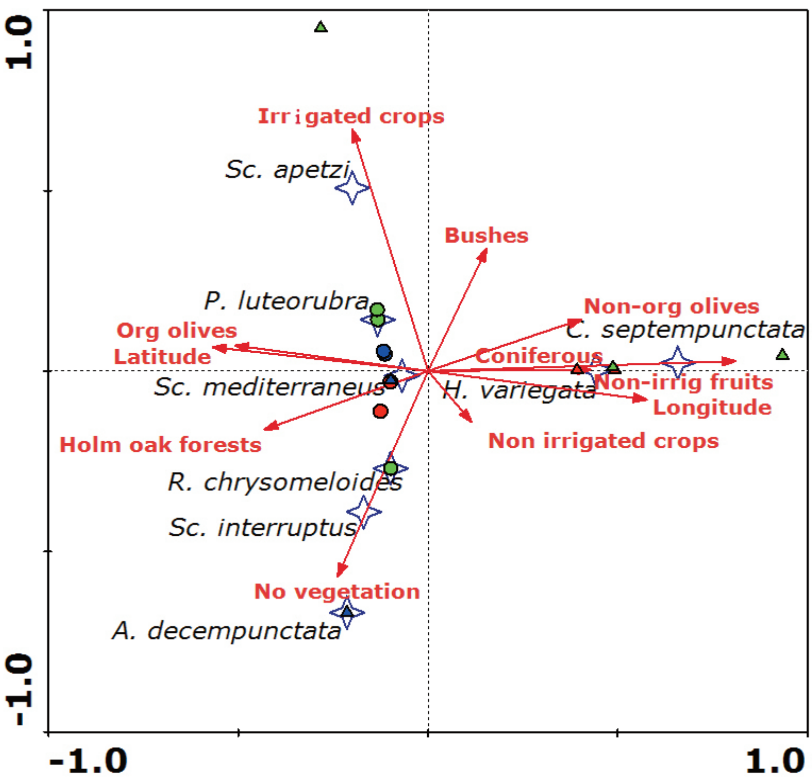


Figure 7.3: CCA triplot of ladybeetle species scores (grey stars) recorded in Córdoba (white circles) and Granada olive orchards (black squares) in May and June 2003. Environmental variables abbreviated according to Table 7.3.

integrated orchard from Granada was included in this group. With regard to Granada orchards, the indicator species were, in order of decreasing power, *C. septempunctata* and *H. variegata*. However, two integrated orchards belonging to Granada (N) and Córdoba (I) were separately represented by *A. decempunctata* and *Sc. interruptus*, and a last organic orchard from Granada was isolated from the rest due to the presence of *Sc. apetzi*.

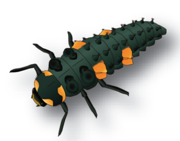
Table 7.6: Ordered two-way table of the ladybeetle occurrence

	M	A	G	L	C	D	E	H	I	N	Q	O	P	R	
Sc. mediterraneus	-	2	2	2	2	5	5	4	1	1	-	2	-	1	*00
R. chysomeloides	-	-	-	-	1	-	-	-	-	-	-	-	-	-	*010
A. decempunctata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	*010
P. luteobrura	-	-	-	-	-	-	1	-	-	-	-	-	-	-	*010
Sc. interruptus	-	-	-	-	-	1	-	-	-	1	-	-	-	-	*010
Sc. apetzi	2	-	-	-	-	-	1	1	-	-	-	-	-	-	*011
C. setempunctata	-	-	-	-	-	-	-	-	-	-	-	1	2	1	*1
H. variegata	-	-	-	-	-	-	-	-	-	-	1	1	-	-	*1
	*00	*0100	*0100	*0100	*0100	*0101	*0101	*0101	*011	*011	*1	*1	*1	*1	

7.5 Discussion

Among the most abundant ladybeetle species captured in the Andalusian olive orchards, predators (Table 7.2), principally poliphagous species (*Sc. mediterraneus*), had a higher frequency. Moreover, all of them are paleartic species and have been located or cited in the Iberian Peninsula before (Alonso Zarazaga, 2007; Fauna Europaea Web Service, 2004; Plaza, 1977; Plaza, 1986). As for the fluctuation in the seasonal pattern of abundance, ladybeetles clearly separated the organic management system from the non-organic systems in July, August and September. Nevertheless, this family showed a highly variable pattern between years. Coccinellidae are vulnerable to microclimate changes as well as to the effects of pollution, pesticides and fertilizers (Iperti, 1999). The abundance of ladybeetles, since they are predatory, may be influenced not only by climatic conditions but also by density of different insect pests (Iperti, 1999; Woin *et al.*, 2000).

Sc. mediterraneus was also the most numerous ladybeetle species captured, just as in Portuguese olive orchards (Rei, 2004) and in Moroccan orchards (Gourreau, 1974; Smirnoff, 1956), although it was not captured in Italian orchards (Castro Rodas *et al.*, 2006). Other ladybeetle species such as *Sc. subvillosus, P. luteorubra* and *S. punctillum* were common in Portuguese and Italian olive orchards and in the present study. Only *Sc. apetzi* and *R. chrysomeloides* were also captured in Portugal, while three other species (*Sc. interruptus*, *A. decempunctata* and *C. septempunctata*) were common only in Spanish and Italian orchards. However, *Sc. mediterraneus* seems to be present in olive agroecosystems in the Mediterranean basin, and furthermore, its presence is associated with *Saissetia oleae* (Olivier 1791) (Ba M'hamed & Chemseddine, 2002), which is a secondary olive pest in Andalusia. Córdoba and Granada provinces showed comparatively high percentages of this ladybeetle, but the total abundance was quite different. It has already been shown that the most widely used chemical pesticides are toxic to *Sc. mediterraneus* (Ba M'hamed & Chemseddine, 2001; Ba M'hamed & Chemseddine, 2002; Santos *et al.*, 2007a; Santos *et al.*, 2007b). The olive culture in the two studied regions has developed in two opposite ways: an intensive farming system looking for the highest production in Granada and an extensive one in Córdoba. For this reason, a long tradition of using chemicals could



be more associated with orchards in Granada, where the populations of *Sc. mediterraneus* and of the rest of the ladybeetle species were less numerous.

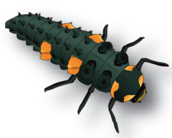
The farming systems determine the ladybeetle composition in olive agroecosystems (Cotes *et al.*, 2009), but the landscape configuration strongly influences the ladybeetle population also (Iperti, 1999). The types of land use and the geographical location have revealed with the multivariate analysis that *Sc. mediterraneus* and *P. luteorubra* capture in higher latitudes (Córdoba location) was favoured by larger organic olive surfaces and by the presence of holm oak forests in the neighbourhood of the orchards. In the case of *C. septempunctata* and *H. variegata*, species present in lower latitudes and higher longitudes (Granada location), larger non-irrigated fruit orchards surfaces and non-organic olive surfaces could determinate their presence. Finally, these species were found to be indicator species for most orchards sampled in Córdoba and Granada.

7.6 Conclusion

Several ladybeetle species are associated with olive agroecosytems; however, the assemblages can vary in response to the type of farming system, especially to pesticide use and landscape configuration. The great differences observed between Granada and Córdoba orchards make it difficult to give a general description of a homogeneous ladybeetle community in southern olive agroecosystems of Spain, due to large areas with different histories of land use. Nevertheless, the evaluation of the species composition might to help identify the state of conservation of these agroecosystems, principally by the presence of *Sc. mediterraneus*. On the other hand, this knowledge could be used to improve more sustainable landscapes, in order to increase the presence of coccinellids and their ecological function in olive pest control.

7.7 References

Alonso Zarazaga, M. A. (2007). El Reino Animal en la Península Ibérica y las Islas Baleares. Coccinellidae (Coleoptera), Fauna Iberica. Ministerio de Ciencia y Tecnología. Available online at: http://www.fauna-iberica.mncn.csic.es/faunaib/arthropoda/insecta/coleoptera/coccinellidae.php.



Ba M'hamed, T. & Chemseddine, M. (2001). Assessment of temperature effects on the development and fecundity of *Pullus mediterraneus* (Col., Coccinellidae) and consumption of *Saissetia oleae* eggs (Hom., Coccoida). *Journal of Applied Entomology,* **125**, 527-531.

Ba M’hamed, T. & Chemseddine, M. (2002). Selective toxicity of some pesticides to *Pullus mediterraneus* Fabr. (Coleoptera: Coccinellidae), a predator of *Saissetia oleae* Bern. (Homoptera: Coccoidea). *Agricultural and Forest Entomology*, 4, 173-178.

Bertolaccini, I., Núñez-Pérez, E. & Tizado, E. J. (2008). Effect of Wild Flowers on Oviposition of *Hippodamia variegata* (Coleoptera: Coccinellidae) in the Laboratory. *Journal of Economic Entomology*, **101**, 1792-1797.

Burgio, G., Ferrari, R., Boriani, L., Pozzati, M. & van Lenteren, J. (2006). The role of ecological infrastructures on Coccinellidae (Coleoptera) and other predators in weedy field margins within northern Italy agroecosystems. *Bulletin of Insectology*, **59**, 59-67.

Castro Rodas, N., Petacchi, R. & Canovai, R. (2006). Studio sui Coccinellidi (Coleoptera) dell’agroecosistema oliveto gestito a diversi livelli di input chimico, in un areale della Toscana Centrale. *L’informatore Fitopatologico*, **6**, 24-32.

Cotes, B., Ruano, F., García, P. A., Pascual, F. & Campos, M. (2009). Coccinellid morphospecies as an alternative method for differentiating management regimes in olive orchards. *Ecological Indicators*, **9**, 548-555.

Chinery, M. (1993). *Insects of Britain and Western Europe*. Harper Collins, London, 320 pp.

Dekoninck, W., Desender, K., Grootaert, P., Maelfait, J.-P., Baert, R., De Bakker, D. & Adriaens, T. (2004). Observations of the ladybird *Platynaspis luteorubra* (Goeze) on motorway verges along the ring-road of Brussels, with comments on its habitat and host preference (Coleoptera Coccinellidae Chilocorinae). Bulletin S.R.B.E./K.B.V.E., 140, 123-125.

Duverger, M. (1990). Catalogue des Coléoptères Coccinellidae de France continentale et de Corse. *Bulletin the la Societé Linneane Bordeaux*, **17**, 143-157.

Fauna Europaea Web Service (2004). Fauna Europaea version 1.1. Available online at: http://www.faunaeur.org.

Fürsch, H. (1966). Bermerkungen zur Systematic mitteleuropärischer Coccinelliden (Col.) *Nachrichtenblatt der Bayerischen Entomologen*, **9/10**, 85-90.

Gordon, R. D. (1985). The Coccinellidae (Coleoptera) of America North of México. Journal of the New York *Entomological Society*, **93**, 1-912.

Gourreau, J. M. (1974). Systematique de la tribu de Scymnini (Coccinellidae). Annales de Zoologie et d’Ecologie Animale, 215-221.

Hill, M. O. (1979). DECORONA: A FORTRAN program for detrending correspondance analysis and reciprocal averaging. In Cornell University. Ithaca, N.Y.

Hill, M. O. & Šmilauer, P. (2005). TWINSPAN for Windows version 2.3. In Centre for Ecology and Hydrology & University of South Bohemia, Huntingdon & Ceske Budejovice.

Iperti, G. (1999). Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture, Ecosystems & Environment*, **74**, 323-342.

Junta de Andalucía (2001). REDIAM: Red Medioambiental de Andalucía, Junta de Andalucía. Sevilla.

Kapur, A. K. (1948). On the old world species of the genus Stethorus Weise (Coleoptera, Coccinellidae). *Bulletin of Entomological Research*, **37**, 297-320.

Klausnitzer, B. (1968). Zur Biologie von Myrrha octodecimguttata (L.) (Col., Coccinellidae). *Entomologische Nachrichten*, **12**, 102-104.

Leps, J. & Smilauer, P. (2003). *Multivariate analysis of ecological data using CANOCO*, Cambridge, UK, 269 pp.

Majerus, M. E. N. (1988). Some notes on the 18-spot ladybird (*Myrrha 18-guttata* L.) (Coleoptera: Coccinellidae). *British Journal of Entomology and Natural History*, **1**, 11-13.

Majerus, M. E. N. & Kearns, P. (1989). *Ladybirds*. Richmond Publishing Co. Ltd., Slough, 103 pp.

Majerus, M. E. N., Sloggett, J. J., Godeau, J.-F. & Hemptinne, J.-L. (2007). Interactions between ants and aphidophagous and coccidophagous ladybirds. *Population Ecology*, **49**, 15-27.

Marí, F. G., Alvis, L., Raimundo, A. & Villalba, M. (2002). Identificación y abundancia de coleópteros coccinélidos en los cultivos de cítricos valencianos. Boletín de sanidad vegetal, 28, 479-492.

Núñez-Pérez, E., Tizado Morales, E. J. & Nieto Nafría, J. M. (1992). Coccinélidos (Col.: Coccinellidae) depredadores de pulgones (Horn. Aphididae) sobre plantas cultivadas de León. *Boletín de sanidad vegetal. Plagas*, **18**, 765-775.

Panis, A. (1977). Caractères écologiques et biocénotiques de la cochenille noir de l'olivier: *Saissetia oleae*. *Bolletin del servicio de defensa contra plagas. Inspeccion Fitotopatologica*, **3**, 199-205.

Plaza, E. (1977). Los Hippodamini de la Península Ibérica (Col. Coccinellidae). *Graellsia*, **33**, 171-198.

Plaza, E. (1986). Clave para la identificación de los géneros y catálogo de las especies españolas peninsulares y baleáricas de Coccinellidae (Coleoptera). *Graellsia*, **42**, 19-45.

Pope, R. D. (1957). South African animal life, Coleptera, *Coccinellidae*, **4**, 292-322.

Raimundo, A. A. C. (1992). Novas espécies de Scymnini para a fauna de coccinelídeos de Portugal. *Boletim da Sociedade Portuguesa de Entomologia Supplemento*, **3,** 373-384.

Raimundo, A. A. C. & Alves, M. L. G. (1986). *Revisão dos Coccinelídeos de Portugal.* Universidade de Évora, Évora, 106 pp.

Rei, F. T. (2004). Coccinellidae em *Olea europea* L. In XI Congresso Ibérico de Entomologia, Resumos das Comunicações. Funchal, Madeira, pp. 33.

Ruano, F., Lozano, C., García, P., Peña, A., Tinaut, A., Pascual, F. & Campos, M. (2004). Use of artrhopods for the evaluation of the olive-orchard management regimes. *Agriculture and Forest Entomology,* **6,** 111-114.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007a). Coccinellids as potential predators of *Saissetia Oleae* (Olivier). In 3*rd European Meeting of the IOBC/WPRS* Working Group "Integrated Protection of Olive Crops", Programme and Abstract Book. Bragança - Portugal.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007b). Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pests in olive groves from north-east of Portugal. *Chemosphere*, **67**, 131-139.

Silvestri, F. (1903). Contribuzioni alla conoscenza dei Mirmecophili, I. Osservazioni su alcuni mirmecophili dei dintorni di Portici. *Annuario Dell Instituto e Museo Di Zoologia Del Universita di Napoli*, **1**, 1-5.

Smirnoff, W. W. (1956). *Observations sur les prédaterus et parasites des cochenilles nusibibles du Maroc et sur leurs enemies*. Service de la Défense de Végétaux, Maroc, 11, 60.

TerBraak, C. J. F. (1995). Ordination. In *Data analysis in community and landscape ecology*, eds. R. H. G. Jongman, C. J. F. ter Braak & O. F. R. van Tongeren, Cambridge Univ. Press, pp. 91-173.

TerBraak, C. J. F. & Smilauer, P. (2002). CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5), Ithaca, New York, USA.

Toccafondi, P., Covassi, M. & Pennacchio, F. (1991). Studi sugli entomofagi predatori di cocciniglie del Gen. Matsucoccus Cock. in Italia. II Note bioetologiche su *Rhyzobius chrysomoloides* Herbst in pinete della Liguria (Coleoptera, Coccinellidae). *Redia*, **2**, 599-620.

Varela, J. L. & González, R. (1999). Estudio sobre la entomofauna de un olivar en la provincia de Granada, durante el periodo de vuelo de la generación antófaga de *Prays oleae* (Lep. Yponomeutidae) Phytoma España, **111**, 42-55.

Völkl, W. (1995). Behavioral and Morphological Adaptations of the Coccinellid, *Platynaspis luteorubra* for Exploiting Ant-Attended Resources (Coleoptera: Coccinellidae). *Journal of Insect Behavior*, **8**, 653-670.

Weise, J. (1885). Bestimmungs-tabellen der Eurepäischen Coelopteran. Mdling, 1-83.

Woin, N., Volkmar, C. & Wetzel, T. (2000). Seasonal activity and diversity of ladybirds (Coleoptera: Coccinellidae) as ecological bioindicators in paddy-fields. *Mitteilungen der Deutschen Gesellschaft für angewandte Entomologie*, **12**, 203 - 206.

Xiong-Fei, P. & Gordon, R. D. (1986). The Scymnini (Coleoptera: Coccinellidae) of China. *The Coleopterists Bulletin*, **40**, 157-199.

8. Comparing taxonomic levels of epigeal insects under different farming systems in Andalusian olive agroecosystems

Comparing taxonomic levels of epigeal insects under different farming systems in Andalusian olive agroecosystems

Submitted to Applied Soil Ecology

8.1 Abstract

The intensification of olive production methods in southern Spain, has involved a widespread use of chemicals and the progressive loss of many Mediterranean forest patches, natural landscapes and semi-natural vegetation. Species level inventories require an enormous amount of time and financial resources, mainly due to the necessity of employing a taxonomist in the early stages of a study. The use of a higher taxonomic level is particularly useful when rapid biodiversity surveys are required. This survey investigates the reliability of a rapid procedure method to detect which high taxonomic level of epigeal insects could best distinguish different farming systems in olive agroecosystems, taking into account three high taxa categories as surrogate measures of insect diversity: orders for all the insects, families of Coleoptera and carabid morphospecies. We collected insects by pitfall traps in olive orchards under organic, integrated and conventional farming systems in two provinces in Andalusia (Córdoba and Granada) with different surrounding landscapes over three different years. In 1999 and 2000 a study of trends over time was undertaken between March and October of both years in Granada, and in 2003 a geographically extended study was conducted in 18 different orchards during pre-blooming and post-blooming periods in Granada and Córdoba.

To rapidly assess biodiversity in olive agroecosystems taking into account soil communities, in order to classify farming systems on a regional scale, the taxonomic level of insect order seems to be a more reliable approach than a lower taxonomic level.

This methodology could be used as a possible useful short-cut to assess biodiversity in olive orchards at a local scale, the order surrogacy being useful when results are required rapidly and in a context of limited financial resources.

Keywords: Carabidae, Coleoptera; farming systems, high taxonomic level, Insecta, olive agroecosystems; morphospecies.

8.2 Introduction

The intensification of olive production methods in southern Spain, involving a widespread use of chemicals and the progressive loss of many patches of Mediterranean forest have led to an impoverishment in biodiversity in agroecosystems (Biaggini *et al.*, 2007) and more specifically in arthropod fauna in olive agroecosystems (Ruano *et al.*, 2004; Santos *et al.*, 2007). In Andalusian landscapes, natural and semi-natural vegetation has been removed to enlarge the olive growing area, leading to a decrease and a fragmentation of the Mediterranean forests (de Graaff & Eppink, 1999; Milgroom *et al.*, 2007; Parra López & Calatrava Requena, 2006). Low-intensity cropping systems have been related to greatest abundance and activity of beneficial ground-dwelling arthropod communities (Lundgren *et al.*, 2006). According to Guzmán & Alonso (2004), conventional soil practices tend to diminish diversity and activity of the soil fauna.

Studies based on biodiversity require morphological recognition of different specimens; they can be carried out through species level inventories, however this demands an enormous amount of time and financial resources (Cardoso *et al.*, 2004; Wilkie *et al.*, 2003), mainly due to the necessity of a taxonomist being involved in the early stages of a study (Biaggini *et al.*, 2007). An alternative approach is to use a higher taxonomic level and this is particularly useful when rapid biodiversity surveys are required (Andersen, 1995; Oliver & Beattie, 1996).

Attempts to identify higher insect taxa for evaluating types of farming systems have appeared to be a promising solution in recent studies (Balmford *et al.*, 1996; Biaggini *et al.*, 2007), since higher-level taxa (such as orders or families) may be more easily surveyed than a large number of invertebrate species. Ruano *et al.* (2004) observed that the abundance of five higher-level taxa groups from soils in olive agroecosystems differed when management regimes were compared, one of these taxa being the coleopteran order. Indeed, coleopterans are one of the best represented arthropod orders and a group often used in biodiversity assessment in agroecosystems (Asteraki *et al.*, 1995; Petit & Usher, 1998; Woodcock *et al.*, 2005). A previous survey (Cotes *et al.*, 2009b) established the use

of an approach based on coccinellids from olive canopies as a tool for rapid detection of organic farming systems, through the use of morphospecies. This recognizable taxonomic unit (RTU) (Krell, 2004) is a species surrogacy that considers morphological similarities without using taxonomic literature or taxonomic standards. From all beetle families, carabid morphospecies were selected because they are species rich and abundant in arable habitats and because of their predatory polyphagous nutrition, reacting sensitively to the impact of cultivation (Kromp, 1999) and the morphospecies level of carabids has already been used (Oliver & Beattie, 1996). Moreover, previous studies have shown that soil carabids of olive orchards can be affected by soil management (Castro *et al.*, 1996; González *et al.*, 2004; Morris & Campos, 1999).

This survey investigates whether abundances of high taxa of insects, coleopteran families and carabid morphoespecies differ between the different management systems and could be used as a rapid procedure to detect and test management regimes.

8.3 Materials and methods

8.3.1 Study zones and sampling periods

The study area covers parts of two different provinces in Spain extending about 104 km from north to south and 117 km at its widest point from east to west, with the experimental fields located at an altitude 400 to 1100 m a.s.l. Córdoba and Granada provinces are two of the largest commercial olive producing areas in southern Spain, but natural surroundings and the land use traditions make the olive landscape diverse (Figure 8.1). In Córdoba, the sampling was carried out in the valley of Los Pedroches, which is the largest area of organic production in Andalusia. Though there are some non-organic farmers in this valley, the organic olive farming system is widespread. This region is close to the Cardeña and Montoro natural park, and contains a semi-natural olive landscape with patches of Mediterranean forest. Olive orchards from Granada are located near mountain oak stands; however, in Granada the surrounding olive orchards are cultivated under intensive farming systems and the patches of natural vegetation are smaller than in Córdoba.

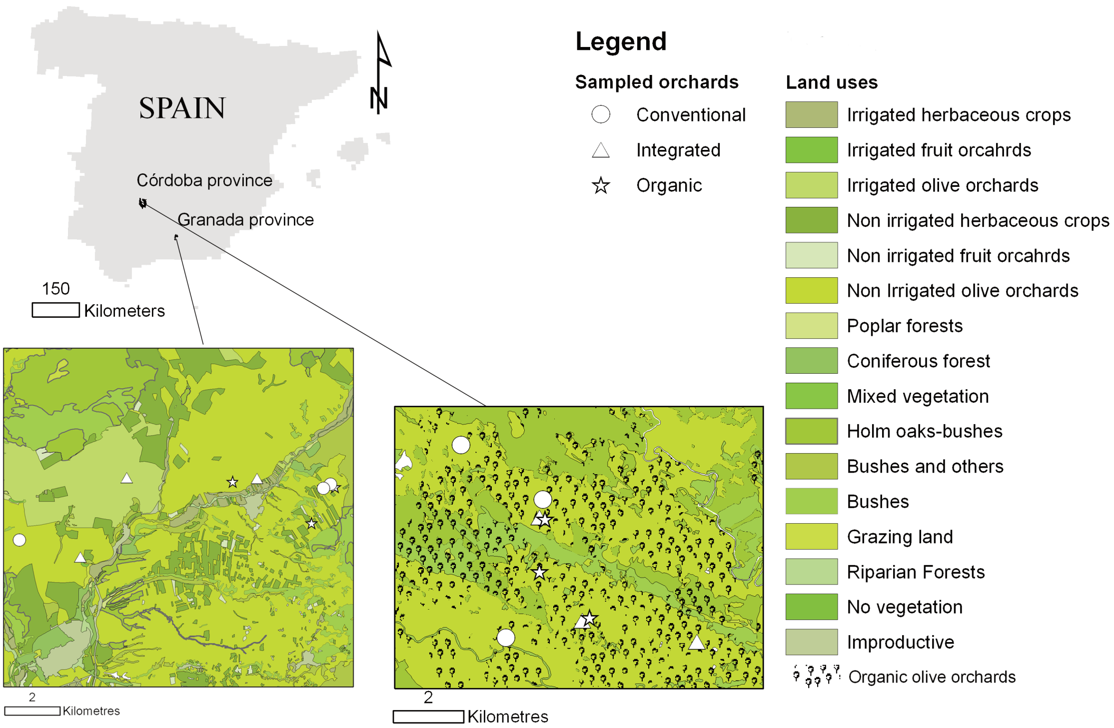


Figure 8.1: Locations, types of farming systems and surrounding land uses.

First, three large olive orchards in Granada using organic, integrated and conventional farming systems were sampled from March to October in 1999 and 2000, in order to include both interannual variability of epigeal insect abundance (order, family and morphospecies) and the distribution patterns of insects over time. Additionally, samples were collected from nine large orchards (three per farming system) in Granada and nine other orchards in Córdoba in pre-blooming (May) and post-blooming (June) periods in 2003, when arthropods were the most abundant (Ruano *et al.*, 2004); overall, a total of 18 orchards were sampled in 2003. We then undertook a temporal variability study in Granada (1999 and 2000) in three large olive orchards and another study at a higher spatial scale in 18 olive orchards (nine per province) over the same months in 2003.

The different farming systems were implemented in compliance with the legislation in force at that time; the farming practices of each type are summarised in Table 8.1.

Table 8.1: Type of farming systems, sampling year and agronomic practices of the sampled olive orchards (Córdoba: A to I and Granada: J to R).

Province		Farming system	Sampling year	Irrigation	Plough	Insecticides	Herbicides	Vegetal cover	Hedge row
Córdoba	A	Conventional	2003	No	No	Yes	Yes	No	No
	B	Integrated	2003	No	No	Yes	Yes	Yes	No
	C	Organic	2003	No	Yes	No	No	Yes	No
	D	Conventional	2003	No	Yes	Yes	Yes	Yes	Yes
	E	Organic	2003	Yes	No	No	No	Yes	No
	F	Conventional	2003	No	Yes	Yes	Yes	No	Yes
	G	Integrated	2003	No	No	Yes	No	Yes	No
	H	Organic	2003	No	Yes	No	No	Yes	Yes
	I	Integrated	2003	No	No	Yes	Yes	No	No
Granada	J	Conventional	1999 2000 2003	Yes	Yes	Yes	Yes	No	No
	K	Integrated	2003	Yes	No	No	Yes	Yes	Yes
	L	Integrated	1999	Yes	Yes	Yes	Yes	No	No
			2000						
			2003				No		
	M	Organic	2003	Yes	Yes	No	No	Yes	No
	N	Integrated	2003	No	Yes	Yes	No	No	No
	O	Conventional	2003	Yes	No	Yes	Yes	No	No
	P	Organic	1999 2000 2003	Yes	Yes	No	No	Yes	Yes
	Q	Conventional	2003	Yes	No	Yes	Yes	Yes	No
	R	Organic	2003	Yes	Yes	No	No	Yes	Yes

8.3.2 Insect collection

The epigeal insects were collected in pitfall traps which were set-up on a north-facing site, consisting of a 200-mL plastic glasses with a 7-cm opening, half-filled with water and one drop of detergent to avoid surface tension and the escape of arthropods. Traps were placed in holes dug carefully with a minimum disturbance of soil and vegetation so that the lip of the trap was even with the soil surface. The traps were left in place for 24 h. Samples from soils were filtered and frozen and, subsequently, the insects were separated from vegetal and non-organic remains. Insects (adults and juveniles) were identified to order level, Coleoptera order was determined to families and Carabidae family to morphospecies level.

The sampling unit was a block, each block consisting of a row of five trees. Two sampled trees in the block were separated by an unsampled tree, so that the distance between sampled trees was 20 metres. Each block was considered a true replication because of the large area covered by the olive zones studied, and the distance between blocks (a minimum of 0.5 km) ensures independence between them. In each olive orchard four blocks were sampled.

8.3.3 Univariate statistical analysis

In order to characterize the arthropod fauna of different management regimes, the mean abundance of insect orders, coleopteran families and carabid morphospecies were compared monthly among farming systems in 1999, 2000 and 2003 by non-parametric tests. Specifically, the Mann-Whitney U test and Kruskal-Wallis test were used for comparison of the differences in means, due to the non-normality of the data even after several transformations. These analyses were carried out with SPSS 17.0 for Windows.

8.3.4 Multivariate statistical analysis

Ordination methods were applied in order to characterise the composition of epigeal insects in the Andalusian olive orchards comparing data from Granada and Córdoba only during pre-blooming and post-blooming over the three years. The multivariate approach was chosen for the ordination methods to determine relationships between the three taxonomic groups (insect orders, coleopteran families and carabid morphospecies) and environmental variables (agronomic practices) in olive orchards of two different regions, using R statistical software (R Development Core Team, 2005), evaluating which taxonomic level could group the farming systems in the different orchards best. Direct gradient analysis was performed given that the aim of this study was to extract patterns from the variation explained by each environmental variable. This analysis takes into account only the portion of biological data that are related to environmental

variation. Accordingly, Detrended Canonical Correspondence Analysis (DCCA) was used to carry out the direct gradient analysis to determine the adequate approach (unimodal or linear) that best fit the data set. The significance level of the analyses was assessed using a Monte-Carlo test with 499 random permutations. The environmental variables and the abundance of insects at different levels were log transformed (log (y+1)).

8.4 Results

8.4.1 Local and seasonal pattern of abundance and richness of soil insects

A total of 14,173 insects were captured in the three orchards in Granada from March to October in 1999, while 13,289 individuals were collected in 2000. Fourteen orders of insects were identified over this whole sampling (Table 8.2), and insect abundance varied between farming systems and years with no similar pattern emerging between years (Figure 8.2).

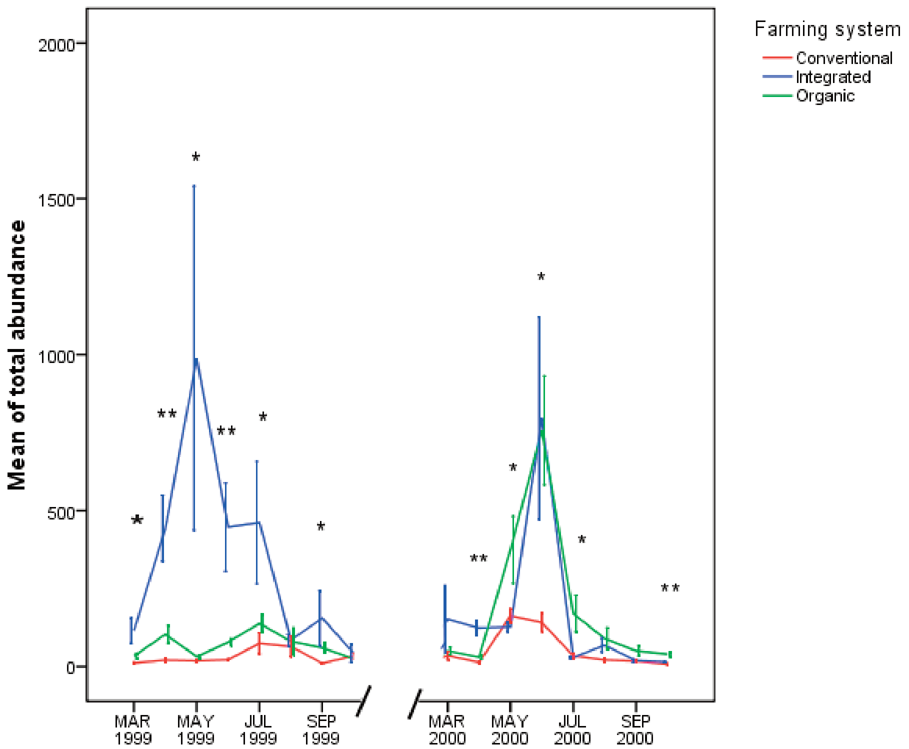


Figure 8.2: Seasonal variation of the mean abundance of insects per block in each management regime: conventional, integrated and organic in 1999 and 2000. (Bars indicate the standard error and significance levels: * 0.05>P=0.01; ** 0.01>P=0.005; ***P<0.005).

Hymenopterans (principally represented by ants in all the samplings) and hemipterans were the most abundant orders collected throughout 1999 in the three orchards, while hymenopterans and dipterans were the most abundant in 2000 (Table 8.2).

Table 8.2: Percentage of insect orders and coleopteran families (arranged by their relative abundance) in olive orchards under integrated, conventional and organic farming systems from Granada in 1999 and 2000.

	1999			2000		
	Integrated	Conventional	Organic	Integrated	Conventional	Organic
HYMENOPTERA	96.81	23.27	57.40	69.25	14.49	21.35
DIPTERA	0.89	10.69	5.24	22.85	79.01	73.46
COLEOPTERA	0.63	42.14	4.33	0.54	2.63	1.77
Carabidae	41.67	17.91	26.32	45.00	15.63	21.25
Staphylinidae	5.56	1.49	42.11	10	15.63	28.75
Tenebrionidae	2.78	47.76	0	10	25.00	11.25
Anthicidae	2.78	29.85	15.79	10	18.75	6.25
Ptinidae	33.33	0	0	15.00	0	0
Scarabaeidae	2.78	0	5.26	5.00	9.38	0
Silvanidae	2.78	0	0	5.00	3.13	2.50
Rhynchitidae	2.78	0	0	0	3.13	6.25
Curculionidae	2.78	0	0	0	3.13	5.00
Histeridae	0	0	5.26	0	0	2.50
Coccinellidae	0	1.49	0	0	3.13	2.50
Elateridae	2.78	0	0	0	0	3.75
Cucujidae	0	1.49	0	0	0	5.00
Chyrsomelidae	0	0	5.26	0	0	0
Mycetophagidae	0	0	0	0	0	3.75
Byrrhidae	0	0	0	0	3.13	0
Nitidulidae	0	0	0	0	0	1.25
HEMIPTERA	0.49	18.87	20.73	3.06	2.72	2.72
PSOCOPTERA	0	1.26	6.83	0.70	0.08	0.07
LEPIDOPTERA	0.26	2.52	0.91	0.27	0.49	0.27
DICTYOPTERA	0.77	0	0.23	3.19	0	0.02
THYSANOPTERA	0.03	0	2.73	0.03	0.16	0.18
EMBIOPTERA	0.02	0.63	0.23	0.03	0	0.11
NEUROPTERA	0	0	0.46	0.08	0.41	0.04
TRICHOPTERA	0.09	0	0.68	0	0	0
ORTHOPTERA	0.02	0.63	0	0	0	0
DERMAPTERA	0	0	0.23	0	0	0.02

Further, hymenopterans and hemipterans showed significant differences among management regimes in nine of the months, followed by dipterans in seven months (Table 8.3). It was found that from April to October 1999 a similar number of orders per month (three or four orders) were significantly different between management regimes, except in August in which only two orders were significantly affected by the farming systems (Table 8.3). As for 2000, the greatest number of differences between management regimes was found in June (with differences in six orders), while the remaining months had fewer significant orders (three), August (1999 and 2000) and September 2000 representing the lowest number of differences (two and one, respectively).

Regarding soil beetles, 17 families were identified in the two years of sampling in the three orchards (Table 8.2), carabids and anthicids being the most abundant groups in both years. It can also be observed that anthicids and tenebrionids were more abundant in the conventional orchards in both years, while carabids and staphylinids were more abundant in the organic and integrated orchards. Eight Coleopteran families showed significant differences between the farming systems in the two years, however only a number of three beetle families significantly differed from May to July in 1999 and 2000 (Table 8.4). On the one hand, tenebrionids differed significantly between farming systems from April to June in 1999, and, on the other, anthicids in June and July in 1999 and from July to September in 2000. This seems to indicate a seasonal pattern which is more stable than other families found in olive soils.

Using Recognizable Taxonomic Units (RTUs) or morphospecies, 15 different types of carabids were identified over the two years in Granada (206 and 117 specimens in 1999 and 2000 respectively). However significant differences (Kruskal-Wallis, $\chi 2 = 7.54$, $p < 0.05$) were found only in one carabid mophospecies (msp 4) in September 1999, it being present only in the organic orchards, thus carabid morphospecies could not be used to indicate the farming practices.

Table 8.3: Results from the Kruskal-Wallis test applied to blocks obtained in the soil during 1999 and 2000. Comparisons were performed for each of the orders of insects present in the three different types of management regime.

	1999																2000																Number of significantly different months per order
	MARCH		APRIL		MAY		JUNE		JULY		AGUST		SEPT		OCT		MAR		APR		MAY		JUNE		JULY		AUGUST		SEPT		OCT		
	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	
Coleoptera	4.39	NS	3.29	NS	3.77	NS	5.87	NS	7.79	*	0.56	NS	8.46	*	1.89	NS	2.69	NS	2.09	NS	4.56	NS	7.91	*	3.26	NS	1.69	NS	0.57	NS	7.18	*	4
Dermaptera	2.00	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	2.00	NS	2.00	NS	0	NS	0	NS	2.00	NS	0
Dictyoptera	0	NS	2.00	NS	10.46	**	2.00	NS	8.78	*	3.90	NS	3.85	NS	0	NS	2.00	NS	0	NS	7.33	*	9.37	**	2.72	NS	9.37	**	2.00	NS	4.36	NS	5
Diptera	4.48	NS	5.17	NS	3.06	NS	8.04	*	4.89	NS	3.25	NS	6.90	*	4.16	NS	1.83	NS	5.21	NS	8.77	*	6.58	*	7.01	*	6.48	*	4.94	NS	7.36	*	7
Embioptera	7.48	*	2.00	NS	2.00	NS	1.10	NS	1.10	NS	2.00	NS	0	NS	6.22	*	2.72	NS	4.81	NS	4.40	NS	1.11	NS	1.10	NS	2.00	NS	7.20	*	5.68	NS	3
Hemiptera	9.40	**	7.59	*	6.68	*	4.56	NS	7.11	*	5.17	NS	2.49	NS	8.87	*	7.19	*	9.46	**	7.88	*	8.62	*	4.38	NS	1.84	NS	0.81	NS	0.52	NS	9
Hymenoptera	8.00	*	9.30	**	7.84	*	9.92	**	6.04	*	0.47	NS	8.12	*	2.59	NS	1.19	NS	7.45	*	2.93	NS	7.54	*	7.42	*	3.14	NS	5.91	NS	1.86	NS	9
Lepidoptera	7.33	*	2.44	NS	0.81	NS	2.15	NS	1.54	NS	2.00	NS	2.75	NS	1.10	NS	2.44	NS	2.00	NS	5.12	NS	1.24	NS	3.22	NS	2.62	NS	2.62	NS	8.26	*	2
Neuroptera	4.40	NS	0	NS	0	NS	4.40	NS	7.12	*	2.62	NS	0.86	NS	2.00	NS	2.00	NS	0	NS	1.10	NS	0.44	NS	2.75	NS	4.40	NS	2.62	NS	1.10	NS	1
Orthoptera	0	NS	0	NS	2.00	NS	2.00	NS	3.65	NS	6.71	*	9.37	**	0	NS	0	NS	0	NS	0	NS	0	NS	2.00	NS	4.38	NS	5.25	NS	0.69	NS	2
Pscoptera	5.68	NS	8.17	*	4.36	NS	8.42	*	2.73	NS	5.34	NS	0.63	NS	9.23	**	9.23	**	10.51	**	3.71	NS	10.51	**	2.00	NS	0	NS	0	NS	4.40	NS	6
Thysanoptera	2.00	NS	5.01	NS	5.01	NS	2.87	NS	2.44	NS	0	NS	2.00	NS	2.00	NS	0	NS	2.75	NS	2.62	NS	2.75	NS	4.40	NS	0	NS	0	NS	2.00	NS	0
Trichoptera	0	NS	0	NS	0	NS	2.75	NS	0	NS	8.26	*	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	7.33	*	0	NS	0	NS	4.36	NS	0
Zygentoma	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS					
Number of significantly different orders per month	4		3		3		3		4		2		4		3		2		3		3		6		3		2		1		3		

P values are: *, < 0.05; **, < 0.01; ***,<0.005; NS, not significant (> 0.05)

Table 8.4: Results from the Kruskal-Wallis test applied to blocks obtained in the soil during 1999 and 2000. Comparisons were performed for each of the beetle families present in the three different types of management regime.

	1999																2000																Number of significantly different months per family
	MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPT		OCT		MAR		APR		MAY		JUNE		JULY		AuGUST		SEPT		OCT		
	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	χ2	*p*	
Anthicidae	2.00	NS	2.00	NS	2.00	NS	6.96	*	6.61	*	2.00	NS	2.00	NS	0	NS	0	NS	0	NS	4.28	NS	2.85	NS	9.84	**	5.45	NS	8.86	*	0	NS	4
Byrrhidae	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
Carabidae	3.63	NS	0.29	NS	3.43	NS	0.33	NS	3.20	NS	2.66	NS	8.68	*	4.03	NS	4.36	NS	1.66	NS	1.04	NS	3.39	NS	0.91	NS	2.62	NS	2.75	NS	5.72	NS	1
Chrysomelidae	0	NS	2.00	NS	2.00	NS	0	NS	2.00	NS	0	NS	2.00	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
Coccinellidae	2.00	NS	4.40	NS	2.00	NS	0	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	4.40	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0
Cucujidae	0	NS	2.00	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	2.75	NS	0	NS	4.40	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
Curculionidae	2.00	NS	4.36	NS	0	NS	2.00	NS	5.01	NS	2.00	NS	2.00	NS	1.10	NS	2.00	NS	0	NS	2.00	NS	7.20	*	2.39	NS	1.11	NS	4.40	NS	0	NS	1
Elateridae	0	NS	4.40	NS	0	NS	2.00	NS	2.00	NS	2.00	NS	0	NS	0	NS	2.00	NS	0	NS	4.36	NS	0	NS	0	NS	4.36	NS	2.00	NS	0	NS	0
Histeridae	0	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0
Mycetophagidae	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	4.36	NS	7.20	*	0	NS	2.00	NS	0	NS	1
Nitidulidae	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0
Ptinidae	0	NS	0	NS	7.16	*	0	NS	7.33	*	0	NS	0	NS	0	NS	0	NS	0	NS	7.33	*	0	NS	0	NS	0	NS	0	NS	0	NS	3
Rhynchitidae	0	NS	0	NS	2.00	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	2.00	NS	2.62	NS	7.20	*	1.10	NS	0	NS	0	NS	0	NS	0	NS	1
Scarabaeidae	2.00	NS	0	NS	2.00	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	1.11	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
Silvanidae	0	NS	0	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0	NS	2.00	NS	0	NS	5	NS	0	NS	2.00	NS	0	NS	0	NS	0	NS	0
Staphylinidae	2.44	NS	2.75	NS	4.40	NS	1.22	NS	1.10	NS	0	NS	0	NS	2.44	NS	1.10	NS	1.98	NS	4.05	NS	8.56	*	0	NS	0	NS	0	NS	5.31	NS	1
Tenebrionidae	0	NS	7.20	*	8.90	*	10.51	**	9.06	*	2.62	NS	1.04	NS	0	NS	0	NS	2.00	NS	5.01	NS	4.01	NS	3.65	NS	5.69	NS	0.37	NS	0.69	NS	4
Number of significantly different families per month	0		1		2		2		3		0		1		0		0		0		2		2		2		0		1		0		

P values are: *, < 0.05; **, < 0.01; ***,<0.005; NS, not significant (> 0.05)

8.4.2 Pre- and post-blooming period

Having observed between May and June the highest abundance of insects (Figure 8.2) (Ruano *et al.*, 2004) and, besides that, a few coleopteran families which could be used to distinguish between farming systems (Table 8.4) in this same period, in 2003 a new sampling was carried out in a new province (Córdoba), along with Granada province during pre-blooming (May) and post-blooming (June) periods.

A total number of 15,657 insects were collected in Granada, belonging to 13 orders, while only 7,152 were captured in Córdoba in the three management regimes, belonging to 12 orders (Table 8.5).

Table 8.5: Percentage of insect orders (arranged by their relative abundance) in olive orchards under integrated, conventional and organic farming systems from Granada and Córdoba in 2003.

	Córdoba			Granada		
	Integrated	Conventional	Organic	Integrated	Conventional	Organic
Hymenoptera	89.05	88.39	83.11	95.92	85.46	61.61
Coleoptera	2.14	2.50	3.54	1.08	7.43	16.80
Diptera	3.19	2.38	3.49	0.93	4.35	18.57
Hemiptera	4.57	5.20	8.16	1.65	1.76	2.13
Lepidoptera	0.12	0.31	0.09	0.12	0.55	0.28
Pscoptera	0.61	0.23	0.57	0.05	0.14	0.20
Orthoptera	0.08	0.31	0.52	0.05	0.03	0.08
Dictyoptera	0.08	0.47	0.05	0.06	0	0.03
Dermaptera	0.08	0.00	0.00	0.10	0.09	0.06
Embioptera	0.08	0.12	0.14	0	0.03	0.11
Thysanoptera	0	0.08	0.14	0.01	0.12	0.08
Neuroptera	0	0	0.19	0.01	0.06	0.06
Trichoptera	0	0	0	0.02	0	0

As in the previous years studied, hymenopterans were the most abundant group in both provinces, and the second most numerous were coleopterans in Granada and hemipterans in Córdoba. When all the insect orders were studied, only hemipterans differed significantly in abundance between organic, integrated and conventional during post-blooming in both provinces. On the one hand, the three farming systems in Granada were observed to be significantly different in coleopteran, dipteran, hymenopteran and hemipteran orders, while, on the other hand, lepidopterans, neuropterans, dictyopterans and orthopterans could discriminate between farming systems in Córdoba province (Table 8.6).

Table 8.6: Results from the Kruskal-Wallis test applied to blocks obtained in Granada and Córdoba provinces during pre-blooming and post-blooming in 2003. Comparisons were performed for each of the insect orders present in the three different types of management regime.

	MAY				JUNE			
	GRANADA		CÓRDOBA		GRANADA		CÓRDOBA	
	χ^2	*p*	χ^2	*p*	χ^2	*p*	χ^2	*p*
Coleoptera	10.95	***	1.50	NS	15.73	***	5.14	NS
Dermaptera	1.34	NS	4.12	NS	2.00	NS	0	NS
Dictyoptera	2.00	NS	2.19	NS	4.11	NS	6.18	*
Diptera	18.37	***	2.75	NS	22.94	***	3.96	NS
Embioptera	2.12	NS	0.45	NS	4.12	NS	2.12	NS
Hemiptera	3.90	NS	0.75	NS	6.38	*	8.28	*
Hymenoptera	6.89	*	4.44	NS	11.83	***	4.29	NS
Lepidoptera	0.01	NS	3.83	NS	2.42	NS	3.49	NS
Neuroptera s.l.	0	NS	8.75	*	0.46	NS	0	NS
Orthoptera	0	NS	7.28	*	2.22	NS	1.30	NS
Psocoptera	0.55	NS	2.81	NS	0.96	NS	0.13	NS
Thysanoptera	0	NS	1.03	NS	3.16	NS	1.03	NS
Trichoptera	0	NS	0	NS	2.00	NS	0	NS
Zygentoma	0	NS	0	NS	0	NS	0	NS

P values are: *, < 0.05; **, < 0.01; ***,<0.005; NS, not significant (> 0.05)

Another approach consisted of comparing each farming system between provinces to establish certain orders that could be significantly different in Granada and Córdoba. Accordingly, the conventional orchards from each province were compared, coleopterans (U de Mann Whitney: z = -4.06, p <0.005), dipterans (U de Mann Whitney: z = -2.88, p <0.005), hemipterans (U de Mann Whitney: z = -3.09, p <0.005) and dictyopterans (U de Mann Whitney: z = -2.58, *p* <0.01) being found to be significantly different, while in the case of the integrated orchards only coleopterans (U de Mann Whitney: z = -2.17, *p* <0.05) and hymenopterans (U de Mann Whitney: z = -3.78, *p* <0.005) showed statistically significant differences. Finally, the organic orchards showed the highest number of orders with significant differences between provinces: coleopterans (U de Mann Whitney: z = -5.13, *p* <0.005), dipterans (U de Mann Whitney: z = -5.58, *p* <0.005), lepidopterans (U de Mann Whitney: z = -2.46, *p* <0.05), hemipterans (U de Mann Whitney: z = -2.08, *p* <0.05) and orthopterans (U de Mann Whitney: z = -2.29, *p* <0.05). Since several insect orders showed differences between the two provinces within the same farming systems, they were investigated independently.

Despite coleopterans not distinguishing between farming systems in Córdoba, they were investigated to the family level in order to determine their response to the different agronomic practices, because it has been suggested previously that the beetles from olive soils differentiate between farming systems (Ruano *et al.*, 2004). The total number of beetles from the Granada orchards was 951 individuals, compared to Córdoba where we counted only 192. In both provinces a total number of 26 families were identified. From the percentage composition of beetle families (Table 8.6), it can be observed that carabids are more abundant in non-organic farming (conventional and integrated) in both Granada and Córdoba orchards, during May and June. Using the Kruskal-Wallis test, significant differences were observed in carabids (Kruskal-Wallis, $\chi 2 = 9.21$, $p < 0.05$), staphylinids (Kruskal-Wallis, $\chi 2 = 13.77$, $p < 0.005$), tenebrionids (Kruskal-Wallis, $\chi 2 = 12.02$, $p < 0.005$) and elaterids (Kruskal-Wallis, $\chi 2 = 15.24$, $p < 0.005$) in Granada orchards. No beetle family could distinguish between farming systems in Córdoba orchards, since only apionids showed significant differences and they were not considered due to their scarcity in the olive orchards.

From June to May, the eight carabid morphospecies were recognized in Córdoba (32 specimens), while 11 morphospecies were identified in Granada (262 specimens). Significant differences were only observed in one carabid morphospecies (msp 3) in May in Granada province, this morphospecies being more abundant in the conventional orchards (Kruskal-Wallis, $\chi 2 = 6.74$, $p < 0.05$).

8.4.3 Multivariate analysis

In the DCCA, the longest axis gradient length being less than 3 units, therefore a linear ordination model was suitable, so two Redundancy Analyses (RDA) were performed to establish the relationship between abundance of the three insect groups (insect orders, coleopteran families and carabid morphospecies) and environmental variables (ploughing, insecticide and herbicide application, vegetal cover and hedgerow presence) in pre-blooming and post-blooming over the three years. Table 8.7 shows the cumulative percentage variance of the canonical axis values, the first and second axes of insect orders best explained the insect variability (Table 8.7).

Table 8.7: Cumulative percentage variance of the canonical axis values from RDA performed on the correlation between three taxonomic groups of insects and environmental variables.

	Cumulative Percentage Variance (%)			
Axes	1	2	3	4
Insect orders	39.80	72.60	90.90	97.20
Coleopteran families	33.50	64.40	83.70	93.60
Carabids morphospecies	36.60	68.40	89.60	97.10

The triplot among insect orders environmental variables and sampled orchards showed a clear separation between non-organic orchards (integrated and conventional) and organic orchards from both Córdoba and Granada provinces (Figure 8.3). The first and second axes represent environmental stress, with all the organic orchards from Granada and Córdoba in the upper corners and almost all the integrated and conventional orchards in the lower corners. Moreover, the presence of vegetal cover and hedgerows was related to a higher number of insect orders, among them the most abundant (dipterans, coleopterans and hemipterans), although hymenopterans did not seem to be related with any agricultural practice, while herbicide use and ploughing favoured the lepidopteran population. Using coleopteran families the sampling sites could not be separated according to farming system. From the triplot it was observed that presence of covers and hedgerows, as in the case of orders, corresponded to a higher abundance of beetle families (carabids, staphylinids, elaterids), while ploughing appeared closer to other families such as anthicids and cryptophagids. Finally, only the silvanid family was more closely related to the use of herbicides and insecticides. When the carabid morphospecies are observed, a more useful result is found than with coleopterans. In the triplot it is possible to localize most organic orchards in the left upper corner together with vegetal cover and hedgerows and associated with them, carabid morphospecies 5, 6, 14, 15 and 16. However, non-organic orchards are not uniformly distributed throughout the triplot, although morphospecies 1, 9 and 10 indicate non-organic orchards associated with ploughing and herbicides.

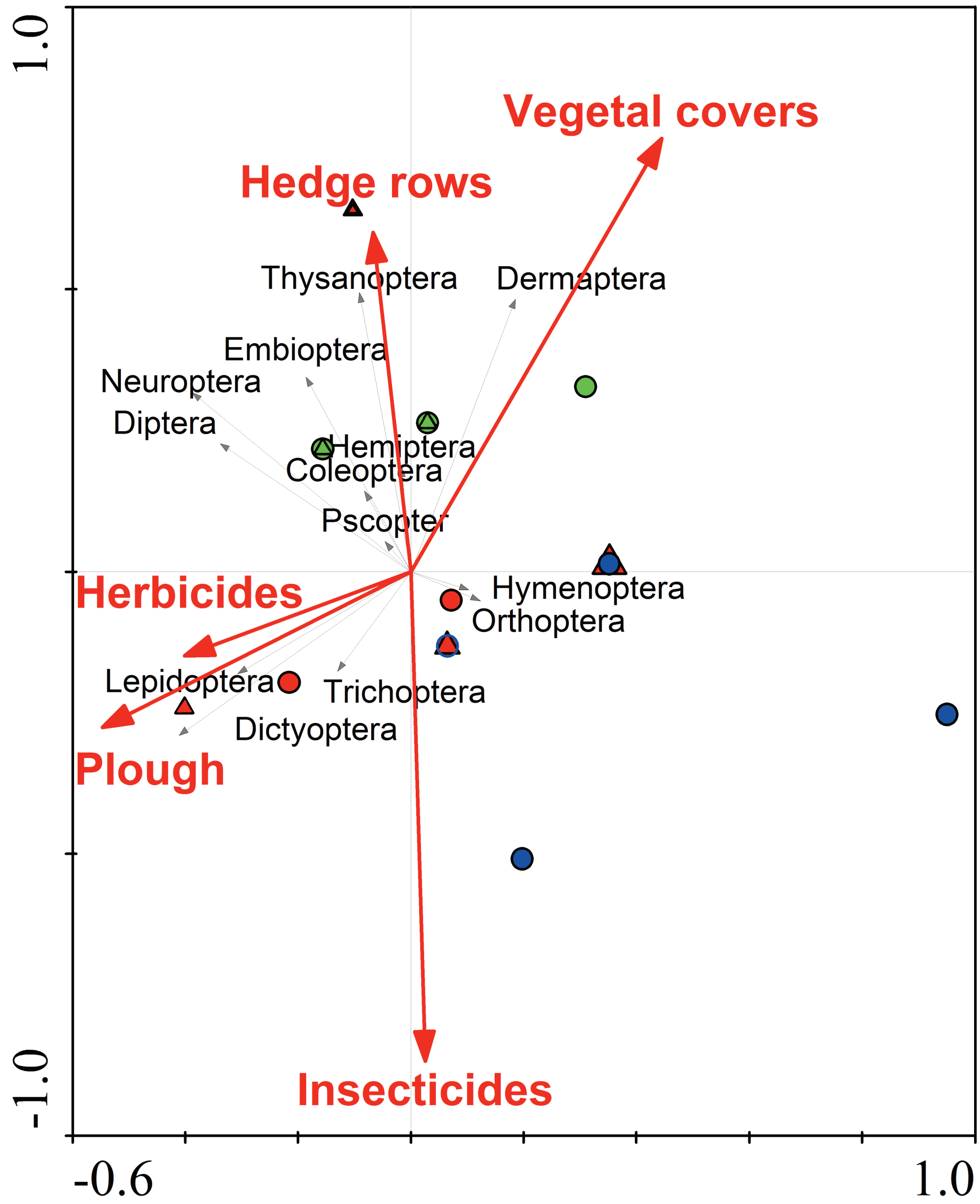


Figure 8.3: Redundancy analysis (RDA) of farming practices and insect orders with sampling sites (olive orchards) in Granada (triangle) and Córdoba (circle). The red. blue and green colours represent conventional, integrated and organic farming respectively.

8.5 Discussion

Although the seasonal pattern was similar only in the case of integrated orchards over the years 1999 and 2000, it was observed that the highest differences among insect orders were found in May and June. In accordance with other studies on the soils of olive orchards (Castro *et al.*, 1996; González *et al.*, 2004), hymenopterans were the most abundant group, being represented principally by ants. Further, when we studied the pre-blooming and post-blooming period in 2003, differences among farming systems were found. Coleopterans, dipterans, hymenopterans and hemipterans were most abundant in Granada, while lepidopterans, neuropterans and orthopterans in Córdoba. This result is understandable, with orders from the olive canopies in the same region showing great variation due to heterogeneity of farming practices, as well as the importance of differences in landscape features, from one province to another.

Since that epigeal coleopteran families have already shown that soil beetles of olive orchards can be affected by the soil management (Castro *et al.*, 1996; Cotes *et al.*, 2009a; González *et al.*, 2004; Morris & Campos, 1999), we undertook the identification of coleopteran families, observing in Granada that when the period of March to October was considered, carabids and staphylinids were significantly more abundant in organic orchards, while there were more tenebrionids and anthicids in non-organic orchards. However when only the pre-blooming and post-blooming periods were studied carabids were the most abundant in non-organic in the two provinces. Probably the great differences of abundance among coleopterans families between the two provinces can be explained by the corresponding landscape features.

In Córdoba province their scarcity did not allow to definitive comparisons to be made, however in Granada, in spite of their high abundance, only one morphospecies (msp 4) could distinguish between farming systems in September 1999. Previous studies (Morris *et al.*, 1999) have already reported that some carabid species increase in number with the presence of vegetal cover, however the study of carabids at morphospecies level does not help to distinguish farming systems. The results obtained from the multivariate analysis showed that the best explained variance was achieved with insect orders rather than families and morphospecies.

A high number of insect orders (dermapterans, embiopterans) is favoured by the presence of vegetal cover and hedge rows, and similarly both carabid, staphylinid and elaterid beetles and carabid morphospecies.

8.6 Conclusion

To rapidly assess biodiversity in olive agroecosystems taking into account soil communities in order to classify farming systems on a regional scale, the taxonomic level of insect order seems to be a more reliable approach than lower taxonomic levels.

This methodology could be employed as a useful short-cut to assess biodiversity in olive orchards at a local scale, the order surrogacy being an advantage when results are required rapidly and in a context of limited financial resources.

8.7 References

Andersen, A. N. (1995). Measuring more of biodiversity: Genus richness as a surrogate for species richness in Australian ant faunas. B*iological Conservation*, **73**, 39-43.

Asteraki, E. J., Hanks, C. B. & Clements, R. O. (1995). The influence of different types of grassland field margin on carabid beetle (Coleoptera, Carabidae) communities. *Agriculture, Ecosystems & Environment,* **54**, 195-202.

Balmford, A., Green, M. J. B. & Murray, M. G. (1996). Using higher taxa richness as a surrogate for species richness. I. Regional tests, Vol. 263, *Proceedings of the Royal Society*. London, pp. 1267–1274.

Biaggini, M., Consorti, R., Dapporto, L., Dellacasa, M., Paggetti, E. & Corti, C. (2007). The taxonomic level order as a possible tool for rapid assessment of Arthropod diversity in agricultural landscapes *Agriculture, Ecosystems & Environment*, **122**, 183-191

Cardoso, P., Silva, I., de Oliveira , N. G. & Serrano, A. R. M. (2004). Higher taxa surrogates of spider (Aranea) diversity and their efficiency in conservation. *Biological Conservation*, **117**, 453-459.

Castro, J., Campos, P. & Pastor, M. (1996). Influencia de los sistemas de cultivo empleados en olivar y girasol sobre la composición de la fauna de artrópodos en el suelo. *Boletín Sanidad Vegetal: Plagas*, **22**, 557-570.

Cotes, B., Castro, J., Cárdenas, M. & Campos, M. (2009a). Responses of epigeal beetles to the removal of weed cover crops in organic olive orchards. *Bulletin of Insectology*, **62**, 47-52.

Cotes, B., Ruano, F., García, P. A., Pascual, F. & Campos, M. (2009b). Coccinellid morphospecies as an alternative method for differentiating management regimes in olive orchards. *Ecological Indicators*, **9**, 548-555.

de Graaff, J. & Eppink, L. A. A. J. (1999). Olive oil production and soil conservation in southern Spain, in relation to EU subsidy policies. *Land Use Policy*, **16**, 259-267.

González, F., Rodríguez, E., Fernández, F., Civantos, M. & Campos, M. (2004). Influencia del manejo del suelo en las poblaciones de artrópodos en el cultivo del olivo. In *III Jornadas Técnicas del Aceite de Oliva, INIA*. Madrid.

Guzmán, G. & Alonso, A. (2004). Manejo del suelo en el olivar ecológico. In *Manual de Olivicultura ecológica*, Vol. II, Universidad de Córdoba. Córdoba, pp. 27-51.

Krell, F. T. (2004). Parataxonomy vs. taxonomy in biodiversity studies-pitfalls and applicability of "morphospecies" sorting. *Biodiversity and Conservation*, 13, 795-812.

Kromp, B. (1999). Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems & Environment*, **74**, 187-228.

Leps, J. & Smilauer, P. (2003). *Multivariate analysis of ecological data using CANOCO*, Cambridge, UK, 269 pp.

Lundgren, J. G., Shaw, J. T., Zaborski, E. R. & Eastman, C. E. (2006). The influence of organic transition systems on beneficial ground-dwelling arthropods and biological control of insects and weed seeds. *Renewable Agriculture and Food Systems*, **21**, 227-237.

Milgroom, J., Soriano, M. A., Garrido, J. M., Gómez, J. A. & Fereres, E. (2007). The influence of a shift from conventional to organic olive farming on soil management and erosion risk in southern Spain. *Renewable Agriculture and Food Systems*, **22**, 1-10.

Morris, T. I. & Campos, M. (1999). Entomofauna depredadora del suelo del olivar. *Zoologia baetica*, **10**, 149-160.

Morris, T. I., Campos, M., Kidd, N. A. C., Jervis, M. & Symondson, W. O. C. (1999). Dynamic of the predatory arthropod community in Spanish olive groves. *Agricultural and Forest Entomology*, **1**, 219-228.

Oliver, I. & Beattie, A. J. (1996). Designing a cost-effective invertebrate survey: A test of methods for rapid assessment of biodiversity. *Ecological Applications*, **6**, 594-607.

Parra López, C. & Calatrava Requena, J. (2006). Comparison of farming techniques actually implemented and their rationality in organic and conventional olive groves in Andalusia, Spain. *Biological Agriculture & Horticulture*, **24**, 35-59.

Petit, S. & Usher, M. B. (1998). Biodiversity in agricultural landscapes: the ground beetle communities of woody uncultivated habitats. *Biodiversity and Conservation*, **7**, 1549-1561.

Ruano, F., Lozano, C., García, P., Peña, A., Tinaut, A., Pascual, F. & Campos, M. (2004). Use of artrhopods for the evaluation of the olive-orchard management regimes. *Agriculture and Forest Entomology*, **6**, 111-114.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007). Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pests in olive groves from north-east of Portugal. *Chemosphere*, **67**, 131-139.

Wilkie, L., Cassis, G. & Gray, M. R. (2003). A quality control protocol for terrestrial invertebrate biodiversity assessment. *Biodiversity and Conservation*, **12**, 121-146.

Woodcock, B. A., Westbury, D. B., Potts, S. G., Harris, S. J. & Brown, V. K. (2005). Establishing field margins to promote beetle conservation in arable farms. *Agriculture, Ecosystems & Environment*, **107**, 255-266.

9. Responses of epigeal beetles to the removal of weed cover crops in organic olive orchards

Responses of epigeal beetles to the removal of weed cover crops in organic olive orchards

Bulletin of Insectology Volume 62, Issue 1, June 2009, Pages 47-52

9.1 Abstract

The study was conducted in an experimental organically managed olive orchard to test the short-term effects exerted on epigeal coleopteran populations by the removal of the plant cover (RPC) when compared to non-managed natural plant cover (NPC). The changes in abundance and diversity of beetles were analysed in three experimental blocks in which the cover crop was removed during the first week of June in 2005. Pitfall traps and coleopteran family level were a reliable approach to achieve the aim of this study. Related to soil conservation, maintenance of covers can potentially decrease soil erosion risk, and traditional soil practices tend to diminish diversity and activity of the soil fauna. This survey showed that abundance as well as family richness and dominance were greater in uncovered soils RPC compared to control covered soils NPC. Therefore, after a rainfall period, some coleopteran families can be used as a quick assessment tool to evaluate effects of short-term disturbance (abiotic factor) on soil arthropod population. Beetle assemblage under vegetable cover seems to be more favourable. As a matter of fact weeds offer advantage (hospitable temperature and moisture) to beetles with respect to bare soils. Finally silvanids could be used as an indicator group of impact of agronomic practices applied to this soil in olive organic farming, since the removal of any kind of cover in olive orchards is an undesirable practice in terms of erosion protection and in terms of diversity conservation.

Key words: Coleopteran families, disturbance, biodiversity measure, pitfall trap, soil management.

9.2 Introduction

Soil management in olive farming can be employed in different ways, ranging from intensively managed arable land to sown or naturally covered soils. However, Spanish olive farmers routinely eliminate vegetation from soils as a fire prevention measure or out of tidiness (Pastor, 2004). These practices not only contradict the current recommendations of the regional government of Andalusia (Junta de Andalucía, 2002) to reduce erosion by keeping some kind of cover on soils but they also go against good agricultural practices of Cross Compliance of the European Union (Council Regulation No 1782/2003), arguing that covers in olive orchards can efficiently reduce run-off, making more water available to the crop (Rozmarynowska *et al.*, 2003). Soil studies in Andalusia have shown that most land has to cope with severe problems of erosion (Milgroom *et al.*, 2007; Sala *et al.*, 1991) and the practice of maintaining bare soil year-round, underneath and between olive trees is one of the main factors in the reduction of the organic matter content and the water-infiltration capacity of the soil (de Graaff & Eppink, 1999; Milgroom *et al.*, 2007). Intermittent severe thunderstorms during September and October cause an autumn peak in precipitation (Sumner *et al.*, 2001), making the issue of covered soils important. In this sense, several studies have been carried out in Andalusia to ascertain the current situation of the olive soils under different farming methods, showing that low impact techniques seem to be more common in the case of organic management (Parra López & Calatrava Requena, 2006). It is demonstrated that the shift to organic farming in olive orchards in some provinces can be accompanied by increased protection of the soil and lower erosion risk (Milgroom *et al.*, 2007), although the weed removal continues to be a widespread practice even in organic farming.

Low-intensity cropping systems have been related to a most favourable abundance and activity of beneficial ground-dwelling arthropod communities (Lundgren *et al.*, 2006). According to Guzmán & Alonso (2004), conventional soil practices tend to diminish diversity and activity of the soil fauna. Inventories at species level require an enormous amount of time and financial resources (Cardoso *et al.*, 2004; Wilkie *et al.*, 2003), mainly due to the necessity of taxonomist employment at previous stages of studies (Biaggini *et al.*, 2007). The use of higher taxa level is particularly useful when rapid biodiversity surveys are

required (Andersen, 1995; Oliver & Beattie, 1996). Coleopterans are one of the best represented arthropod orders, due to their contribution to pest control (Iperti, 1999; Kromp, 1999) or their role as a food source for farmland birds (Holland & Luff, 2000). As a result of their sensitivity, their reaction can be used to detect and identify the nature of disturbances or changes in environmental quality (Çilgi, 1994), as well as to predict the impact of disturbances (Bohac, 1999), therefore the beetle response can be considered as indicator (McGeoch, 1998). It is safe to say that epigeal coleopteran families (e.g. carabids and staphylinids) have often been used as indicator groups in agro-ecosystems biodiversity assessment (Biaggini *et al.*, 2007; Bohac, 1999; Woodcock *et al.*, 2006), and previous studies have already shown that soil beetles of olive orchards can be affected by the soil management (Castro *et al.*, 1996; González *et al.*, 2004; Morris & Campos, 1999). The effects of elimination of covers on the whole epigeal beetle community (carnivorous, detritivorous, herbivorous living directly on the ground) can be assessed by pitfall traps, although they are not selective (Adis, 1979; Spence & Niemelä, 1994), they passively collect organisms moving across the ground, and thus provide measures of activity rather than absolute density (Southwood, 1994). Pitfall traps are the best known and most often used inventory method in agroecosystems (Duelli *et al.*, 1999), even though they have already been used within the same issue of this study, arriving at an indication of habitat quality (Cole *et al.*, 2005; Krooss & Schaefer, 1998; Mossakowski & Paje, 1985; Perner & Malt, 2003).

This survey seeks to determine: (1) how weed cover and weed-management practices (mowing and removal) could influence on abundance and composition of epigeal beetle families in olive orchards; (2) how coleopterans can be used as a quick assessment tool to evaluate effects of short-term disturbance on soil arthropod population; and (3) which beetle family or families could be used as indicator groups of impact regarding the agronomic practices applied to this soil in olive organic farming.

9.3 Materials and methods

9.3.1 Design of the soil-cover management

Two soil treatments were compared, including a covered soil management (non-managed natural plant cover - NPC) and an uncovered soil management (removal of plant cover - RPC). In the NPC soil-treatment management, no crop was sown and the field was covered with the natural seed bank and roots of annual Gramineae (e.g. Bromus sp, Hordeum sp, and Diplotaxis sp) and finally, no herbicides were applied. In the RPC soil treatment, cover crop was managed by some agronomic practices during the first week of June 2005 as follows: (1) pre-sampling intervention consisted of passing a tine harrow over the dry remains of the cover trimmed by the mower; (2) remains were shredded and tilled into the soil to a depth of a few centimetres; (3) the litter and seed remained in the soil, though partially buried; and (4) the mower was applied four times until the remains were not visible on the soil's surface. Plant litter, including fallen leaves and fruits, were later gathered by hand under the canopy of olive trees. Four sampling times were carried out: 14, 30, 75 and 90 days after the removal of natural vegetation.

9.3.2 Field-experiment description

The study was conducted in a large olive-growing orchard in southern Spain, located at the coordinates of 37°51'38"N - 3°38'36"W. The organically managed orchard consisted of single-trunk olive trees (cv. Picual), with a crown diameter of 1.5-3 m, planted on 8 x 8 m.

A randomized complete block design was performed with two treatments, covered (NPC) and uncovered soils (RPC) grouped into three blocks. Within each isolated block, the conditions were as uniform as possible, but between blocks, marked differences existed. In the inline array of blocks the distance of separation between them was 0.5 km.

Each block, with 429 trees (88 x 312 m), consisted of two plots representing the two treatments. In each single plot, with 121 trees (88 x 88 m), a total number of 20 pitfall traps were set just below the canopy of 20 selected trees. The sampling unit consisted of a row of five trees separated by unsampled one, and each sampling unit was separated from the other by two unsampled rows of trees. Furthermore, rainfall data were collected from the three weather stations closest to the experimental orchard (maximum distance of 20 km) and the average precipitation was calculated for the whole sampling period (Figure 9.1).

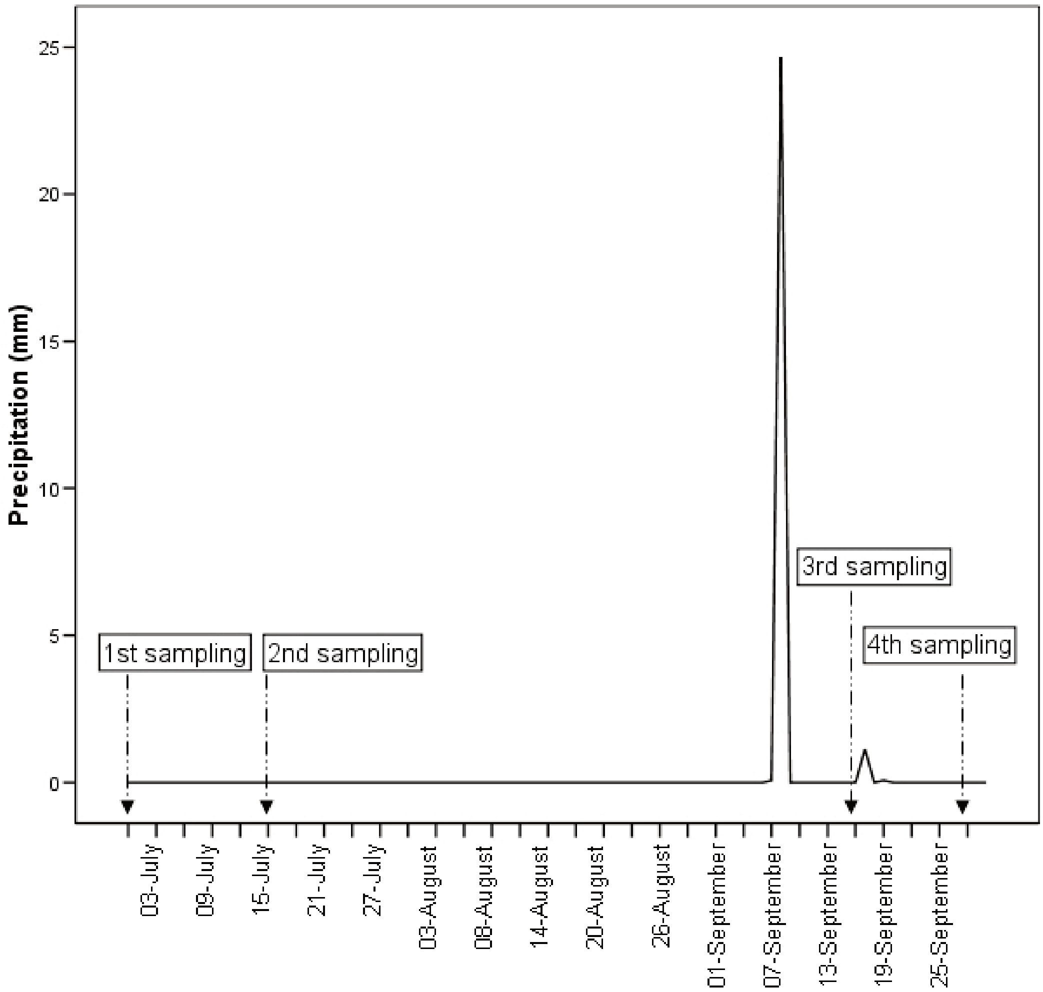


Figure 9.1: Precipitation (mm) values of the three nearest weather stations from the first to the last sampling.

9.3.3 Coleoptera collection

The epigeal beetles were collected in pitfall traps which were set on a north- facing site, consisting of glass cups 11 cm in diameter and set in the soil for 48 h. The pitfall traps were filled with Scheerpeltz liquid (60% ethanol 97º, 38% distilled water, 1% pure aceticacid, 1% glycerine).

Captured arthropods were separated from the vegetal and inorganic remains, and beetles were identified under a stereomicroscope (Stemi SV8, Zeiss) as to the taxonomic level of order and family.

For the assessment of Coleoptera diversity, the following measures were calculated: family richness, dominance and Hurlbert's PIE (probability of interspecific encounters) index. Family richness and dominance are the most commonly used facet of biodiversity (Purvis & Hector, 2000). The Hurlbert's PIE index indicates the probability of two individuals randomly sampled from the same population belonging to two different families. The indices were calculated by the program Ecosim 7.0 (Gotelli & Entsminger, 2001).

9.3.4 Statistical analysis

With five tree rows as the unit sampling size, a comparison was made between NPC and RPC in terms of total abundance, abundance of different families, as well as the diversity measures in each sampled period. After testing to confirm that the data did not have a normal distribution, a log transformation [Ln (y + 1)] was performed to normalize the data. The parametric Student's t-test for two independent groups was used to test for statistical differences among soil treatments and dates. In addition repeated measures MANOVA withinsubject factors (sampling period and soil treatment) was performed in order to analyze the most coleopteran families, using SPSS 15.0 for Windows.

Finally to visualize the results, a Principal Component Analysis (PCA) was performed to relate soil treatments and the abundance of the most abundant families. Calculations and resulting biplots were performed using XLStat (Addinsoft, 2004).

9.4 Results

The total number of specimens collected at the end of the sample periods was 348 in the NPC and 617 in RPC (966 beetles altogether). The abundance of collected beetles varied on a monthly basis, the highest numbers being captured in the last sampling, 90 days after the removal of the natural cover (Table 9.1).

The beetles were classified into 19 families, 18 of which being found in RPC and only 16 in NPC (Table 9.1).

The most abundant family was Tenebrionidae, accounting for over 50% of the total of captured beetles. Aphodiidae was the second most numerous family (18% of the beetles collected), followed by Silvanidae (10%), Anthicidae (5%), Carabidae (4%), Curculionidae (3%), Cucujidae and Staphylinidae (1%). The 11 remaining families accounted for over 4% of the total of captured beetles (Table 9.1).

Regarding sampling dates, 15 and 30 days after the removal of natural cover, the number of individuals increased significantly in RPC (first sampling: t = ˜5.47, gl = 22, *P* < 0.0001; second sampling: t = ˜2.82, gl = 22, *P* < 0.05). This increase was due mainly to silvanid beetles, which were positively influenced by the elimination of covers. Silvanidae specimens were mainly captured during the two first samplings and presented significant differences with regard to sampling at 14 days (t = ˜4.85, gl = 22, *P* < 0.001) and sampling at 30 days (t = ˜2.82, gl = 13.4, *P* < 0.05). In the third trapping, the number of beetles decreased suddenly in RPC but increased in NPC. In this period aphodiid beetles, which started to become active in September in the olive orchard, were significantly more abundant in NPC (t = 2.96, gl = 22, *P* < 0.05), indicating that they preferred covered soils. Finally, in the last trapping, RPC values peaked due to an increase in tenebrionid beetles; this family showed significant differences 90 days after the removal of natural cover (t = ˜2.29, gl = 22; *P* < 0.05), the number of specimens being favoured by this fact. After running the repeated measures MANOVA procedure, the six most abundant families (Tenebrionidae, Aphodiidae, Silvanidae, Anthicidae, Carabidae and Curculionidae) were analyzed, obtaining different significances for the 2 within-subject factors (sampling period and soil treatment).

Table 9.1: Mean and standard deviation (SD) of total abundance, family abundance and diversity measures of beetles captured in natural plant covered (NPC) and in removal plant covered (RPC) over time.

		14 days	30 days	75 days	90 days
FAMILY	Treatment	Mean± SD	Mean± SD	Mean± SD	Mean± SD
Tenebrionidae	NPC	0.06± 0.20	0.17± 0.31	0.12± 0.27	1.87± 1.17
	RPC	0.35± 0.55	0.39± 0.50	0.26± 0.41	2.87± 0.95
Aphodiidae	NPC	0	0	1.62± 0.67	1.35± 0.96
	RPC	0	0	0.75± 0.77	1.18± 0.72
Silvanidae	NPC	0.31± 0.51	0.17± 0.31	0	0
	RPC	1.40± 0.58	0.98± 0.94	0.06± 0.20	0
Anthicidae	NPC	0.51± 0.56	0.57± 0.65	0	0
	RPC	0.24± 0.45	0.81± 0.68	0	0.12± 0.27
Carabidae	NPC	0.12± 0.27	0.17± 0.31	0.12± 0.27	0.12± 0.27
	RPC	0.48± 0.58	0.51± 0.60	0.12± 0.27	0.15± 0.36
Curculionidae	NPC	0.09± 0.32	0	0.12± 0.27	0.12± 0.27
	RPC	0.46± 0.66	0.26± 0.41	0.15± 0.36	0.23± 0.34
Cucujidae	NPC	0.12± 0.27	0	0	0
	RPC	0.29± 0.46	0.23± 0.34	0	0
Staphylinidae	NPC	0	0.12± 0.27	0.12± 0.27	0
	RPC	0.21± 0.39	0.06± 0.20	0	0.06± 0.20
Scraptiidae	NPC	0.12± 0.27	0.21± 0.39	0	0
	RPC	0.12± 0.27	0	0	0
Anobiidae	NPC	0.06± 0.20	0	0	0.06± 0.20
	RPC	0.06± 0.20	0.12± 0.27	0	0.12± 0.27
Cetoniidae	NPC	0	0.06± 0.20	0	0
	RPC	0.23± 0.45	0	0	0
Cryptophagidae	NPC	0	0	0	0
	RPC	0.06± 0.20	0	0.06± 0.20	0
Histeridae	NPC	0	0	0.06± 0.20	0
	RPC	0	0	0	0.09± 0.32
Byrrhidae	NPC	0	0	0	0
	RPC	0.06± 0.20	0	0.06± 0.20	0
Coccinellidae	NPC	0.06± 0.20	0	0	0
	RPC	0	0.06± 0.20	0	0
Dermestidae	NPC	0	0.12± 0.27	0	0
	RPC	0	0	0	0
Chyrsomelidae	NPC	0	0	0	0
	RPC	0	0	0	0.06± 0.20
Nitidulidae	NPC	0	0	0.12± 0.27	0
	RPC	0	0.06± 0.20	0.06± 0.20	0.06± 0.20
Laemophloeidae	NPC	0	0.06± 0.20	0	0
	RPC	0	0	0	0.06± 0.20
Average of total abundance	NPC	1.13± 0.44	1.06± 0.79	1.82± 0.52	2.40± 1.02
	RPC	2.13± 0.45	1.93± 0.71	1.11± 0.81	3.05± 0.93
Family Richness	NPC	5,00±1,00	6,50±0,71	4,67±0,58	3,67±1,15
	RPC	8,67±1,53	7,33±1,53	4,33±2,08	6,67±2,08
PIE Hurlbert´s index	NPC	0,83±0,14	0,77±0,16	0,30±0,07	0,46±0,18
	RPC	0,75±0,13	0,79±0,07	0,58±0,38	0,28±0,13
Dominance	NPC	0,36±0,09	0,45±0,20	0,84±0,04	0,68±0,18
	RPC	0,43±0,19	0,40±0,03	0,60±0,30	0,83±0,10

On the one hand, the sampling period significantly contributed to the model in the case of the case of Tenebrionidae (F = 9.66, $P < 0.0001$), Aphodiidae (F = 15.54, $P < 0.0001$), Silvanidae (F = 11.21, $P < 0.0001$) and Anthicidae (F = 10.62, P < 0.0001), while the same kind of treatment contributed only in Aphodiidae (F = 6.15, $P < 0.05$), Silvanidae (F = 44.41, $P < 0.0001$) and Curculionidae (F = 15.63, $P < 0.05$). On the other hand, the interaction between sampling period and soil treatment showed to contribute to the model only in silvanids (F = 6.28, $P < 0.05$).

In order to find a better representation of the six most abundant families and soil treatment, a PCA was performed to establish the relationship between these data, with a total explained variance of 70.60% (Figure 9.2). Axis 1 (39.30% of the variance) represents the family data, covered sampling units in the left corners, and uncovered sampling units in the right corners. As the PCA shows, the removal of the plant cover is related to the presence of silvanids, tenebrionids, and to a lesser extent of curculionids, anthicids and carabids, while the presence of non-managed vegetation in soils seems to favor the presence of aphodiids.

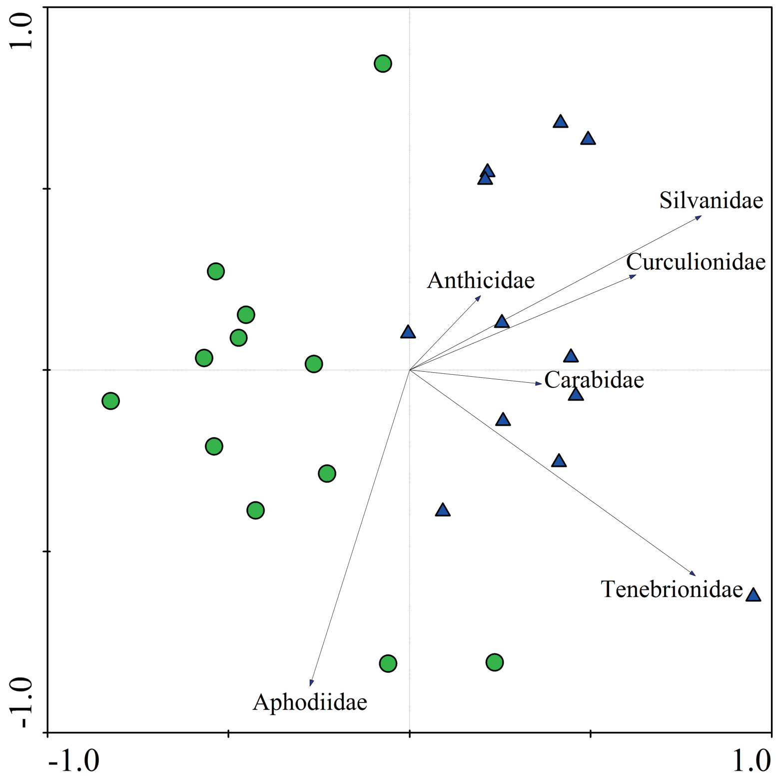


Figure 9.2. Principal Components Analysis (PCA) of covered (green circles) and uncovered sampling units (blue triangles) and the most abundant families of all sampling periods.

With regard to the diversity measures (Table 9.1), during the first two samplings, 14 days after the removal of vegetation, higher family richness and dominance were found in RPC than in NPC, although in the second sampling, the values tended to become similar. As with the abundance, a different trend was found in the third sampling, since higher family richness and dominance were found in NPC and, only 15 days later (fourth sampling), both richness and dominance again became higher in the RPC. However, no diversity measures showed significant differences among treatments over time.

With regard to precipitation, a few days before the third sampling (8 September), heavy rainfalls were registered (Figure 9.1). Flash storms, even for a few days, can be considered as an erosive factor in bare-soil areas.

9.5 Discussion

The removal of the natural cover (RPC) increased the abundance, family richness, and dominance of epigeal beetles with a significant tendency in the samplings, except for the third sampling period. Therefore, this managed cover instead of non-managed natural cover proved to have some effect on epigeal beetle populations in olive orchards. These effects are evident even over a short-term after the removal. From the results, three situations can clearly be identified. Firstly, 30 days after the removal of the cover (14 July), families such as Silvanidae, which primarily feed on seeds, were encouraged to further explore the open space and as a result found more food, or better climatic conditions and, although richness and abundance increased, the dominance was also higher in bare soils. However, 70 days after removal of covers (14 September), beetle diversity, richness, and abundance suddenly decreased in RPC, while the abundance remained high and even increased in NPC. Precipitation could have had a dramatic impact on beetle communities in RPC. In this sense, aphodiid beetles (strictly coprophagous) appeared to be the most sensitive group to rainfall and due to the lack of cover, they were much more abundant in NPC. The soil surface without vegetation did not offer any shelter and beetles had to take refuge in other places, resulting in more unstable beetle assemblages in uncovered soils. Nearly 20 days after the rainfall (last sampling), beetle abundance and dominance

was higher in RPC. Tenebrionids, detritivorous beetles, were the group most significantly abundant in the last period, favoured by the elimination of weeds. The polyphagous families: anthicids and curculionids, as well as the predatory family carababid were favoured by the removal of vegetation, although less numerous than tenebrionids, silvanids and aphodiids, which predominantly seemed to be more related to uncovered soils. There is evidence that soil biodiversity confers stability to stress and disturbance (Brussaard *et al.*, 2007), and resistance and resilience appeared to be greater in beetles assemblages in NPC, given that they continued to increase in abundance. Meanwhile, after a rainfall period, RPC values abruptly declined. As discussed above, harvesting and mowing of vegetation significantly alter the microclimate, particularly soil-surface temperatures, and this can affect beetle assemblages, which are sensitive to microclimatic and soil moisture (Perner & Malt, 2003). Consequently, beetles in RPC responded to these changing parameters, making the response of beetle assemblage or some beetle families a quick assessment tool for changes in the agroecosystems.

From the significance tests, silvanids were significantly different keeping into account the interaction between sampling period and soil treatments. The fact that the abundance of the captured silvanids was significantly different over the sampling periods, this family becomes a possible indicator group of impact on soils. Nowadays, carabids and staphylinids are being proposed as indicators groups to assess the soil health, because they are predators and abundant in soils. However, several studies show that their populations are favoured by non-managed soils (Andersen, 1999; Castro *et al.*, 1996; Fereres, 1997; Marasas *et al.*, 2001). In the case of olive orchards higher carabid population was related with higher intensity of soil agronomic practices (Castro *et al.*, 1996), but in our study coinciding with others (González *et al.*, 2004), they represent a small part of the total captured beetles.

9.6 Conclusion

This study shows that the removal of the natural cover (RPC) in organic olive orchards augmented the abundance, richness and dominance of epigeal

beetle families captured by pitfall traps (tenebrionids and silvanids). Although an abrupt decrease in primarily tenebrionid abundance might be caused by abiotic factors such as a thunderstorm, a quick assessment tool could be used to evaluate effects of short-term disturbance on soil arthropod in RPC. Silvanid could be used as an indicator group of impact of this soil agronomic practice in olive organic farming, since the removal of any kind of cover in olive orchards is an undesirable practice in terms of erosion protection and in terms of diversity conservation.

9.7 References

Addinsoft. (2004). XLstat for excel, version 7.5. 7.5 ed, Addinsoft. New York.

Adis, J. (1979). Problems of interpreting arthropods sampling with pitfall traps. *Zoologischer Anzeiger,* **202**, 177-184.

Andersen, A. (1999). Plant protection in spring cereal production with reduced tillage. II. Pests and beneficial insects - a five-year study on the rove beetle fauna (Coleoptera: Staphylinidae) of winter wheat. *Crop Protection*, **18**, 651-657.

Andersen, A. N. (1995). Measuring more of biodiversity: Genus richness as a surrogate for species richness in Australian ant faunas. *Biological Conservation*, **73**, 39-43.

Biaggini, M., Consorti, R., Dapporto, L., Dellacasa, M., Paggetti, E. & Corti, C. (2007). The taxonomic level order as a possible tool for rapid assessment of Arthropod diversity in agricultural landscapes. *Agriculture, Ecosystems & Environment*, **122**, 183-191

Bohac, J. (1999). Staphylinid beetles as bioindicators. *Agriculture, Ecosystems & Environment*, 74, 357-372.

Brussaard, L., de Ruiter, P. C. & Brown, G. G. (2007). Soil biodiversity for agricultural sustainability. *Agriculture, Ecosystems & Environment*, **121**, 233-244.

Cardoso, P., Silva, I., de Oliveira , N. G. & Serrano, A. R. M. (2004). Higher taxa surrogates of spider (Aranea) diversity and their efficiency in conservation. *Biological Conservation*, **117**, 453-459.

Castro, J., Campos, P. & Pastor, M. (1996). Influencia de los sistemas de cultivo empleados en olivar y girasol sobre la composición de la fauna de artrópodos en el suelo. *Boletín Sanidad Vegetal: Plagas*, **22**, 557-570.

Çilgi, T. (1994). Selecting arthropod "indicator species" for environmental impact assessment of pesticides in field studies. *Aspects of Applied Biology*, **37**, 131-140.

Cole, L. J., McCracken, D. I., Downie, I. S., Dennis, P., Foster, G. N., Waterhouse, A., Murphy, K. J., Griffen, A. L. & Kennedy, M. P. (2005). Comparing the effects of farming practices on ground beetle (Coleoptera: Carabidae) and spider (Araneae) assemblages on Scottish farmland. *Biodiversity & Conservation*, **14**, 441-460.

de Graaff, J. & Eppink, L. A. A. J. (1999). Olive oil production and soil conservation in southern Spain, in relation to EU subsidy policies. *Land Use Policy*, **16**, 259-267.

Duelli, P., Obrist, M. K. & Schmatz, D. R. (1999). Biodiversity evaluation in agricultural landscapes: above-ground insects. *Agriculture, Ecosystems & Environment*, **74**, 33-64.

Fereres, A. (1997). Control de insectos-plaga en el laboreo de conservación. In *Laboreo de Conservación, una agricultura mejor para el medio ambiente*, eds. L. García Torre & P. González Fernández, Sociedad Española de Laboreo de Conservación. Córdoba, pp. 144-155.

González, F., Rodríguez, E., Fernández, F., Civantos, M. & Campos, M. (2004). Influencia del manejo del suelo en las poblaciones de artrópodos en el cultivo del olivo. In *III Jornadas Técnicas del Aceite de Oliva*, INIA. Madrid.

Gotelli, J. & Entsminger, G. L. (2001). EcoSim: Null models software for ecology. 7.0. ed, Acquired Intelligence Inc. & Kesey-Bear. Jericho.

Guzmán, G. & Alonso, A. (2004). Manejo del suelo en el olivar ecológico. In *Manual de Olivicultura ecológica,* Vol. II, Universidad de Córdoba. Córdoba, pp. 27-51.

Holland, J. M. & Luff, M. L. (2000). The Effects of Agricultural Practices on Carabidae in Temperate Agroecosystems. *Integrated Pest Management Reviews*, **5**, 109-129.

Iperti, G. (1999). Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture, Ecosystems & Environment*, **74**, 323-342.

Junta de Andalucía (2002). Orden de 18 de julio de 2002, por la que se aprueba el Reglamento Específico de Producción Integrada de Olivar. Consejería de Agricultura y Pesca, B.O.J.A. nº 88, 27 de julio.

Kromp, B. (1999). Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems & Environment*, **74**, 187-228.

Krooss, S. & Schaefer, M. (1998). The effect of different farming systems on epigeic arthropods: a five-year study on the rove beetle fauna (Coleoptera: Staphylinidae) of winter wheat. *Agriculture, Ecosystems & Environment*, **69**, 121-133.

Lundgren, J. G., Shaw, J. T., Zaborski, E. R. & Eastman, C. E. (2006). The influence of organic transition systems on beneficial ground-dwelling arthropods and biological control of insects and weed seeds. *Renewable Agriculture and Food Systems*, **21**, 227-237.

Marasas, M. E., Sarandón, S. J. & Cicchino, A. C. (2001). Changes in soil arthropod functional group in a wheat crop under conventional and no tillage systems in Argentina. *Applied Soil Ecology*, **18**, 61-68.

McGeoch, M. A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, **73**, 181-201.

Milgroom, J., Soriano, M. A., Garrido, J. M., Gómez, J. A. & Fereres, E. (2007). The influence of a shift from conventional to organic olive farming on soil management and erosion risk in southern Spain. *Renewable Agriculture and Food Systems*, **22**, 1-10.

Morris, T. I. & Campos, M. (1999). Entomofauna depredadora del suelo del olivar. *Zoologia baetica*, **10**, 149-160.

Mossakowski, D. & Paje, F. (1985). Ein Bewertungsverfahren von Raumeinheiten an Hand der Carabidenbestände. *Verhandlungen der Gesellschaft für Ökologie,* **13**, 747-750.

Oliver, I. & Beattie, A. J. (1996). Designing a cost-effective invertebrate survey: A test of methods for rapid assessment of biodiversity. *Ecological Applications,* **6**, 594-607.

Parra López, C. & Calatrava Requena, J. (2006). Comparison of farming techniques actually implemented and their rationality in organic and conventional olive groves in Andalusia, Spain. *Biological Agriculture & Horticulture,* **24**, 35-59.

Pastor, M. (2004). Sistemas de manejo del suelo. In *El cultivo del olivo*, Barranco, D., Fernandez-Escobar, R., Rallo, T. España, pp. 231-285.

Perner, J. & Malt, S. (2003). Assessment of changing agricultural land use: response of vegetation, ground-dwelling spiders and beetles to the conversion of arable land into grassland. *Agriculture, Ecosystems & Environment*, **98**, 169-181.

Purvis, A. & Hector, A. (2000). Getting the measure of biodiversity. *Nature*, **405**, 212-219.

Rozmarynowska, D., Najmanova, K., Latorre, M. & Duteau, M. (2003). *Improving the Environment Through CAP Reform. With a special focus on olive production.* Centre for Environmental Studies, 90 pp.

Sala, M., Rubio, J. L. & García-Ruíz, J. M. (1991). *Soil Erosion Studies in Spain*. Geoforma Ediciones, Logroño, 228 pp.

Southwood, T. R. E. (1994). *Ecological Methods - With particular reference to the study of insect populations.* 2nd ed, London, New York, 524 pp.

Spence, J. R. & Niemelä, J. K. (1994). Sampling carabid assemblages with pitfall traps: the madness and the method. *The Canadian entomologist*, **126**, 881-894.

Sumner, S., Homar, V. & Ramis, C. (2001). Precipitation seasonality in eastern and southern coastal Spain. *International Journal of Climatology*, **21**, 219-247.

Wilkie, L., Cassis, G. & Gray, M. R. (2003). A quality control protocol for terrestrial invertebrate biodiversity assessment. *Biodiversity and Conservation*, **12**, 121-146.

Woodcock, B. A., Lawson, C. S., Mann, D. J. & McDonald, A. W. (2006). Effects of grazing management on beetle and plant assemblages during the re-creation of a flood-plain meadow. *Agriculture, Ecosystems & Environment*, **116**, 225-234.

10. Discusión general

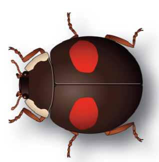
10. Discusión general

La evaluación de la entomofauna en el agroecosistema del olivar es considerada en este trabajo de Tesis como un método que puede llegar a comparar distintos tipos de manejo agronómico, ya que está asociada a cambios en los usos agrícolas. Con el indicador apropiado y teniendo en cuenta el tipo de manejo, la estructura del paisaje y los usos del suelo en el olivar andaluz, es posible comparar olivares con diferente intensificación y determinar cuál es el más sostenible, en aras de conseguir un método rápido y fiable para poder certificar cultivos que muestran un manejo más respetuoso con el medio ambiente.

Así, basado en un periodo de muestreo de tres años en los olivares de la provincia de Granada, se han encontrado grupos de insectos indicadores del tipo de manejo. Los resultados obtenidos a distintos niveles taxonómicos han determinado la época de postfloración (junio) como el periodo óptimo de muestreo para poder señalar algunos grupos de insectos indicadores presentes en la copa de los olivos.

Paisaje como factor

Puesto que cualquier indicador es dependiente del factor espacial (Moreno *et al.*, 2007), se propuso una mayor escala geográfica mediante la incorporación de la provincia de Córdoba al estudio. Se observaron diferencias en cuanto a la diversidad y abundancia de los insectos en varios niveles taxonómicos entre ambas provincias, lo cual puede ser debido a que la provincia de Granada presenta una mayor intensificación agrícola, la cual determina una disminución de la biodiversidad en los agroecosistemas (Chamberlain *et al.*, 2000), aunque también otros elementos biogeográficos deben estar actuando sobre la misma. Estas diferencias hicieron que no se pudieran aplicar los indicadores encontrados en Granada a la provincia de Córdoba, poniendo de manifiesto la complejidad de las comunidades de artrópodos asociadas a los cultivos, las cuales están determinadas por factores biológicos, socio-culturales y ambientales (Liss *et al.*, 1986). Profundizando en este aspecto, se propuso comparar el grado de intensificación agrícola de ambas provincias, teniendo en cuenta el tipo de



manejo, la estructura del paisaje y los usos del suelo como sugiere Firbank *et al.* (2008). Los diferentes descriptores del paisaje reflejan niveles de conservación y han sido usados para verificar las hipótesis que unen los efectos de la estructura del paisaje con la diversidad de insectos (Wiens & Milne, 1989). Mediante el manejo de la información cartográfica con los sistemas de información geográfica ha sido posible calcular el índice de Hemerobia (Jalas, 1955). Este índice, además, de ser una herramienta innovadora y útil para estudiar la heterogeneidad de paisaje en el olivar, ha servido para evaluar la influencia del tipo de manejo, estructura del paisaje y usos del suelo sobre la entomofauna del olivar. Así se ha determinado que altos valores del índice están asociados a paisajes con manejos agronómicos menos sostenibles con alta intensificación agrícola como ocurre en la provincia de Granada, frente a más bajos valores de Hemerobia en la zona de Córdoba (Valle de los Pedroches), donde las explotaciones son manejadas bajo criterios ecológicos (Alonso *et al.*, 2001).

Tipo de manejo agronómico como factor

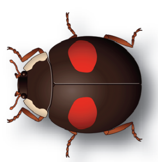
En cuanto a los tres sistemas de manejo: ecológico, integrado y convencional, no ha sido posible establecer una clara diferencia entre prácticas agronómicas asociadas a cada uno de ellos. Aunque algunas prácticas son de aplicación obligatoria, otras son meras recomendaciones por lo que se aplican a elección del agricultor, que puede incluso, llevarlas a cabo según su criterio. En la provincia de Granada se ha demostrado que algunas parcelas cercanas a pesar de estar sometidas al mismo tipo de manejo no mostraban la misma composición de insectos, lo cual podría ser debido no sólo a factores climáticos, sino también a cambios en las prácticas agronómicas. Por ello, éstas fueron evaluadas en función de su presencia o ausencia, pudiendo confirmar individualmente como cada una de ellas condicionaban la abundancia y diversidad de insectos a diferentes niveles taxonómicos.

Entomofauna como indicadora: Órdenes de insectos en la copa

En cuanto a los insectos capturados en los olivos, fueron estudiados, por un lado los insectos presentes en las copas y por otro los capturados en el suelo, con el fin de evaluar los distintos tipos de manejos. La entomofauna fue estudada a nivel taxonómico de orden buscando el método más rápido y sencillo para determinar los grupos indicadores sin tener que recurrir a especialistas o claves taxonómicas complejas. Según Moreno *et al.* (2007) este tipo de selección de grupo indicador tiene como inconvenientes por un lado, la dependencia del tipo de región con el grupo biológico en cuestión, y por otro la sistemática de los grupos (sobre todo invertebrados) que cambia constantemente haciendo difícil la identificación de muchos individuos. Al valorar la posibilidad de utilizar un orden o varios órdenes de insectos como indicadores del tipo de manejo en olivar, al menos a escala local, a pesar de las diferencias entre provincias, ya mencionadas, un alto número de parcelas pudieron ser clasificadas entre ecológicas y no ecológicas (integrado y convencional). Mediante una función discriminante, usando abundancias totales de coleópteros y hemípteros muestreados durante postfloración (junio) no todas las parcelas ecológicas de Granada fueron bien clasificadas, debido a la baja presencia de coleópteros en las mismas. Sin embargo mediante otra función discriminante (incluyendo coleópteros, hemípteros, lepidópteros y algodoncillo) eran clasificadas claramente tres grandes grupos: (1) parcelas ecológicas de Granada, (2) no ecológicas de Granada y (3) todas las parcelas de Córdoba. Por lo tanto, los tipos de manejo en Córdoba son difíciles de diferenciar usando los insectos a nivel de orden, cuando se comparan con los de la provincia de Granada, aunque la mayoría de las parcelas sí pudieron ser clasificadas según el tipo de manejo teniendo en cuenta algunos órdenes de insectos.

Entomofauna como indicadora: Familias de coleópteros en la copa

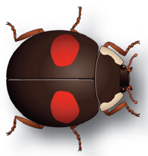
Se ha descrito cierta correlación entre taxones sustitutivos y taxones inferiores (Cardoso *et al.*, 2004), lo que condujo a la propuesta de indicadores a niveles taxonómicos más bajos buscando un indicador compatible para las dos provincias. El orden elegido para ser estudiado a nivel de familia fue el de los coleópteros, ya que discriminó los tipos de manejo en el olivar con una mayor contribución en la función discriminante que el de los hemípteros; además, es el orden más abundante en la copa de los olivos y ha sido ya utilizado en otros



estudios como indicador (Bohac, 1999; Çilgi, 1994; McGeoch, 1998). Como ocurrió al estudiar el nivel de orden, también la abundancia total de las familias de coleópteros capturados en la provincia de Granada fue mayor en las parcelas ecológicas, mientras que en Córdoba no se vieron diferencias entre parcelas ecológicas y no ecológicas. El siguiente paso fue la descripción de la evolución temporal en la abundancia de las diferentes familias de coleópteros teniendo en cuenta las prácticas agronómicas, así como la estructura del paisaje basándonos en el índice de Hemerobia. Los resultados mostraron una alta diversidad de familias representadas principalmente por Coccinellidae, Scraptiidae, Chrysomelidae, Curculionidae y Apionidae. Al analizar la respuesta de las diferentes familias frente a las prácticas agronómicas y a la heterogeneidad del paisaje, mediante estadística multivariante, se observó que un mayor número de familias estaban asociadas a prácticas agronómicas más sostenibles, como presencia de cubiertas vegetales, etc. Por el contrario el uso de herbicidas y plaguicidas estaba negativamente correlacionado con la abundancia de la mayoría de las familias de coleópteros a excepción de las familias Anthicidae y Staphylinidae.

Entomofauna como indicadora: Morfoespecies de coccinélidos en la copa

El uso del nivel de familia de coleópteros dio buenos resultados, indicando las prácticas agronómicas frente a las que respondían las diferentes familias existentes en las copas de los olivos. Sin embargo, la ecología de las familias de coleópteros es muy diversa y las respuestas obtenidas muy diferentes para las dos provincias, por lo que se planteó, con el objetivo de buscar el mejor indicador del tipo de manejo, la posibilidad de utilizar otros niveles taxonómicos más bajos como es el de morfoespecie de coccinélidos. Esta familia fue escogida por ser la más abundante en la copa de los olivos en diferentes regiones (Ba M'hamed & Chemseddine, 2002; Cirio, 1997; Ruano *et al.*, 2001; Santos *et al.*, 2007; Varela & González, 1999) y por cumplir muchas de las características necesarias para ser un buen indicador (Iperti, 1999). La identificación a nivel de morfoespecie supone una reducción temporal y económica (Ward & Stanley, 2004) y en el caso de la provincia de Granada, para un periodo bianual, esta taxonomía sustitutiva permitió



diferenciar tipos de manejo (Cotes *et al.*, 2009). La fiabilidad del uso de morfoespecies de coccinélidos se demostró por la existencia de una relación entre especie-morfoespecie, prerrequisito que ha de cumplir un taxón sustitutivo (Moreno *et al.*, 2007).

Coccinélidos y la influencia del paisaje

Puesto que la configuración y la existencia de ciertas estructuras en el paisaje influencian la composición de las comunidades de coccinélidos (Iperti, 1999), se decidió describir las agrupaciones presentes en las dos regiones estudiadas. Concretamente se determinó que *Sc. mediterraneus* y *P. luteorubra* están favorecidas por grandes extensiones de olivar ecológico y por la presencia de bosques de quercíneas (caso de la provincia de Córdoba), mientras que *C. septempunctata* y *H. variegata* están positivamente influenciadas por zonas de frutales de secano y superficies de olivar no ecológico (caso de la provincia Granada).

En resumen y en relación con los insectos de copa en olivar, se ha determinado que éstos pueden indicar fiablemente el manejo ecológico, incluso recurriendo a altos taxones, coincidiendo con los resultados obtenidos en trabajos previos (Ruano *et al.*, 2004).

Entomofauna como indicadora: Órdenes de insectos, familias de coleópteros y morfoespecies de carábidos en el suelo

Cuando los insectos del suelo fueron evaluados en la provincia de Granada y Córdoba, el nivel de orden fue el nivel taxonómico que mejor clasificó las parcelas con manejo ecológico y no ecológico, comparativamente frente a los resultados obtenidos para las familias de coleópteros y las morfoespecies de carábidos. Según algunos estudios (Bengtsson *et al.*, 2005), los depredadores aumentan su abundancia bajo prácticas más sostenibles en los agroecosistemas. Sin embargo en este estudio se observó que determinados depredadores presentes en el suelo, como los carábidos y los estafilínidos, cuando eran estudiados por un periodo anual en la provincia de Granada, fueron más abundantes en las parcelas ecológicas, mientras que cuando eran analizados sólo durante prefloración y postfloración el efecto fue el contrario en esta provincia. Por tanto, también los periodos de estudio son determinantes a la hora de conocer cómo afectan las prácticas agronómicas a determinados grupos de insectos. Otras investigaciones llevadas a cabo en el olivar han relacionado grandes poblaciones de carábidos con alta intensidad de manejo en el suelo (Castro *et al.*, 1996), mientras que en otras se ha relacionado el aumento de las poblaciones con la presencia de cubiertas vegetales (Morris *et al.*, 1999). Sin embargo el estudio de las comunidades de carábidos en suelo, a pesar de su popularidad como indicadores (Kromp, 1999), queda condicionado por su demostrada dependencia de la heterogeneidad del paisaje (Brose, 2003; Martins da Silva *et al.*, 2008), la necesidad de grandes diferencias entre los manejos que se comparen (Döring *et al.*, 2003; Duelli & Obrist, 1998), así como los tipos de suelo (Irmler, 2003). Por todo lo anterior y a la vista de nuestros resultados, parece compleja la evaluación de la entomofauna de suelo en el olivar, teniendo en cuenta la complejidad de factores que actúan sobre los organismos epígeos.

Efecto de la cubierta sobre los coleópteros epigeos

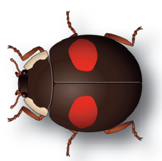
Puesto que el efecto de los manejos sobre la entomofauna es difícil de evaluar dada la complejidad en las comunidades de insectos, se realizó un estudio para observar cómo una práctica agronómica (eliminación de la cubierta vegetal) podía afectar a los coleópteros de suelo en una parcela con manejo ecológico. Se observó un incremento en la abundancia, riqueza y dominancia de las familias de los coleópteros presentes en el suelo, lo que indica su frágil equilibrio ante una pequeña perturbación. Es sabido que el manejo de cualquier cubierta vegetal altera el microclima, particularmente las temperaturas de la superficie, lo que puede afectar a las comunidades de coleópteros en el suelo (Perner & Malt, 2003).

Agrodiversidad, prácticas agronómicas y paisaje

Muchos estudios analizan la riqueza y la abundancia de especies u otros taxones en relación con el tipo de manejo aplicado a los cultivos (Álvarez *et al.*, 2000; Bengtsson *et al*., 2005; Cárdenas, 2008; Döring *et al*., 2003; Fan *et al*., 1993; Jackson *et al*., 2007; Letourneau & Goldstein, 2001; Purtauf *et al*., 2005) y, en la mayoría de los casos, se ha determinado que la agricultura ecológica tiene efectos positivos sobre la abundancia y la riqueza de los diferentes taxones estudiados, pero estos efectos difieren entre grupos de organismos y paisajes (Bengtsson *et al*., 2005). Además en una amplia escala geográfica, la estructura del paisaje y la heterogeneidad también afectan a la diversidad en los agroecosistemas (Benton *et al*., 2003; Burel *et al*., 1998; Dauber *et al*., 2003; Fahrig & Jonsen, 1998; Krebs *et al*., 1999 ; Marino & Landis, 1996; Weibull *et al*., 2000). En el caso del olivar, los resultados obtenidos indican que la abundancia de los órdenes de insectos fue mayor en todas las parcelas ecológicas de las dos provincias, pero la abundancia y diversidad de familias de coleópteros sólo fue mayor en parcelas ecológicas de Granada. De acuerdo con el estudio de Bengtsson *et al*. (2005), se ha observado que los efectos positivos del manejo ecológico en el olivar sobre la diversidad y abundancia de algunos taxones pueden también ser esperados en extensas zonas olivareras cultivadas bajo criterios no ecológicos como ocurre en la provincia de Granada, mientras que no necesariamente en paisajes compuestos por pequeños mosaicos que alternan parcelas agrícolas y zonas no cultivadas, como ocurre en la provincia de Córdoba. Por tanto, el diseño y la escala de estudio sugiere que una amplia región en la que el paisaje circundante es un factor a tener en cuenta en la determinación de indicadores, la variabilidad en la diversidad y abundancia de insectos se debe sólo parcialmente a las diferentes prácticas agronómicas, siendo incluso en algunos casos variables predictoras secundarias (Weibull *et al*., 2000; Weibull *et al*., 2003).

Los resultados obtenidos han puesto de manifiesto que tanto las prácticas agronómicas como la estructura del paisaje juegan un papel importante sobre las comunidades de insectos presentes en el olivar.

Así, la posibilidad de buscar grupos de insectos como indicadores del tipo de manejo en el olivar andaluz, pasa por reconocer la heterogeneidad de paisajes de olivar existentes en este territorio, los cuales han sido ya descritos en detalle desde varios puntos de vista (Guzmán Álvarez, 2004). Por tanto encontrar un grupo "universal" de insectos indicadores para todos los olivares es una tarea compleja, a la vista de los resultados. Sin embargo mediante la caracterización de los



diferentes tipos de paisaje existentes en el olivar andaluz y extender el estudio de la entomofauna a todos estos tipos de olivar, podría dar lugar a la determinación de los grupos indicadores para cada paisaje.

10.1 Bibliografía

Alonso, A., Sevilla, E., Jiménez, M. & Guzmán, G. (2001). Rural Development and Ecological Management of Endogenous Resources. The Case of Mountain Olive Tree in Los Pedroches Comarca (Spain). *Journal of Environmental Policy & Planning*, **3**, 163-175.

Álvarez, T., Frampton, G. K. & Goulson, D. (2000). Epigeic Collembola in winter wheat under organic, integrated and conventional farm management regimes. *Agriculture, Ecosystems & Environment*, **83**, 95-110.

Ba M'hamed, T. & Chemseddine, M. (2002). Selective toxicity of some pesticides to *Pullus mediterraneus* Fabr. (Coleoptera: Coccinellidae), a predator of *Saissetia oleae* Bern. (Homoptera: Coccoidea). *Agricultural and Forest Entomology*, **4**, 173-178.

Bengtsson, J., Ahnström, A. C. & Weibull, J. (2005). The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology*, **42**, 261-269.

Benton, T. G., Vickery, J. A. & Wilson, J. D. (2003). Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution*, **18**, 182-188.

Bohac, J. (1999). Staphylinid beetles as bioindicators. *Agriculture, Ecosystems & Environment*, **74**, 357-372.

Brose, U. (2003). Regional diversity of temporary wetland carabid beetle communities: a matter of landscape features or cultivation intensity?. *Agriculture, Ecosystems & Environment*, **98**, 163-167.

Burel, F., Baudry, J., Butet, A., Clergeau, P., Delettre, Y., Le Couer, D., Dubs, F., Morvan, N., Paillat, G., Petit, S., Thenail, C., Brunel, E. & Lefeuvre, J. C. (1998). Comparative biodiversity along a gradient of agricultural landscapes. *Acta Oecologica*, **19**, 47-60.

Cárdenas, M. (2008). Análisis de la actividad ecológica de las arañas en el agroecosistema del olivar, Universidad de Granada. Granada, pp. 312.

Cardoso, P., Silva, I., de Oliveira , N. G. & Serrano, A. R. M. (2004). Higher taxa surrogates of spider (Aranea) diversity and their efficiency in conservation. *Biological Conservation*, **117**, 453-459.

Castro, J., Campos, P. & Pastor, M. (1996). Influencia de los sistemas de cultivo empleados en olivar y girasol sobre la composición de la fauna de artrópodos en el suelo. *Boletín Sanidad Vegetal: Plagas*, **22**, 557-570.

Çilgi, T. (1994). Selecting arthropod "indicator species" for environmental impact assessment of pesticides in field studies. *Aspects of Applied Biology*, **37**, 131-140.

Cirio, U. (1997). Productos agroquímicos e impacto ambiental en olivicultura. *Olivae*, **65**, 32-39.

Cotes, B., Ruano, F., García, P. A., Pascual, F. & Campos, M. (2009). Coccinellid morphospecies as an alternative method for differentiating management regimes in olive orchards. *Ecological Indicators*, **9**, 548-555.

Chamberlain, D. E., Fuller, R. J., Bunce, R. G. H., Duckworth, J. C. & Shrubb, M. (2000). Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of Applied Ecology*, **37**, 771-788.

Dauber, J., Mirsch, M., Simmering, D., Waldhardt, R., Otte, A. & Wolters, V. (2003). Landscape structure as an indicator of biodiversity: matrix effects on species richness. *Agriculture, Ecosystems & Environment*, **98**, 321-329.

Döring, T. F., Möller, A., Wehke, S., Schulte, G. & Broll, G. (2003). Biotic indicators of carabid species richness on organically and conventionally managed arable fields. *Agriculture, Ecosystems & Environment*, **98**, 133-139.

Duelli, P. & Obrist, M. K. (1998). In search of the best correlates for local organismal biodiversity in cultivated areas. *Biodiversity and Conservation*, **7**, 297-309.

Fahrig, L. & Jonsen, I. (1998). Effect of habitat patch characteristics on abundance and diversity of insects in an agricultural landscape. *Ecosystems*, **1**, 197-205.

Fan, Y., Liebman, M., Groden, E. & Alford, A. R. (1993). Abundance of carabid beetles and other ground-dwelling arthropods in conventional versus low-input bean cropping systems. *Agriculture, Ecosystems & Environment*, **43**, 127-139.

Firbank, L. G., Petit, S., Smart, S., Blain, A. & Fuller, R. J. (2008). Assessing the impacts of agricultural intensification on biodiversity: a British perspective. *Philosophical Transactions of the Royal Society (B)*, **363**, 777-787.

Guzmán Álvarez, J. R. (2004). *Geografía de los paisajes del olivar andaluz*. Consejería de Agricultura y Pesca, Sevilla.

Iperti, G. (1999). Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture, Ecosystems & Environment*, **74**, 323-342.

Irmler, U. (2003). The spatial and temporal pattern of carabid beetles on arable fields in northern Germany (Schleswig-Holstein) and their value as ecological indicators. *Agriculture, Ecosystems & Environment*, **98**, 141-151.

Jackson, L. E., Pascual, U. & Hodgkin, T. (2007). Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agriculture, Ecosystems & Environment*, **121**, 196-210.

Jalas, J. (1955). Hemerobe und hemerochore Pflanzenarten. Ein terminologischer Reformversuch. *Acta Societatia Pro Fauna et Flora Fennica*, **72**, 1- 15.

Krebs, J. R., Wilson, J. D., Bradbury, R. B. & Siriwardena, G. M. (1999). The second silent spring? *Nature*, **400**, 611-612.

Kromp, B. (1999). Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems & Environment*, **74**, 187-228.

Letourneau, D. K. & Goldstein, B. (2001). Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology*, **38**, 557-570.

Liss, W. J., Gut, L. J., Westigard, P. H. & Warren, C. E. (1986). Perspectives on arthropod community structure, organization, and development in agriculture crops. *Annual Review of Entomology*, **31**, 455-478.

Marino, P. C. & Landis, D. A. (1996). Effect of landscape structure on parasitoid diversity and parasitism in agroecosystems. *Ecological Applications*, **6**, 276-284.

Martins da Silva, P., Aguiar, C. A. S., Niemelä, J., Sousa, J. P. & Serrano, A. R. M. (2008). Diversity patterns of ground-beetles (Coleoptera: Carabidae) along a gradient of land-use disturbance. *Agriculture, Ecosystems & Environment*, **124**, 270-274.

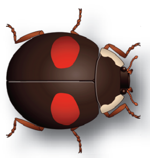
McGeoch, M. A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, **73**, 181-201.

Moreno, C. E., Sanchez-Rojas, G., Pineda, E. & Escobar, F. (2007). Shortcuts for biodiversity evaluation: a review of terminology and recommendations for the use of target groups, bioindicators and surrogates. *International Journal of Environment and Health*, **1**, 71-86.

Morris, T. I., Campos, M., Kidd, N. A. C., Jervis, M. & Symondson, W. O. C. (1999). Dynamic of the predatory arthropod community in Spanish olive groves. *Agricultural and Forest Entomology*, **1**, 219-228.

Perner, J. & Malt, S. (2003). Assessment of changing agricultural land use: response of vegetation, ground-dwelling spiders and beetles to the conversion of arable land into grassland. *Agriculture, Ecosystems & Environment*, **98**, 169-181.

Purtauf, T., Roschewitz, I., Dauber, J., Thies, C., Tscharntke, T. & Wolters, V. (2005).



Landscape context of organic and conventional farms: influences on carabid beetle diversity. *Agriculture, Ecosystems & Environment*, **108**, 165-174.

Ruano, F., Lozano, C., García, P., Peña, A., Tinaut, A., Pascual, F. & Campos, M. (2004). Use of artrhopods for the evaluation of the olive-orchard management regimes. *Agriculture and Forest Entomology*, **6**, 111-114.

Ruano, F., Lozano, C., Tinaut, A., Peña, A., Pascual, F., García, P. & Campos, M. (2001). Impact of pesticides on beneficial arthropod fauna of olive groves. IOBC/wprs Bull. 113-120.

Santos, S. A. P., Pereira, J. A., Torres, L. M. & Nogueira, A. J. A. (2007). Coccinellids as potential predators of *Saissetia oleae* (Olivier). In *3rd European Meeting of the IOBC/WPRS* Working Group "Integrated Protection of Olive Crops", Programme and Abstract Book. Bragança - Portugal.

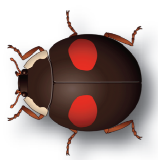
Varela, J. L. & González, R. (1999). Estudio sobre la entomofauna de un olivar en la provincia de Granada, durante el periodo de vuelo de la generación antófaga de *Prays oleae* (Lep. Yponomeutidae) *Phytoma España*, **111**, 42-55.

Ward, D. F. & Stanley, M. C. (2004). The value of RTUs and parataxonomy versus taxonomic species. *New Zealand Entomologist*, **27**, 3-9.

Weibull, A.-C., Bengtsson, J. & Nohlgren, E. (2000). Diversity of butterflies in the agricultural landscape: the role of farming system and landscape heterogeneity. *Ecography*, **23**, 743-750.

Weibull, A. C., Östman, Ö. & Granqvist, A. (2003). Species richness in agroecosystems: The effect of landscape, habitat and farm management. *Biodiversity and Conservation*, **12**, 1335-1355.

Wiens, J. A. & Milne, B. T. (1989). Scaling of 'landscapes' in landscape ecology, or, landscape ecology from a beetle's perspective. *Landscape Ecology*, **3**, 87-96.



11. Conclusiones
(Conclusions)

11. Conclusiones

A partir de los resultados obtenidos en este trabajo de Tesis, se extraen las siguientes conclusiones:

1. Los insectos del olivar pueden ser utilizados para diferenciar entre manejos ecológicos y no ecológicos (integrado y convencional).

2. El periodo de postfloración (junio) resultó ser la época más favorable para muestrear altos taxones de insectos (órdenes de insectos y familias de coleópteros) en la copa de los olivos.

3. La abundancia de los órdenes Coleoptera y Hemiptera y de las familias de Coccinellidae y Scraptiidae, es indicadora del manejo ecológico en extensas zonas olivareras, mientras que no lo es, en paisajes compuestos por pequeños mosaicos que alternan parcelas de olivar ecológico, otros cultivos y zonas de vegetación natural.

4. Las morfoespecies de coccinélidos más abundantes en la copa de los olivos pueden ser usadas como indicadores de manejo ecológico y no ecológico en extensas zonas olivareras, siendo el periodo óptimo de muestreo de junio a agosto.

5. Existe una correlación entre morfoespecie vs especie taxonómica en el caso de los coccinélidos, lo que valida el nivel taxonómico de morfoespecies de coccinélidos como indicadores.

6. La composición de las comunidades de coccinélidos presentes en los olivares de Andalucía está determinada por el tipo de manejo, especialmente por el uso de plaguicidas y por la estructura del paisaje. Las especies *Scymnus mediterraneus* Iablokoff-Khnzorian 1972 y *Platynaspis luteorubra* (Goeze, 1777) están relacionadas con grandes extensiones de olivar ecológico y por la presencia de bosques de quercíneas, mientras que *Coccinella septempunctata* Linnaeus, 1758 y *Hippodamia variegata* (Goeze, 1777) están asociadas a zonas de frutales de secano y superficies de olivar no ecológico.

7. El nivel taxómico de orden de los individuos capturados en suelo es el mejor indicador para diferenciar los olivares manejados de forma ecológica, en comparación con las familias de coleópteros o morfoespecies de carábidos.

8. La eliminación de la cubierta natural de vegetación en un olivar ecológico provoca un incremento de la abundancia, riqueza y dominancia de las familias de coleópteros de suelo.

11. Conclusions

From the results obtained in this dissertation project, the following conclusions can be drawn:

1. Insects captured in the olive orchards can be used to distinguish between organic and non-organic (integrated and conventional) farming systems.

2. The postblooming period (June) was the most favourable time to sample a greater number of insect taxa (insect orders and families of Coleoptera) in the olive canopies.

3. The abundance of Coleoptera and Hemiptera orders and Coccinellidae and Scraptiidae families is indicator in organic farming systems within large olive growing regions, but it is not indicator in landscapes consisting of small mosaics of organic olive orchards, other crops, and natural vegetation.

4. The coccinellid morphospecies most abundant in olive canopies can be used as indicators in organic and non-organic olive farming systems in widespread olive growing regions, with June to August being the optimal sampling period.

5. There is a correlation between morphospecies and taxonomic species in the case of the coccinellid family which validates the use of coccinellid morphospecies as an indicator.

6. The composition of coccinellid communities in Andalusian olive orchards is determined by the type of farming system and is especially affected by the use of pesticides and by the surrounding landscape. The *Scymnus mediterraneus* Iablokoff-Khnzorian 1972 and *Platynaspis luteorubra* (Goeze, 1777) species were related with large organic olive systems and the presence of holm oak forests near the orchards, while the *Coccinella septempunctata* Linnaeus, 1758 and *Hippodamia variegata* (Goeze, 1777) species were associated with large non-irrigated fruit orchards and non-organic olive systems.

7. The best indicator in differentiating between organic and non-organic olive orchards was insect order compared to Coleoptera families and carabid morphospecies.

8. The removal of the ground cover in an organic olive orchard caused an increase of abundance, richness and dominance of epigeal families.