UNIVERSIDADE DE ÉVORA

ESCOLA DE CIÊNCIAS E TECNOLOGIA

DEPARTAMENTO DE BIOLOGIA

"Influência de albufeiras e charcos na actividade e diversidade de morcegos em paisagens mediterrânicas"

Inês Fernandes

Orientação: Prof. António Mira
Co-orientação: João Tiago Marques
Denis Medinas

Mestrado em Biologia da Conservação

Dissertação

Évora, 2013

Esta dissertação inclui as críticas e as sugestões feitas pelo júri

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"How could I look my grandchildren

in the eye and say I knew what was

happening to the world and I did nothing?"

Sir David Attenborough

A presente dissertação encontra-se escrita

de acordo com a anterior ortografia.

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RESUMO

"Influência de albufeiras e charcos na actividade e diversidade de morcegos em paisagens mediterrânicas"

A paisagem mediterrânica apresenta uma elevada biodiversidade de morcegos. No entanto, a aceleração do aquecimento global e maior frequência de secas podem reduzir a disponibilidade hídrica e de presas. A actividade de morcegos foi amostrada em 16 massas de água, entre Maio e Setembro de 2011 e 2012. Entre 4270 passagens foram identificadas doze espécies, sendo o género *Pipistrellus* o mais representado (66,6%). A actividade de morcegos foi superior junto aos corpos de água, aumentando significativamente em 2012, um ano muito seco, especialmente no Verão. A área dos corpos de água foi a característica mais importante na explicação dos padrões de actividade, mostrando uma associação positiva. Maiores áreas florestais na vizinhança contribuíram para o aumento da actividade destes mamíferos. O aumento dos requisitos da água dos morcegos nas condições climáticas severas previstas suportam a elevada necessidade de preservação destas paisagens, dominadas por mosaicos de carvalhos e corpos de água dispersos.

Palavras-chave: morcegos, corpos de água, montado, paisagem mediterrânica, seca, aquecimento global.

ABSTRACT

“Influence of lakes and ponds in the activity and diversity of bats in Mediterranean landscapes”

The Mediterranean landscape has a high bat diversity. However, as a result of the acceleration of global warming and consequent increasing summer dryness may reduce water and prey availability. Between May and September of 2011 and 2012 we surveyed bat activity near 16 water bodies. Of a total of 4270 bat passes twelve species were recorded, with *Pipistrellus* genus the most represented (66,6%). Bat activity was higher near ponds, increasing significantly in 2012, an extremely dry year, especially in summer. Water bodies’ area was the most important feature in the explication of bat activity pattern, showing a positive association. Larger forest areas (*montado*) next to the ponds also had a significant contribution to higher bat activity. The increase of water requirements for bats in the predicted harsh climatic conditions supports the urgent need of preservation of this landscape, dominated by oak-woodland and several scattered water bodies.

Key words: bats, water bodies, *montado*, Mediterranean landscape, drought, global warming.

Introdução

Embora sejamos apenas uma entre as cerca de 1,9 milhões de espécies vivas descritas, somos a que tem maior impacto no planeta. Apesar da extinção ser um processo natural da evolução, há cerca de 50.000 anos o ser humano começou a ser o responsável pelo desaparecimento de vertebrados e esta taxa de ocorrência tem vindo a aumentar (Burnie *et al.*, 2007; Pough *et al.*, 2008; Samper *in* DK Publishing, 2010). O facto de que os perigos, de origem humana, encontrados pelas várias espécies, têm aumentado é bastante visível a partir do século XVI, com o começo da recolha e colecção de espécimes, bem como com a exploração do mar e a introdução, acidental ou deliberada, de espécies exóticas (Burnie *et al.*, 2007).

Mais recentemente pode verificar-se que o crescimento das populações humanas (7 biliões de indivíduos, actualmente; o dobro da população de há 50 anos), assim como a sua distribuição global, têm provocado alterações no planeta, devido aos avanços na tecnologia, os quais, poder-se-á dizer, começaram há 2,5 milhões de anos com as ferramentas líticas (Pough *et al.*, 2008; Ehrlich, 2010). Uma destas alterações é a aceleração do aquecimento global, através da libertação dos gases de efeito de estufa para a atmosfera, essencialmente dióxido de carbono e metano. Este processo interfere com a entrada de energia solar através da atmosfera e com a temperatura em todo o planeta: nos oceanos, na terra e no ar. Esta alteração prejudica as espécies adaptadas a determinados ambientes, não se conseguindo readaptar num tão curto espaço de tempo (Burnie *et al.*, 2007; DK Publishing, 2010; Lovejoy, 2010).

As alterações climáticas e a deterioração dos habitats estão actualmente a ocorrer a uma escala sem precedentes (Jones *et al.*, 2009). Vários estudos têm-se focado nos efeitos destas alterações nas populações de fauna selvagem (Adams & Hayes, 2008; Frick *et al.*, 2010b). Segundo as pesquisas de Walther *et al.* (2002), nos últimos 30 anos do séc. XX, as variações climáticas têm vindo a modificar a fenologia dos organismos, a biogeografia das espécies e a composição e dinâmica das comunidades. Como tal, combinadas com a destruição de habitat e a degradação de outros recursos ambientais, estas mudanças aumentam a ameaça à biodiversidade (Walther *et al.*, 2002).

Modelos de alterações climáticas prevêem que os gases de efeito de estufa resultem num aumento da frequência, intensidade e duração de ondas de calor, bem como na maior incidência de secas no futuro (Meehl & Tebaldi, 2004; Schär *et al.*, 2004). Através de um estudo incidente nos impactos das alterações climáticas globais, das populações, da produção eléctrica e da eficiência no uso da água, verifica-se que, até à década de 50 do século XXI, e dependendo do cenário e modelo climático projectado, o stresse hídrico poderá atingir mais de 62% da totalidade das bacias hidrográficas. Este agravamento terá como principal causa o uso doméstico de água, bem como os sectores agrícola e industrial. O mesmo estudo indica ainda que uma área muito menor poderia ser sujeita a uma diminuição deste stresse, o que apenas ocorreria devido ao aumento da precipitação anual causada pelas alterações climática (Alcamo *et al*., 2007).

Como tal, esta aceleração do aquecimento global, aliada a um clima mediterrânico, caracterizado por apresentar um período prolongado bastante seco, durante o Verão (Blondel & Aronson, 2004), faz com que a água se torne um recurso escasso, constituindo, assim, um factor limitante para o uso do espaço de muitos grupos faunísticos, em particular dos morcegos (Rainho, 2007; Rainho & Palmeirim, 2011; Sherwin *et al*., 2012). Dado que em muitos casos a proximidade a uma fonte de água aumenta o uso do habitat na sua envolvência (Rainho & Palmeirim, 2011), muitas espécies dependem de recursos hídricos permanentes próximos dos abrigos, o que faz com que as alterações climáticas possam ter consequências graves, devido à falta de adaptabilidade a ambientes com stresse hídrico (Adams & Hayes, 2008).

Uma vez que a aerosfera influencia o movimento sazonal e diário dos organismos, estas mudanças nas condições atmosféricas, como o vento, a temperatura, a precipitação e a densidade do ar, influenciam mais visivelmente aqueles que a utilizam rotineiramente, como os morcegos. A aerosfera pode influenciar, assim, as funções comportamental, sensorial, metabólica e respiratória (Kunz *et al*., 2008). Segundo Burles *et al*. (2009), a sobrevivência e o sucesso reprodutivo dos morcegos insectívoros são, com frequência, influenciados negativamente por condições temporais adversas. Para além disto, a dinâmica das populações de morcegos da região temperada pode ser afectada negativamente por Verões secos associados às alterações climáticas globais (Frick *et al*., 2010b). Isto porque, apesar de utilizarem vários habitats para procurar alimento, os locais com água são normalmente os mais procurados por estes mamíferos. Como tal, os habitats ripícolas, barragens ou charcas rodeados por florestas autóctones proporcionam áreas importantes de alimentação na época estival (Verboom *et al*., 1999; Russo & Jones, 2003; Rainho, 2007; Rebelo & Rainho, 2008). Zonas com elevada actividade agrícola, mesmo que com a presença de água, não são tão usadas, uma vez que o uso de pesticidas e fertilizantes alteram a qualidade da água e diminuem a disponibilidade de insectos (principal fonte de alimento dos morcegos em Portugal) (Rainho, 2007). Dada a importância ecológica destes predadores e polinizadores, e sendo eles sensíveis a acumulações de pesticidas e outras toxinas, as alterações nestas populações influenciam também as guildas tróficas inferiores (Jones *et al*., 2009; Boyles *et al*., 2011), reflectindo-se nas comunidades de insectos dos quais se alimentam e das plantas que estes polinizam (Jones *et al*., 2009). Como tal, como a abundância de insectos é influenciada pelas condições climáticas, a alteração destas determina também a actividade dos morcegos (Burles *et al*., 2009; Wang *et al*., 2010). A procura de alimento pode ser influenciada por estas alterações em ambientes susceptíveis de sofrer stresse hídrico e/ou de se tratar de espécies dependentes espacial e temporalmente de alimentos em risco (Sherwin *et al*., 2012).

Considera-se que os morcegos têm enorme potencial enquanto bioindicadores das variações climáticas, uma vez que se distribuem largamente pelo globo, apresentam estabilidade taxonómica e as tendências das populações, a curto e longo termo, podem ser monitorizadas (Jones *et al*., 2009). Inclusivamente, a abundância de morcegos em abrigos subterrâneos na Europa tem sido considerada um indicador destas alterações, uma vez que a temperatura e humidade são factores importantes para controlar a hibernação (Newson *et al*., 2008), evidenciando, assim, que a existência de alterações climáticas tem impactos também em aspectos da ecologia destas espécies (Sherwin *et al*., 2012). Outros estudos indicam que pode ser possível detectar alterações climáticas a partir de alterações na distribuição de morcegos migratórios capazes de percorrer grandes distâncias (Lundy *et al*., 2010). Portanto, a nível da biogeografia as alterações climáticas podem afectar espécies de morcegos de latitudes e altitudes elevadas, com movimentos sazonais ou limitados e espécies restritas a uma pequena extensão (Sherwin *et al*., 2012). De acordo com os grupos biogeográficos, a distribuição dos morcegos pode diminuir ou variar (Rebelo *et al*., 2010).

A taxa de evaporação hídrica é superior nos morcegos do que em outros mamíferos de tamanho semelhante, devido à relação entre a elevada área de superfície corporal e o volume, bem como a existência de membranas de vôo desprovidas de pêlos (Webb *et al*. 1995). Assim, para além da temperatura ambiente influenciar por si só a temperatura corporal mínima (Chruszcz & Barclay, 2002) e a biogeografia, influencia os morcegos também noutros aspectos, de acordo com os requisitos das espécies, como o acesso ao alimento, o momento da hibernação, a reprodução e desenvolvimento, a frequência e duração de entorpecimento e a taxa de gasto energético (Sherwin *et al*., 2012).

É também visível a existência de um risco associado entre as alterações climáticas e a reprodução de morcegos, podendo ocorrer uma alteração no momento do parto, resultante da alteração da disponibilidade alimentar e hídrica, para além de se considerar que os climas mais quentes favoreçam o número de fêmeas reprodutivas (Adams & Hayes, 2008; Barclay, 2012; Sherwin *et al*., 2012). Embora temperaturas quentes possam beneficiar morcegos, aumentando a disponibilidade de alimento, antecipando o parto, acelerando o desenvolvimento dos juvenis e aumentando a distribuição, pode também causar uma mortalidade significativa através da interrupção da hibernação, difusão de doenças e, como já foi referido, ocorrências adversas (tempo extremo) e redução da disponibilidade hídrica em ambientes áridos. Se a disponibilidade alimentar não aumentar, com as elevadas temperaturas a estimular um aumento de actividade no inverno, as reservas energéticas podem ser gastas antes do período de maior abundância de presas, a Primavera e o Verão (Sherwin *et al.*, 2012).

Apesar de se saber hoje o papel ecológico importante que os morcegos desempenham, estes mamíferos foram perseguidos durante séculos por se considerarem vampiros, transportadores de doenças e pragas de plantações (Hooi *et al.*, 1996). Na realidade, os morcegos têm um enorme impacto nos seus ecossistemas, uma vez que contribuem para a regulação da quantidade de insectos existentes, prevenindo a ocorrência de pragas ou diminuindo vectores de doenças (Cleveland *et al.*, 2006; Federico *et al.*, 2008; ICNB, 2008). Cada animal pode consumir, por noite, mais de metade do seu peso em insectos. Como tal, é de salientar a importância científica, ecológica e económica destes animais (ICNB, 2008). Segundo alguns estudos, os morcegos englobam-se no grupo dos animais não domésticos mais importantes a nível económico, sendo portanto reforçada a necessidade de atenuar os impactos nas populações para a integridade dos ecossistemas e as economias internacionais (Cleveland *et al.*, 2006; Federico *et al.*, 2008; Boyles *et al.*, 2011).

Apesar dos morcegos da região mediterrânica aparentarem ser mais tolerantes a aumentos de temperatura, prevê-se a possibilidade de várias extinções e declínios. Entre os mamíferos que ocorrem na Península Ibérica, os morcegos são o grupo mais ameaçado (Mathias *et al.*, 1998). Das 27 espécies presentes em Portugal (25 em território continental), 9 encontram-se com um estatuto de ameaça (Criticamente em Perigo, Em Perigo ou Vulnerável) (ICNB, 2008).

Apesar da protecção legal de todas as espécies de morcegos (Directiva Habitats, Convenção de Berna, Convenção de Bona e Acordo sobre a Conservação das Populações de Morcegos Europeus – EUROBATS) e dos seus abrigos (Convenção de Berna e Directiva Habitats), verifica-se um declínio generalizado das populações nas últimas décadas, especialmente na Europa (ICNB, 2008). Este declínio relaciona-se com a destruição e/ou perturbação de abrigos e habitats, a utilização de pesticidas, a intensificação agrícola, a caça, o desaparecimento de biótopos de alimentação, a colisão com aerogeradores, as lesões fatais devido às elevadas diferenças de pressão próximo dos aerogeradores, o atropelamento, a doença e a deterioração da qualidade da água (Mickleburgh *et al.*, 2002; Horn *et al*, 2008; ICNB, 2008; Jones *et al.*, 2009; Frick *et al*, 2010a). Para além destes factores as alterações climáticas estão entre as condições relacionadas com alterações no número e actividade de morcegos, como secas extremas, calor, frio e precipitação, ciclones e aumento do nível do mar (Jones *et al.*, 2009).

Esta situação agrava-se com a dificuldade de recuperação do efectivo populacional após estes declínios. A maturidade sexual é tardia em algumas espécies e o número de crias anual é baixo (frequentemente apenas uma cria por ano). Esta baixa taxa reprodutiva aliada à sua sensibilidade ao stresse ambiental ajuda ao declínio visível nestas populações (Jones *et al.*, 2009). Os hábitos nocturnos, a boa capacidade de voo e o abrigo, normalmente, em locais de difícil acesso, podem traduzir-se em vantagens. No entanto, o comportamento colonial, como no caso dos morcegos cavernícolas, torna-os particularmente vulneráveis a catástrofes naturais ou às intervenções humanas (Mathias *et al.*, 1998). Estes factores de risco traduzem a vulnerabilidade destes mamíferos às alterações climáticas, podendo agravar-se no futuro.

Tendo em conta o atrás exposto, torna-se relevante perceber quais os factores potencialmente limitantes à presença e actividade de morcegos, como seja a disponibilidade de massas de água (Rainho, 2007).

Objectivos

O presente estudo visa determinar de que forma a disponibilidade hídrica influencia a actividade e a diversidade dos morcegos, comparando um ano "típico" com um ano de seca severa/extrema, contribuindo, desta forma, para a conservação dos morcegos e dos seus habitats em zonas Mediterrânicas e avaliar de que forma a gestão da disponibilidade hídrica pode ser integrada neste objectivo. Os objectivos específicos são: a) comparar o efeito de períodos de seca severa/extrema na actividade dos morcegos junto aos corpos de água; b) quantificar o efeito da distância à água no nível de actividade e na riqueza específica; c) determinar a influência das características dos corpos de água e paisagem envolvente no nível de actividade.

Área de estudo

O presente estudo foi realizado no distrito de Évora, na região do Alentejo (38° 34′ 15″ N, 7° 54′ 34″ W). O clima da região é tipicamente mediterrânico, com elevadas amplitudes térmicas diárias e grandes diferenças entre períodos de chuva e de seca. A característica época quente e seca apresenta pouca precipitação e temperaturas médias mensais entre os 20 e os

23°C. A época mais fria e chuvosa pode apresentar uma precipitação superior a 800mm e temperaturas médias que podem alcançar os 10°C (IM, 2008).

A paisagem local é dominada por montado, sistema agro-silvo-pastoril tradicional mediterrânico que cria paisagens heterogéneas, favorecendo a existência de uma rica biodiversidade (Costa *et al*., 1998; Pinto-Correia & Vos, 2004; Galantinho & Mira, 2008). Esta região seca apresenta ainda muitas massas de água mantidas como bebedouros para o gado, ou para finalidades agrícolas e de pesca (Galantinho & Mira, 2008).

Foram selecionadas dezasseis massas de água, aleatoriamente (uma albufeira e 15 charcos) em áreas abertas (maioritariamente pastagens) e de montado (Figura 1). Dois dos charcos seleccionados são adjacentes áreas de agricultura intensiva. As massas de água selecionadas foram agrupadas em três categorias de acordo com a área: quatro pequenas (área menor que 0,30ha), sete médias (entre 0,31ha e 2,50ha) e cinco grandes (mais de 2,51ha).

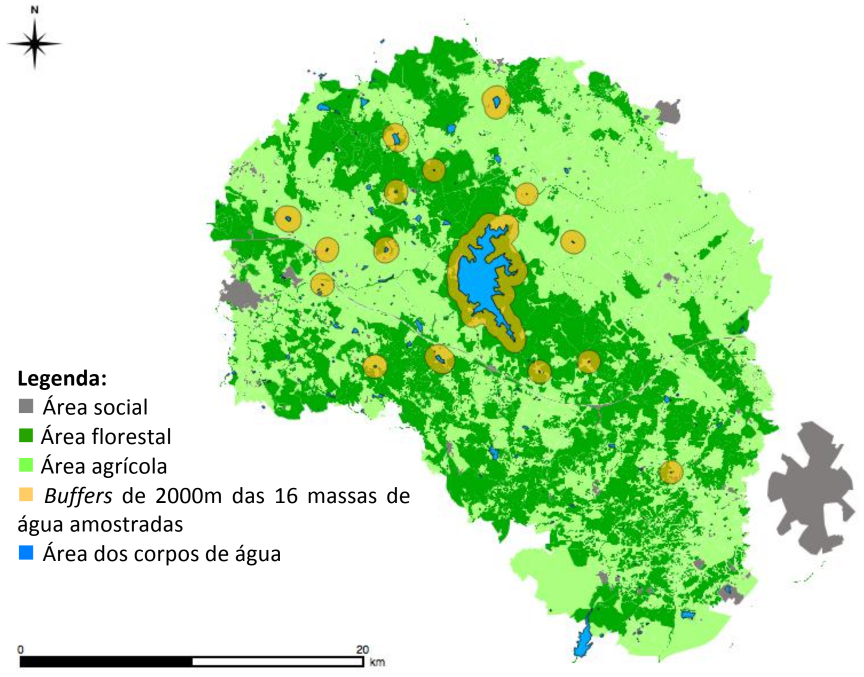

Figura 1: Área de estudo, com as 16 massas de água amostradas e os respectivos *buffers* de 2000m.

Artigo Científico

"Influence of lakes and ponds in the activity and diversity of bats in Mediterranean landscapes"

Fernandes, I.; Mira, A.; Medinas, D.; Marques, J. T.

1. Abstract

The Mediterranean landscape has an high bat diversity. However, as a result of the acceleration of global warming and consequent increasing summer dryness may reduce water and prey availability. Between May and September of 2011 and 2012 we surveyed bat activity near 16 water bodies. Of a total of 4270 bat passes twelve species were recorded, with *Pipistrellus* genus the most represented (66,6%). Bat activity was higher near ponds, increasing significantly in 2012, an extremely dry year, especially in summer. Water bodies' area was the most important feature in the explication of bat activity pattern, showing a positive association. Larger forest areas (*montado*) next to the ponds also had a significant contribution to higher bat activity. The increase of water requirements for bats in the predicted harsh climatic conditions supports the urgent need of preservation of this landscape, dominated by oak-woodland and several scattered water bodies.

Key words: bats, water bodies, *montado*, Mediterranean landscape, drought, global warming.

2. Introduction

It is quite visible that humans have contributed to increase the dangers to several species since the sixteenth century (Burnie *et al.*, 2007). The acceleration of global warming caused by human population growth and distribution affects species adapted to particular environments (Burnie *et al.*, 2007; Pough *et al.*, 2008; DK Publishing, 2010; Ehrlich, 2010; Lovejoy, 2010). Several studies had focused on the effects of these changes on wildlife populations (*e.g.* Walther *et al.*, 2002; Adams & Hayes, 2008; Frick *et al.*, 2010b). Models predict that the climate greenhouse gases result in an increased incidence of dry in the future (Meehl & Tebaldi, 2004; Schär *et al.* 2004) and Alcamo *et* *al*. (2007) project that the water stress could rise more than 62% of the entire watershed, until the 50s of the twenty-first century.

Thus, this acceleration of global warming, combined with a Mediterranean climate with an extended dry period during summer (Blondel & Aronson, 2004), turns the water a scarce resource and a limiting factor for many wildlife groups (Rainho, 2007; Rainho & Palmeirim, 2011; Sherwin *et al*., 2012). The proximity to a source of water increases the habitat use in its surroundings (Rainho & Palmeirim, 2011), so climate change may have serious consequences to those species that rely on permanent water near the shelters and suffer with a lack of adaptability to water stress environments (Adams & Hayes, 2008).

Since aerosphere influences the daily and seasonal movement of the species, these changes in atmospheric conditions such as wind, temperature, rainfall and air density, most noticeably affect those who routinely uses them, like bats (Kunz *et al*., 2008). According to Burles *et al*. (2009), the survival and reproductive success of insectivorous bats are often negatively impacted by climatic adverse conditions. Nevertheless, the bats populations' dynamics in the temperate region can be adversely affected by dry summers associated with global climate change (Frick *et al*., 2010a), once the places with water are usually the most sought by these mammals. Thus, riparian habitats, dams or ponds surrounded by native forests provide important feeding areas during the summer (Verboom *et al*., 1999; Russo & Jones, 2003; Rainho, 2007; Rebelo & Rainho, 2008). Since the use of pesticides and fertilizers affects the water quality and decreases the availability of insects (major bats food source in Portugal), areas with high agricultural activity are less used by them (Rainho, 2007). Given the ecological importance of these predators and pollinators, and being they sensitive to the accumulation of pesticides and other toxins, changes in these populations also influence lower trophic guilds (Jones *et al*., 2009; Boyles *et al*., 2011). Thus, their presence is reflected in insects' communities they feed and in the plants they pollinate (Jones *et al*. 2009).

It is considered that bats have enormous potential as bioindicators of climate change, since they are distributed widely across the globe, presenting taxonomic stability and population trends that can be monitored (Jones *et al*., 2009). According to biogeographical groups, bats distribution can decrease or vary with this change (Rebelo *et al*., 2010).

The water evaporation rate is higher in bats than in other mammals of similar size due to the relationship between higher body surface area and volume, as well as the existence of flight membranes devoid of hair (Webb *et al*., 1995). External temperature influences the minimum body temperature (Chruszcz & Barclay, 2002), biogeography and other aspects such as access to food, time of hibernation, reproduction and development, frequency and duration of torpor and the energy expenditure rate (Sherwin *et al*., 2012).

For centuries bats were considered vampires, carriers of diseases and pests of crops, although it is known today their important ecological role (Hooi *et al*., 1996). Bats play a tremendous impact on its ecosystems, contributing to the insects' amount regulation and preventing pest or disease vectors (Cleveland *et al*. 2006; Federico *et al*. 2008; ICNB, 2008). Each animal may consume more than half of its weight in insects per night. Therefore, it is important to accentuate the scientific, ecological and economic importance of these animals (ICNB, 2008). According to some studies, bats are included in the group of non-domestic animals most economically important and thus should be reinforced the need to mitigate the impacts on populations to ecosystem integrity and international economies (Cleveland *et al*., 2006; Federico *et al*., 2008; Boyles *et al*., 2011).

In spite of the bats in the Mediterranean region appear to be most tolerant to temperature increases, it is anticipated the possibility of multiple extinctions and declines (Sherwin *et al*., 2012). Bats are the most threatened group among the mammals occurring in the Iberian Peninsula (Mathias *et al*., 1998). Of the 27 species present in Portugal (25 on the mainland), nine are with a status of threat (Critically Endangered, Endangered or Vulnerable) (ICNB, 2008). Regardless of the legal protection of all species of bats (Habitats Directive, Bern Convention, Bonn Convention and the Agreement on the Conservation of Populations of European Bats – EUROBATS) and their shelters (Bern Convention and Habitats Directive), it's evident that there has been a general decline of populations in recent decades, especially in Europe (ICNB, 2008).

Among other causes, bat's decline is related to the destruction of shelters and habitats, pesticide use, agricultural intensification and deterioration of water quality (Mickleburgh *et al*., 2002; Horn *et al*., 2008; ICNB, 2008; Jones *et al*., 2009; Frick *et al*., 2010a). Also climate change affects the number and activity of bats, through extreme drought, heat, cold and precipitation. The bat low reproductive rate and its sensitivity to environmental stress, helps in the decline of the populations to (Jones *et al*., 2009). In spite of the nocturnal habits, good flight capacity and shelter in normally hard to reach places could be advantages, the colonial behaviour of some species makes them particularly vulnerable to natural disasters or human interventions (Mathias *et al*., 1998). These risk factors reflect the vulnerability of these mammals to the climate change, which may worsen in the future (Sherwin *et al*., 2012).

In view of the above, it becomes important to understand which factors are potentially limiting the bats activity, such as the availability of water bodies (Rainho, 2007). This question becomes even more relevant if it's taken in consideration that the year 2012 was characterized by a severe/extreme drought, it was the fifth driest year since 1931 with a rainfall lower by 42% from January to September compared to 2011 (MAMAOT, 2013).

The main objectives are: a) compare the effect of periods of severe/extreme drought in bats activity near the water bodies; b) quantify the effect of the distance to the water in bats activity and species richness; c) determine the influence of the characteristics of water bodies and surrounding landscape in the level of activity.

2. Methods

2.1. Study area

Fieldwork took place in Portugal, Alentejo region, in the district of Évora (38° 34′ 15″ N, 7° 54′ 34″ W). The terrain is roughly plain only interrupted by a few low-altitude mountains, like Serra de Monfurado (Costa *et al.*, 1998), a Natura 2000 site (ICN, 2006c).

The climate of this region is typically Mediterranean, with large daily temperature variations and differences between dry and rainy seasons. The characteristic hot and dry season occurs mainly between June and October, with monthly average temperatures ranging from 20 to 23°C and low rainfall. In the colder and wetter season monthly average temperatures ranges from 10 to 15°C and rainfall can be higher than 800mm (IM, 2008).

Local landscape is dominated by *montado*, a traditional Mediterranean agro-forestry--pastoral system that creates heterogeneous landscapes. This system is a mixture of evergreen tree stands of cork (*Quercus suber*) and holm (*Q. rotundifolia*) oaks dispersed, with non-intensive agricultural, grassland and pasture areas, which favors the existence of high biodiversity (Costa *et al.*, 1998; Pinto-Correia & Vos, 2004; Galantinho & Mira, 2008). In this dry region there are many scattered small dams and ponds maintained for cattle drinking, agricultural and fishing purposes (Galantinho & Mira, 2008).

The 16 water bodies were selected randomly (one dam and 15 ponds) in *montado* and open areas, mainly pastures (Figure 1). Two of the selected ponds had adjacent intensive agriculture areas: one had an irrigated cornfield and the other a vineyard. The selected ponds were grouped in three size categories: four small (area smaller than 0.30ha), seven of medium sized (from 0.31ha to 2.5ha) and five large (more than 2.51ha) water bodies.

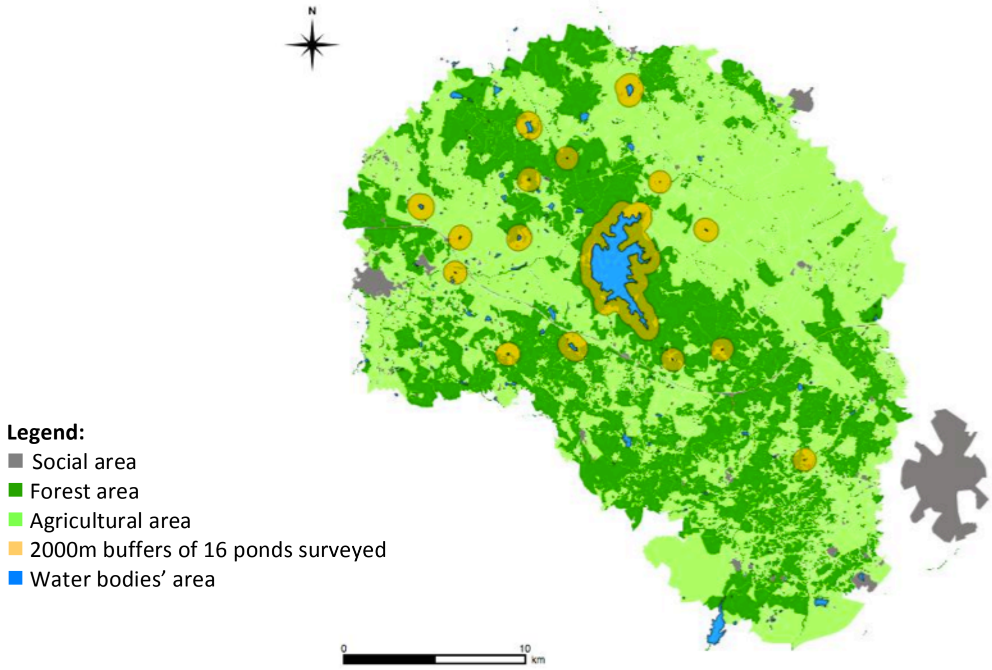

Figure 1: Study area, with buffers of 2000m around water bodies surveyed.

2.2. Bat activity surveys

Bat activity was surveyed at each pond in one linear transect of 500m. Each transect was perpendicular to the pond margin and consisted on 11 evenly spaced monitoring stations, one every 50m. At each station bat passes were recorded for 3 minutes using an ultrasound detector D500x (Pettersson Elektronik AB). Bat activity monitoring was repeated three times at each pond between May and September, in 2011 and 2012 (24 sampling nights in each year). This interval corresponds to the highest annual peak of bat activity. The visits had an interval of one month and a half to uniformly cover the months of bat activity peak.

During the bat activity monitoring we also registered the local air temperature and wind chill, wind speed, moon phase and cloud cover. Given that the bat activity is highly influenced by adverse weather conditions (Vaughan *et al*., 1997), no surveys were made on rainy or windy nights (wind speed higher than 3m/s) or when ambient temperature was lower than 10^{o}C.

2.3. Bat call analysis and species identification

Bat call recordings were analysed using the software Audacity 1.3.10 Beta (Mazzoni & Dannenberg, 2000). The detector sampling frequency was 500 kHz, 16 bits/sample and the spectrograms were calculated with automatic fast Fourier transform size 1024, with a Hanning window.

Bat calls were identified by the shape of the calls (constant frequency – CF; frequency modulation – FM; almost constant frequency – QCF) and by measuring on screen three call parameters: frequency of maximum energy (FMaxE), pulse duration (D) and inter-pulse interval (IPI). When necessary, as for the distinction of some *Myotis* species, we measured the initial (Fi) and end frequency (Ff) (Russo & Jones, 2002; Marques, 2011; Rainho *et al.*, 2011). The frequency was displayed in the "spectrogram" and analysed in detail on "frequency spectrum". The time measures (IPI and D), whenever possible, were measured in the "oscillogram" (Marques, 2011). Faint calls or calls overlapped with insect noises were considered unidentified.

Species identification of bat calls was based primarily on the key “Chave de identificação de vocalizações dos morcegos de Portugal continental”, prepared under the project “Atlas dos morcegos de Portugal continental” (“Atlas of bats in mainland Portugal”). So, the distinction between the Common Bentwing Bat (*Miniopterus schreibersii*) and the Pygmy Pipistrelle (*Pipistrellus pygmaeus*) was not made, since a more detailed and time consuming sound analysis would require to do so, adding the need of multivariate statistical methods. Also, since the *P. pygmaeus* has a greater abundance and wide distribution area, it is not possible to foresee vocalizations *M. schreibersii*, incorporated in vocalizations identified as *P. pygmaeus* (Rainho *et al.*, 2011). The same happened for *Nyctalus noctula*: according to the latest data (Atlas dos Morcegos, unpublished) it is unlikely to exist in this area, so such vocalizations, although similar, were considered to belong to *Nyctalus lasiopterus*.

Additional bat call information from several southern and central European countries was used to help in the identification of sound recordings (Jensen & Miller, 1999; Parsons & Jones, 2000; Denzinger *et al.*, 2001; Russo & Jones, 2002; Obrist *et al.*, 2004; Preatoni *et al.*, 2005; Papadatou *et al.*, 2008).

2.4. Data analyses

Bat activity was measured in number of bat passes at each recording station. One bat pass is a sequence of three or more echolocation pulses (Fenton, 1999). Also, foraging and social activity were measured as the number of feeding buzzes and social calls, respectively. A feeding buzz is a call sequence produced by the detection of an insect-prey, occurring while foraging. Social calls are vocalizations that can communicate social status, individual identity or territorial issues (Pfalzer & Kusch, 2003; Ahlén, 2004).

Bat activity level, foraging guild and the species richness at each point of the sampling were the response variables. Explanatory variables were included in two sets: land use and landscape metrics (LAND) and water bodies' metrics (POND).

2.4.1. Explanatory variables

Ponds and their surrounding landscape were characterized during fieldwork visits, and geographical information system analyses (ESRI, 2011; QGIS Development Team, 2012) using a 2000 meters buffer around each water body. Land use data was reclassified into "agricultural area" (with less than 30% tree cover), "forest area" (*montado* with more than 30% tree cover), "human activity areas" (isolated farmhouses, buildings, roads) or "water bodies" (small rivers, dams, ponds). Landscape metrics descriptors, *e.g.* forest edge density and forest mean patch size, were computed for each buffer, using the Patch Analyst 4 extension for ArcGis 10 (ESRI, 2011). The Euclidian distance between ponds was calculated using GRASS plugin for QGis 1.8.0 (GRASS GIS 6.4.2). On the whole, the characterization of each pond included 61 variables described in Table 1.

Table 1: Description and summary statistics of two sets – LAND and POND – of explanatory variables used to describe bat activity level surrounding water bodies.

Variable	Details (unit)	Average	Range
Landscape features (LAND)[1]			
AGRIC	Agricultural area (%)	0.89 ± 0,42	0.20 – 1.51
FOREST	Forest area (%)	0.59 ± 0.44	0.00 – 1.36
DAM	Total area of water bodies area (%)	0.15 ± 0.15	0.00 – 0.62
HUM_PERT	Social area (%)	0.07 ± 0.09	0.00 – 0.26
SDI	Shannon diversity index	0.18 ± 0.09	0.01 – 0.29
SEI	Shannon evenness index	0.15 ± 0.08	0.01 – 0.26
AWMSI	Area weighted mean shape index	0.49 ± 0.09	0.32 – 0.65
AWMSI_AG	Area weighted mean shape index of agricultural area	0.49 ± 0.09	0.32 – 0.66
AWMSI_FO	Area weighted mean shape index of forest area	0.53 ± 0.09	0.37 – 0.69
MSI	Mean shape index	0.44 ± 0.04	0.36 – 0.50
MSI_AG	Mean shape index of agricultural area	0.45 ± 0.06	0.32 – 0.55
MSI_FO	Mean shape index of Forest area	0.47 ± 0.06	0.37 – 0.56
MPAR	Mean perimeter-area ratio	3.29 ± 0.49	2.58 – 4.25
MPAR_AG	Mean perimeter-area ratio of agricultural area	3.02 ± 0.86	1.62 – 4.53
MPAR_FO	Mean perimeter-area ratio of forest area	2.97 ± 0.88	1.73 – 4.18
MPFD	Mean patch fractal dimension	0.38 ± 0.01	0.36 – 0.40
MPFD_AG	Mean patch fractal dimension of agricultural area	0.39 ± 0.02	0.34 – 0.42
MPFD_FO	Mean patch fractal dimension of forest area	0.39 ± 0.03	0.35 – 0.46
AWMPFD	Area-weighted mean patch fractal dimension	0.36 ± 0.01	0.34 – 0.38
AWMPFD_AG	Area-weighted mean patch fractal dimension of agricultural area	0.36 ± 0.01	0.34 – 0.38
AWMPFD_FO	Area-weighted mean patch fractal dimension of forest area	0.38 ± 0.03	0.35 – 0.47

Table 1: Description and summary statistics of two sets – LAND and POND – of explanatory variables used to describe bat activity level surrounding water bodies (continuation).

Variable	Details (unit)	Average	Range
Landscape features (LAND)[1]			
TE	Total edge	4.14 ± 0.32	3.61 – 5.01
TE_AG	Total edge of agricultural area	3.82 ± 0.25	3.20 – 4.28
TE_FO	Total edge of forest area	3.68 ± 0.71	1.49 – 4.72
ED	Edge density	2.06 ± 0.21	1.65 – 2.45
ED_AG	Edge density of agricultural area	1.75 ± 0.26	1.12 – 2.15
ED_FO	Edge density of forest area	1.64 ± 0.49	0.10 – 2.10
MPE	Mean parcel edge	3.23 ± 0.19	3.05 – 3.73
MPE_AG	Mean parcel edge of agricultural area	3.34 ± 0.29	2.74 – 3.74
MPE_FO	Mean parcel edge in of forest area	3.21 ± 0.63	1.49 – 3.88
MPS	Mean parcel size	1.21 ± 0.31	0.72 – 1.92
MPS_AG	Mean parcel size of agricultural area	1.28 ± 0.50	0.34 – 2.05
MPS_FO	Mean parcel size of forest area	1.09 ± 0.73	0.00 – 2.10
NumP	Number of parcels	0.97 ± 0.25	0.48 – 1.34
NumP_AG	Number of parcels of agricultural area	0.63 ± 0.24	0.30 – 1.08
NumP_FO	Number of parcels of forest area	0.62 ± 0.28	0.30 – 1.04
MedPS	Median patch size	0.39 ± 0.40	0.07 – 1.68
MedPS_AG	Median patch size of agricultural area	0.79 ± 0.76	0.01 – 2.05
MedPS_FO	Median patch size of forest area	0.72 ± 0.82	0.00 – 1.93
PSCoV	Patch Size coefficient of variation	2.28 ± 0.14	2.00 – 2.45
PSCoV_AG	Patch Size coefficient of variation of agricultural area	1.75 ± 0.88	0.00 – 2.39
PSCoV_FO	Patch size coefficient of variation of forest area	1.33 ± 1.06	0.00 – 2.38
PSSD	Patch size standard deviation	1.47 ± 0.26	1.06 – 2.22
PSSD_AG	Patch size standard deviation of agricultural area	1.01 ± 0.61	0.00 – 1.79
PSSD_FO	Patch size standard deviation of forest area	0.61 ± 0.70	0.00 – 2.29
MHAB	Mean of herbaceous/low shrubs (less than 1 meter) in a ray of 20 meters of each sampling point (%)	0.81 ± 0.20	0.11 – 0.95
MAA	Mean of high shrubs (between 1 and 3 meters) in a ray of 20 meters of each sampling point (%)	0.04 ± 0.05	0.00 – 0.22
MDNT	Mean of the distance to the nearest tree to the sampling point (m)	1.27 ± 0.45	0.40 – 2.01
MBS	Mean of bare soil in a sample of 1x1 meters in each sampling point (%)	0.55 ± 0.09	0.41 – 0.75
MSt	Mean of stones in a sample of 1x1 meters in each sampling point (%)	0.36 ± 0.04	0.30 – 0.48
MH	Mean of herbaceous in a sample of 1x1 meters in each sampling point (%)	0.70 ± 0.07	0.51 – 0.78
MSr	Mean of shrubs in a sample of 1x1 meters in each sampling point (%)	0.37 ± 0.08	0.30 – 0.54
MT	Mean of trees in a sample of 1x1 meters in each sampling point (%)	0.30 ± 0.02	0.24 – 0.30
MTN	Mean of the trees number in a ray of 20 meters in each sampling point	0.60 ± 0.54	0.00 – 1.58
MDCH	Mean of the diameter at chest height of the nearest trees in a ray of 20 meters (m)	0.35 ± 0.29	0.00 – 0.94
Pond related features (POND)			
PA	Pond area (ha)	0.50 ± 0.69	0.04 – 2.72
DNP	Distance to the nearest pond (further than 5m) (ha)	2.65 ± 0.43	1.64 – 3.37
DM	Distance to *Minutos* dam (ha)	3.38 ± 0.93	0.00 – 3.97
NP2000	Number of ponds	1.10 ± 0.35	0.00 – 1.46
MDP2000	Mean of the distance to ponds (ha)	2.93 ± 0.78	0.00 – 3.21
DWL	Difference of the water level (max.-min.) (m)	0.89 ± 0.50	0.00 – 1.76

1 – Measured in a 2000m buffer around the pond unless otherwise noted.

2.4.2. Statistical analysis

Before the data exploratory analyses all quantitative variables were log-transformed – [LOG(x+1)], while variables recorded in percentage values were arcsine-square root transformed –

[ASIN(SQRT(X))]. Both types of data transformation helped to normalize the data distribution and reduced the effects of extreme values (Zuur *et al*., 2007; McDonald, 2008).

Statistical and modeling analyses were performed using RStudio 0.97.551, a GUI for *R* (R Core Team, 2013). First, to avoid collinearity, a correlation between all the explanatory variables was calculated. When two correlated variables showed higher values than 0.7, we only considered the most biologically meaningful (Tabachnick & Fidel, 2001). Resulting from this procedure five variables were retained for advance statistical analysis: AGRIC, FOREST, PA, DNP and DM (Table 1).

To analyse if there was a significant difference in bat activity between years, we did a Wilcoxon-paired test, regarding all distances to ponds. A Kruskal-Wallis test was elaborated to evaluate changes in bat activity related to the proximity to ponds in both years (Crawley, 2007; Dytham, 2011).

Given the size of *Minutos* dam, the assumption of its high importance roll in bats activity was considered from the beginning. To test this prediction we did a Pearson product-moment correlation test, that studied the relationship between total bat activity and the distance to *Minutos* dam, and assessed the strength of the association using the coefficient of determination (R^2) of activity explained by distance to *Minutos* (Dytham, 2011).

2.4.3. Model building

Due to data over dispersion in the Generalized Linear Methods (GLM) with a Poisson error structure, we used Negative Binomial Generalized Linear Model (glm.nb) to model bat activity (Burnham & Anderson, 2002; Zuur *et al*., 2007).

Two partial multivariate models with the explanatory variables subsets (LAND and POND) were developed and, through the Akaike Information Criterion (AIC), we selected the best one for each subset (Burnham & Anderson, 2002; Borcard *et al*., 2011; Burnham *et al*., 2011).

To evaluate the effects of each variables set and their shared effect on bat activity, we used variation partitioning following the Borcard *et al*. (1992) recommendations. Also, according to suggestions of Heikkinen *et al*. (2004), data total variation was decomposed in four fractions: a) pure POND effect; b) combined POND and LAND effect; c) pure LAND effect; d) unexplained variation.

3. RESULTS

3.1. Temporal pattern of the bat activity and species richness

In total, 4270 bat calls were recorded, 41.5% in 2011 and 58.5% in 2012, a significant difference of recorded bat activity near ponds in each year (V = 6, *p*-value = 0.014). Despite the difference between years bat activity fluctuated similarly along each year: the highest bat activity was recorded in *season 2* (July), with 47.2%, and it was lowest in *season 1* (May), with 14.7% of the bat passes. From the bat calls recordings, 48.9% could be identified to species level, while 27.0% were assigned to a single-genus complex, 0.6% to a multi-genus complex and 23.4% were not identified (Table 2).

Table 2: Number of assignments of bat recording to species- or genus-complex level and foraging guild at recording locations of different categories, and the Status of species on Portuguese red data of Portugal.

Level	Species	Guild[1]	Total	Conservation Status[2]
Species	*Pipistrellus pygmaeus*	MRE	891	LC
	Pipistrellus pipistrellus	MRE	451	LC
	Pipistrellus kuhlii	MRE	525	LC
	Nyctalus lasiopterus	LRE	2	DD
	Nyctalus leisleri	LRE	72	DD
	Myotis daubentonii	SRE	143	LC
	Myotis escalerai	SRE	2	DD
	Barbastella barbastellus	SRE	3	DD
	Rhinolophus ferrumequinum	SRE	1	VU
Single-genus complex	*Pipistrellus spp.*	MRE	976	LC
	Nyctalus spp.	LRE	18	DD
	Myotis spp.	SRE	76	-
	Eptesicus serotinus/isabellinus	LRE	57	LC
	Myotis myotis/blythii	SRE	25	VU/CR
	Myotis emarginatus/bechsteinii	SRE	2	DD/EN
Multi-genus complex	*Nyctalus leisleri/Eptesicus spp.*	LRE	21	
	Nyctalus spp./Eptesicus spp.	LRE	6	
Not identified			999	

1 – SRE: short-range echolocators; MRE: mid-range echolocators; LRE: long-range echolocators (adapted from Frey-Ehrenbold *et al.*, 2013).
2 – Portuguese red data book (Cabral *et al*. 2005) and "Plano Sectorial da Rede Natura" data (ICN, 2006a,b).

Twelve bat species were recorded and the four most represented were: *Pipistrellus pygmaeus* (20.9%), *Pipistrellus kuhlii* (12.3%), *Pipistrellus pipistrellus* (10.6%) and *Myotis daubentonii* (3.3%). We also registered threatened or data deficient species: *Nyctalus leisleri* (n=72), *Nyctalus lasiopterus* (n=2), *Rhinolophus ferrumequinum* (n=1), *Barbastella barbastellus* (n=3), *Myotis escalerai* (n=2) and *Myotis emarginatus/bechsteinii* (n=2) (Table 2). The two most represented genus were

Pipistrellus (66.6% of total bat passes) and *Myotis* (5.8% of total bat passes). Most of the 3271 identified bat calls were from mid-range echolocators (MRE), representing 86.9% of the total. The other two echolocation guilds contributed with far lower values: 7.7% bat calls were from short--range echolocators (SRE), and 5.4% from long-range echolocators (LRE) (Table 2).

Among the top four sampled species, only *M. daubentonii* activity was greater in 2011 than in 2012 (Figure 2). The activity of these four common species was higher in the second season and lower in the first one (Figure 3).

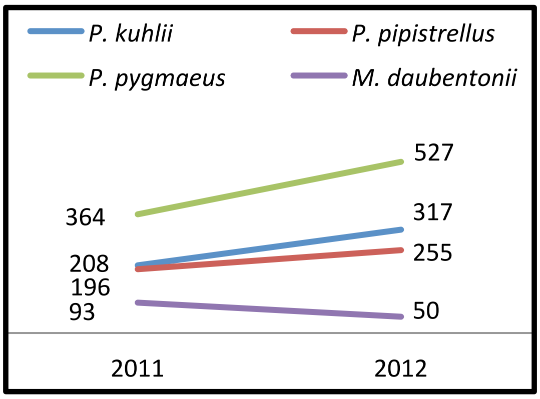

Figure 2: Overall activity of the most frequently recorded bat species, in both years.

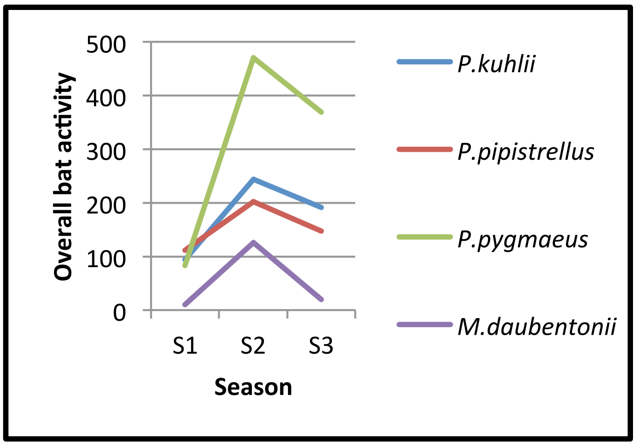

Figure 3: Overall activity of the most frequently recorded bat species, in the three seasons.

Rarest species were recorded in the summer and late summer (*seasons 2* and *3*, respectively). The two passes of *M. emarginatus/bechsteinii* and two passes of *N. lasiopterus* were registered in 2011, and *R. ferrumequinum* was detected only in 2012. In both years only a few passes of *M. escalerai* and *B. barbastellus* were registered.

3.2. Bat activity and distance to water bodies

3.2.1. Distance to ponds

In both years, the average number of bat passes was noticeably higher over or on the margin of water bodies (2011: 40.6% and 2012: 41.4%), drastically declining until 50m away from the margin (2011: 11.3% and 2012: 14.9%). Further from this distance, values decreased slightly or remained constant. However, differences in bat activity variation with distance from the water bodies were only marginally significant (chi-squared = 17.747, d.f. = 10, *p*-value = 0.059). In most stations farther away from the pond margin bat activity during 2012 was higher than in 2011 (Figure 4).

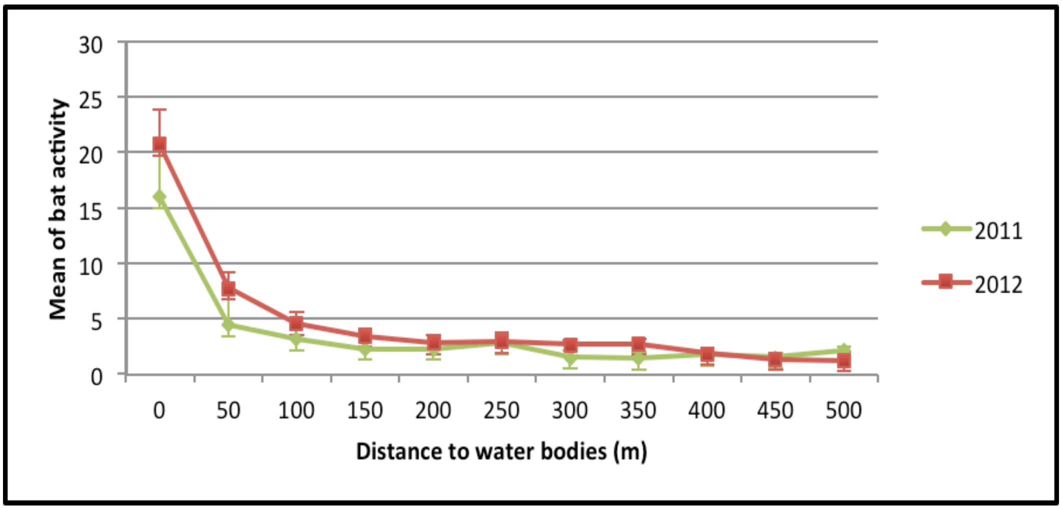

Figure 4: Mean, and respective standard error, of bat activity according to distance to water bodies.

The four most represented species (*Pipistrellus* spp. and *M. daubentonii*) followed the same pattern of activity decreasing away from the ponds (Figure 5). For *M. daubentonii* almost all the bat passes were recorded over or on the margin of the ponds, just over 80% of the bat passes. The three *Pipistrellus* species also showed very high activity near the ponds: *P. pygmaeus* had 50.1%, *P. pipistrellus* had 45.7% and *P. kuhlii* only had 29.3%.

B. barbastellus, *M. emarginatus* and *M. escalerai* had not a clear pattern of activity related to the distance to the water; they were recorded both at the margin of the ponds and beyond 100m. *R. ferrumequinum* (n=1) was only detected at 200m.

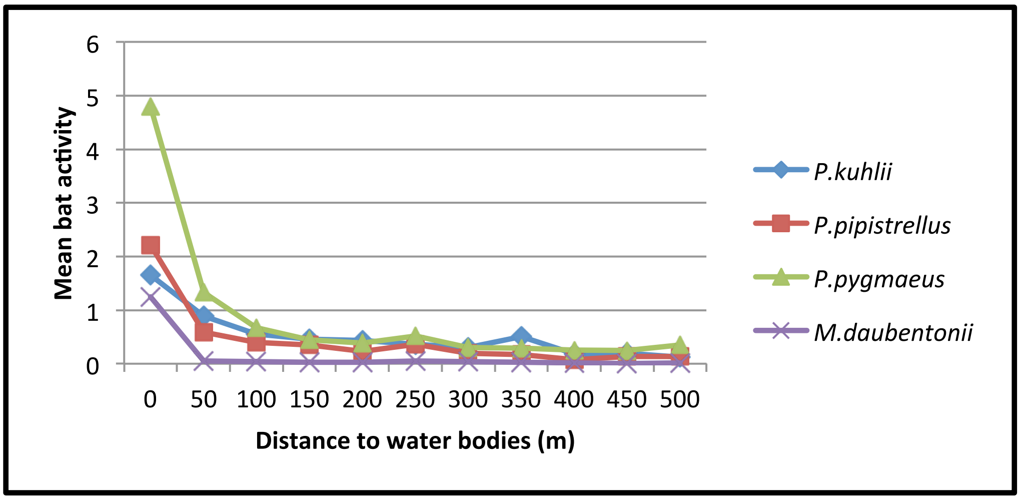

Figure 5: Mean activity of the four most surveyed bats, according to distance to water bodies.

Foraging activity, measured as the number of feeding buzzes (n=573), occurred mostly near the pond margins, at 0m (78.5%), decreasing to 9.1% at 50m from the margin. All the four most surveyed species followed this pattern, being more evident in *P. pygmaeus* (74.1% at the pond margin) and less noticeable in *P. kuhlii* (33.3%). In contrast, all of the 39 feeding buzzes of *M. daubentonii* were detected over the water bodies or close to the margin.

Over 23% of identified social calls (n=457) were also surveyed at the margin, having a second peak at 300m (11.8%). This was also the pattern for *P. pipistrellus* and *P. pygmaeus* social calls. Conversely, *P. kuhlii* had similar numbers of social calls in all distances from the margin survey points.

3.2.1. Distance to Minutos dam

Total bat activity at each pond had a negative association with distance to the *Minutos* dam ($R = -0.82$; d.f. = 14; $P < 0.001$). This relation is quite strong because 68.03% of bat calls variation (R^2) is explained just by the distance to *Minutos* variable.

Without *Minutos* surveyed dates, this relationship weakened, becoming not significant ($R = -0.46$; d.f. = 13; $P = 0.08$). In this analysis, distance to *Minutos* dam only explains 21.5% of activity variation (R^2) (Figure 6).

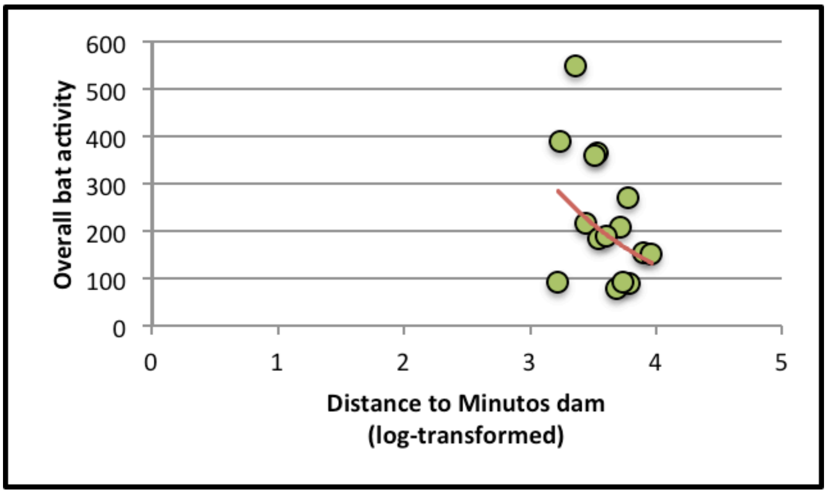

Figure 6: Relation between overall bat activity at each pond and distance to *Minutes* dam, with trend line.

3.3. Pond and landscape variables influencing bat activity

Partial models showed that both area of water bodies (PA) and area of forest in the 2000m buffer radius (FOREST) had a significant positive effect on total bat activity (Table 3). These two variables were also in the overall model with similar coefficients.

Table 3: Coefficients and significance levels (*p*)

Models	Variables	Regression coefficients	*p*	AIC
Partial models				
LAND	FOREST	0.7275	0.038 *	204.53
	Intercept	5.1089	<0.001 ***	
POND	PA	0.5176	0.012 *	206.60
	DNP	0.1758	0.595	
	Intercept	4.7820	<0.001 ***	
Global model				
LAND	FOREST	0.6907	0.012 *	203.2
POND	PA	0.4961	0.005 **	
	DNP	0.4182	0.143	
	Intercept	3.6980	<0.001 ***	

Legend: LAND – Forest area variables; POND – Water bodies' variables; FOREST – Forest area; PA – Pond area; DNP – Distance to the nearest pond.

Sixty-eight percent of the total variance in bat activity near ponds was explained by the overall model. The POND variable subset explained the larger percentage of the total variance, 46.9%. Despite a much lower value, we also found LAND variable set explaining 9.8% of the overall variance. In the same way, POND showed the strongest pure effect on the variance of the total bat activity (48.7%), above four times more than LAND contribution, 11.5%. Results also showed that the interaction between these two variable sets (Adj.R.squared = -0.018) had a competitive effect, one process hindering the contribution of the other (Figure 7).

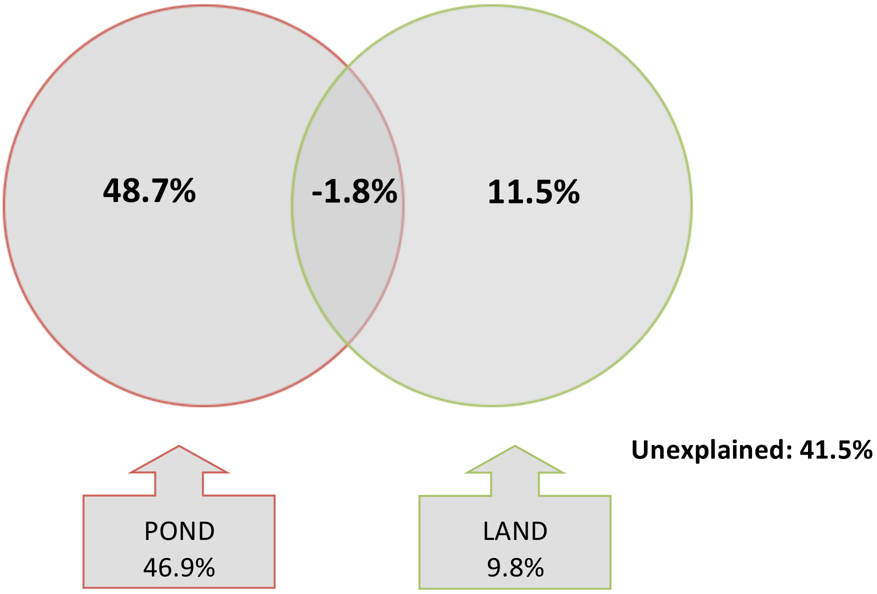

Figure 7: Variation explained by each set of variables (POND and LAND), distinguishing among pure and combined effects.

3.3.1. Pond area

Large ponds had higher bat activity (44.0%) than medium (34.1%) and small (21,9%). This pattern was observed for both years with a slight increase of mean bat activity in 2012 (2011: 44.2% and 2012: 47.2%). Conversely, medium sized ponds had lower mean bat activity in 2012 (2011: 30.8% and 2012: 21.4%). Apparently, bat activity in *season 1* was similar in ponds of small, medium and large sizes, with a slight preference for medium size (36.9%). In summer (*season 2*: 49.1%; and *season 3*: 46.3%), large ponds were clearly the most sought (Figure 8).

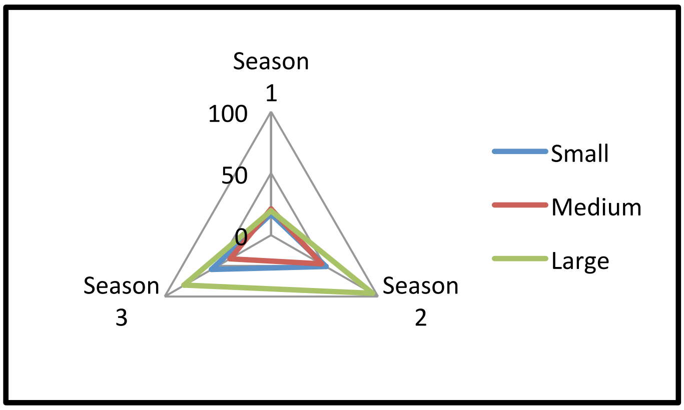

Figure 8: Mean bat activity in the three seasons, according to water body size.

Considering the three *Pipistrellus* spp., their mean activity was also higher in areas surrounding larger water bodies (52.3%), while the difference between small and medium sized ponds was minor, 24.8% and 22.8%, respectively. *M. daubentonii* preferred large (41.7%) and small (50.0%) water bodies, but almost all the bat passes in small ponds where recorded in the same water body near an open area (Figure 9). *M. escalerai* was the only bat specie not recorded in large water bodies.

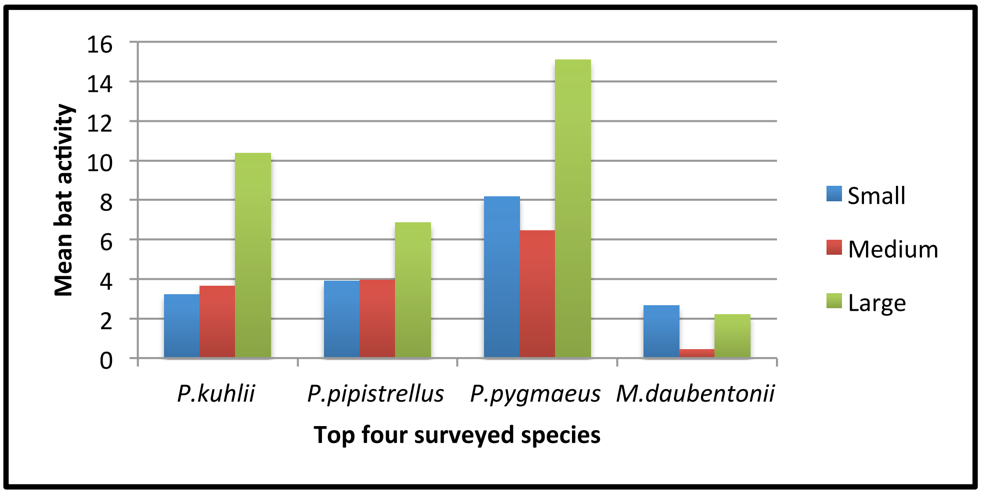

Figure 9: Mean activity of top four surveyed bat species, in different size water bodies.

MRE bats were most often recorded at large (49.5%), than small (26.1%) and medium sized ponds (24.4%). Bats in the LRE guild were detected similarly between all pond sizes, being the medium ponds the preferred ones (42.1%). SRE bats were detected mainly at large (44.2%) and small ponds (42.3%) (Figure 10).

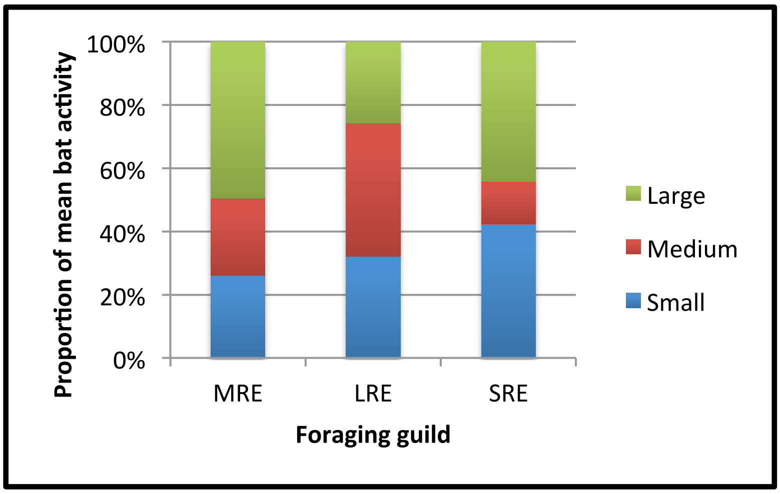

Figure 10: Proportion of mean bat activity of the three foraging guilds, in different size water bodies.

Two bat species had their foraging concentrated in one of the three pond size categories. The majority of *P. pygmaeus* feeding buzzes was detected in large water bodies (52.3%; n=170), and of *P. kuhlii* in medium size ponds (55.6%; n=18), while *P. pipistrellus* foraging activity had similar results for the three size-categories of water bodies. For Daubenton's bat (*M. daubentonii*) foraging activity (n=39) occurred mostly in one small and open pond (before drying), surrounded by *montado* foremost (64.1%), and in large water bodies (30.8%).

Social calls of *Pipistrellus* spp. were most frequent in large water bodies, with higher values for *P. pygmaeus* (47.1%). Soprano pipistrelles (*P. pygmaeus*) were the only specie with social calls concentrated in small ponds.

3.3.2. Forest area

Ponds in *montado* areas had the highest bat activity, with number of bat calls above 300, which is observed in five water bodies with more than 40% of vegetation cover (Figure 11).

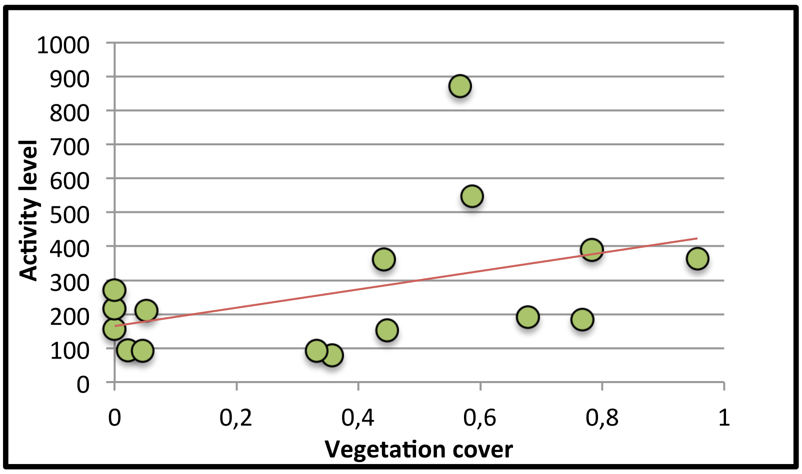

Figure 11: Total number of bat passes according to vegetation cover, with trend line.

The mean activity of the three *Pipistrellus* spp. was higher in forest area (63.6%). For *P. pygmaeus* this preference was not so clear, occurring 55.4% in forest areas, while 75.2% of *P. kuhlii* was observed in these areas. *M. daubentonii* had similar results in both land uses surrounding the ponds, agricultural and forest (Figure 12).

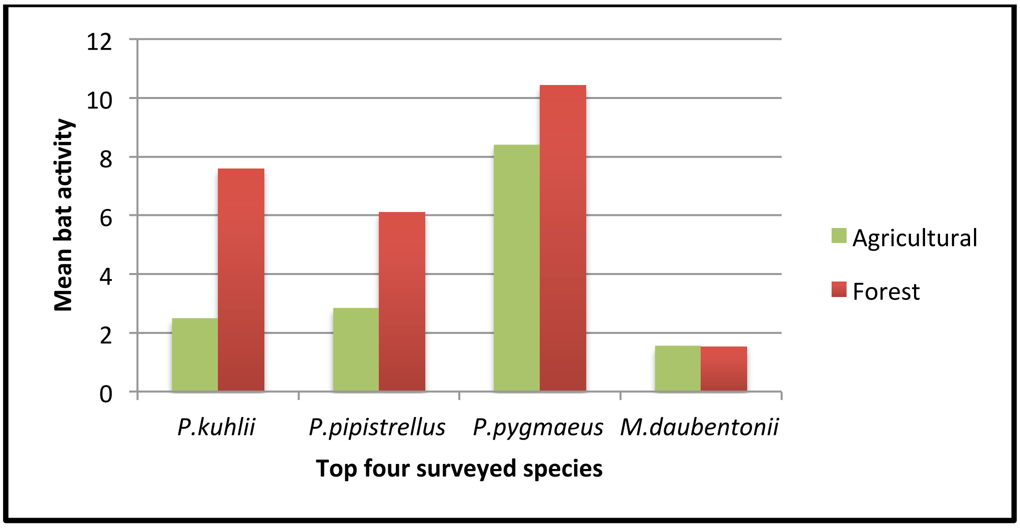

Figure 12: Mean activity of top four surveyed bat species, in agricultural and forest land use.

According to our results, bat species classified in the echolocation guilds MRE and LRE were most registered in forest areas (65.1% and 69.5%, respectively), but those in the SRE guild had similar values of activity for agricultural and forest areas (Figure 13).

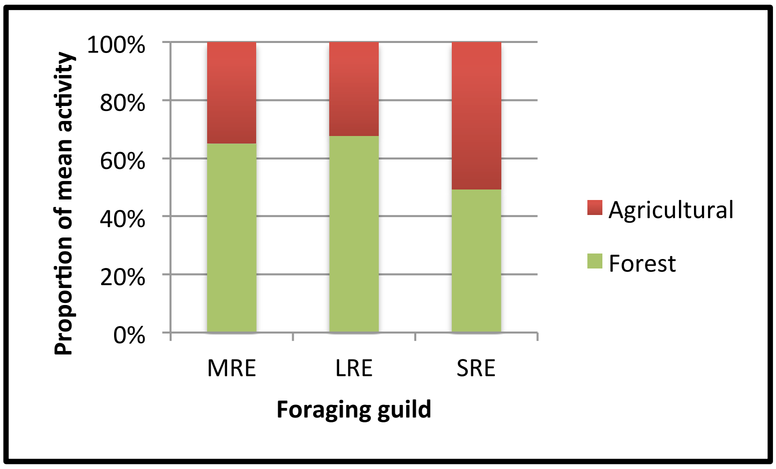

Figure 13: Proportion of mean activity of the three bat foraging guilds, in forest and agricultural areas.

Rare species were detected only in forest areas, except for *M. emarginatus* that was also recorded in an agricultural area.

Foraging activity was higher in *montado* (forest areas) for *P. pipistrellus* (91.7%; n=36), *P. pygmaeus* (76.5%; n=170) and *M. daubentonii* (69.2%; n=39). Conversely, Kuhl's pipistrelle bats (*P. kuhlii*) had similar numbers of feeding buzzes in forest and agricultural areas. Likewise, regarding social calls, all *Pipistrellus* spp. showed the great majority of observations in forest areas (91.4%; n=209).

4. Discussion

4.1. Temporal pattern of the bat activity and species richness

Our results show a high bat activity centred in water bodies with a significant increase in 2012 compared to 2011. The year 2012 was extremely dry, considered the fifth driest year since 1931. Also, total rainfall from January to September was lower by 42% in 2012 compared to 2011 (MAMAOT, 2013). Therefore, the detected increase in bat activity close to water bodies may be due to the higher water requirements of bats (Lacasa *et al.*, 2010) caused by drier conditions in 2012. The much lower water availability in the surrounding landscape in dry periods may play a significant role as well. The typical environmental conditions of the Mediterranean region such as large dry season, high temperature and low relative humidity, combined with the bats high water evaporation (due to the relationship between high body surface area and the existence of flight membranes devoid of hair), increase the rates of evaporative water loss in bats (Webb *et al.*, 1995). These conditions may induce bats to use intensively the few available water sources that exist in the landscape during extremely hot and dry periods. Unlike what McCain (2007) reported, that temperature and water availability affects species richness because of food resources and thermoregulatory constrains, our results showed that detected changes in bat activity at ponds were not mirrored in species richness values, occurring a similar number of bat species in both years, almost the total of the bat species registered in that area.

Bat activity in ponds had a marked increase in summer (seasons 2 and 3), showing seasonal movement according to favourable environments (Robinson *et al*., 2009). During early summer, when female bats are pregnant their water requirements are much higher than those of non--pregnant females (Adams & Hayes 2008) pointing to a strong relation between water availability and breeding success. Therefore, the possible presence of breeding colonies in the neighbourhood (Flaquer *et al*., 2006) of ponds may explain the described pattern. Additionally, bat activity may increase in mid and late summer because of the first flights of young bats (Lesiński *et al*, 2007) that can explore the abundant patches of insect prey over or on the margins of ponds.

As expected, the most surveyed species were four of the most abundant in Portugal: *P. pygmaeus*, *P. pipistrellus*, *P. kuhlii* and *M. daubentonii* (Cabral *et al*., 2006). All of the four referred species were also most recorded in summer. This period is the peak of the Diptera abundance (Anthony & Kunz, 1977 *in* Bartonička & Řehák, 2004), one of the favorite insect preys of *P. pygmaeus* and of *P. pipistrellus* (Kalko, 1995). This can also be explained by the start of juvenile flying and foraging activity during this period (Bartonička & Řehák, 2004).

4.2. Bat activity and distance to water bodies

Bat activity at several distances to water bodies showed a near significant relationship, confirming that, in general, the way that bats forage throughout the landscape is defined by distances to water resources (Zukal & Řehák, 2006; Rainho & Palmeirim, 2011). Flight enables bats to travel long distances in one night, searching resources sparse in the landscape (Wickramasingue *et al*., 2003; Rainho & Palmeirim, 2011), and the impact of the presence of water extends for several kilometres (Rainho & Palmeirim, 2011).

Analysing at a smaller ecological scale we recorded an increase of bat activity at 100m from the ponds that was even sharper at 50m from the margin. Similarly, Downs & Racey (2006) found an increase of bat activity closer than 70m of the rivers. Therefore, our results add to the existing evidence that different water habitats influence bat activity with significant increases but if at distances of 100m or less. Also, the recorded higher bat activity near water bodies, when compared to farther from the margins, shows a clear importance of the proximity to a drinking water source, increasing habitat suitability (Vaughan *et al*., 1997; Mickevièiene & Mickevièius, 2001; Kusch *et al*., 2004; Menzel *et al*., 2005; Rogers *et al*., 2006; Lisón & Calvo, 2011; Rainho & Palmeirim, 2011). Additionally, higher foraging activity also occurred near or over water bodies; the majority of the feeding buzzes occurred at the margin of the selected ponds (station 0m). This pattern increases water bodies' importance for feeding activity of bats because the presence of suitable food resources (Warren *et al*., 2000; Kusch *et al*., 2004; Avila-Flores & Fenton, 2005; Zukal & Řehák, 2006). Also, during the feeding period, bats drink water, having to forage near an easily reachable source of open water (Rainho & Palmeirim, 2011). Water is the major mineral source for bats (Russo *et al*., 2012) and its surface presents a great biomass of bat preys (Rydell *et al*., 1999; Zukal & Řehák, 2006), but the strength of the relation between activity and distance to water depends on each species flight characteristics and drinking needs while foraging (Rainho & Palmeirim, 2011).

The four most sampled bat species (*P. pygmaeus*, *P. pipistrellus*, *P. kuhlii* and *M. daubentonii*) followed the same pattern, showing a higher activity near water bodies and decreasing sharply at 50m and farther from the margin. In general, common bats have a non-selective, opportunistic, foraging behaviour, showing a relation between diet composition with local prey abundance (Bontadina *et al*., 2008), but there are slight differences between food preferences, and consequently in activity over water bodies. Different bat forage strategies evolved in order to discern niches and land uses (Kusch & Schotte, 2007).

The three *Pipistrellus* bat species (*P. pygmaeus. P. pipistrellus* and *P. kuhlii*) have a great preference for aquatic habitats (Warren *et al*., 2000; Russo & Jones, 2003; Davidson-Watts *et al*., 2006; Lisón & Calvo, 2013). Although they tend to dislike irrigated cultures, they are associated with irrigated ponds. In spite of the three species having different habitat preferences we observed an overlap of their habitat *i.e*. all had the higher activity level near ponds, which means that the competition may be prevented and the coexistence maintained through resource partitioning mechanisms (Lisón & Calvo, 2013).

In general, *P. pygmaeus* shows a higher preference for riparian habitats, comparing to *P. pipistrellus* (Vaughan *et al*., 1997; Russo & Jones, 2003; Davidson-Watts *et al*., 2006). Both mainly hunt small insects, mosquito-sized (e.g. Diptera, Trichoptera) (Kalko, 1995; BCT, 2010b, c), but unlike *P. pygmaeus* that feeds mostly on small flies associated with water (BCT, 2010c), *P. pipistrellus* is generalist in using foraging habitats (Vaughan *et al*., 1997; Russo & Jones, 2003), hunting on a wide range of small flies and aquatic midges and mosquitos (BCT, 2010b). However, Lisón & Calvo (2011) study indicates that *P. pipistrellus* also shows a preference for aquatic habitats in the Mediterranean landscape.

Water bodies provide the main items of the Daubenton's bat diet: small flies (especially chironomid midges), caddisflies and mayflies (BCT, 2010a). That is certainly the reason for the foraging pattern of this species, near and over water surfaces (Kalko & Schnitzler, 1989; Rydell *et al.*, 1999; Warren *et al.*, 2000; Mickevièiene & Mickevièius, 2001; Downs & Racey, 2006) and for only occasionally foraging when commuting between colony and foraging areas (Verboom & Huitema, 1997). Our results agree with the findings of these authors. Overall, to *Myotis* genus, aquatic habitats are considered important areas to forage (Warren *et al.*, 2000; Wickramasingue *et al.*, 2003), and this abundant provision of food may regulate the timing of parturition (Arlettaz *et al.*, 2001).

Besides, our results show a significant association between bat activity level and distance to *Minutos* dam. This is the water body with the higher number of calls, decreasing with the distance, which indicates that this dam provides good habitats to forage and drinking water (Lisón & Calvo, 2011).

Distance variables bring a precious value to bat foraging suitability maps. In a Mediterranean area, where water sources are infrequent and scattered in summer, distance to water bodies can be a limiting element in the use of space (Rainho & Palmeirim, 2011).

4.3. What pond features influence bat activity?

Our models show that bat activity is influenced by water bodies and landscape (vegetation cover) features. This habitat combination is associated with a higher bat activity (Owen *et al.*, 2004). Pond area is the most responsible feature, explaining the major part of our results. These results agree with studies that show a higher bat activity over water surface than in other habitats (Vaughan *et al.*, 1997; Bartonička & Řehák, 2004; Rainho & Palmeirim, 2011). In the present study bat activity increased significantly with pond area. Although some studies only relate moderately biodiversity with pond area (Gioria, 2013), others show that activity and composition of bat communities are clearly influenced by pond size (Rabe & Rosenstock, 2005; Downs & Racey, 2006; Lloyd *et al.*, 2006; Razgour *et al.*, 2010), even with the existence of a preference variance between taxa (Oertli *et al.*, 2002).

Also, our model shows a significant positive relationship between bats activity and forest area in pond surrounding area, such as demonstrated in other studies (Avila-Flores & Fenton, 2005; Lumsden & Bennett, 2005; Lentini *et al*., 2012). The *montado* is the dominant land cover in the category forest. It has a complex and diverse structure, with open areas mixed with different tree densities in forest area, that may provide areas to different bat guilds to forage (Costa *et al*., 1998; Kusch & Schotte, 2007; Galantino & Mira, 2008), such as *B. barbastellus* (Lesiński *et al*, 2007). Management actions in the *montado* such as low-levels of livestock grazing increase the availability of insects that feed on dung, that are most of the time the prey for some bat species, like *Myotis myotis* (Rainho, 2007). Also, trees provide wind shelter and availability of food plants to insects (Warren *et al*., 2000), increasing the local availability. Other important resources for bats are also available in the *montados*. Large cork and holm-oaks may offer roosts for bats, giving them protection from predators. Since bat distribution and abundance may be limited for availability of suitable roost sites (Jenkins *et al*., 1998), forest variable gained a higher importance. Therefore, *montado* is considered a preferred habitat for bat communities, providing shelter and availability of insects (Russo & Jones, 2003; Avila-Flores & Fenton, 2005; Rainho, 2007) and its inclusion in the model is indicative of its high importance. Nevertheless, it is important to take into account that the present work does not consider roost availability due to logistic constrains. The distribution of this important resource affects strongly bat populations' landscape use and their activity spatial pattern (Lučan *et al*., 2009).

Our model explains over 50% of the bat activity variance. The two different variable sets convey information at different ecological scales. Subset POND, measured at the local scale has a greater contribution to explain bat activity (pure effect, 46.7%). Landscape scale level subset (LAND), related to forest area in a 2000m buffer, shows a much smaller although significant contribution (pure effect, 11.5%) in bat activity. This is in contrast to other author's findings where woodland habitats are indispensable if only associated with water bodies (Mickevièiene & Mickevièius, 2001). So, our results suggest that local scale features, like pond area, can influence bat communities (Razgour *et al*., 2010) to a greater extent than landscape variables.

4.3.1. The role of large water bodies, as Minutos Dam, on bat activity

In the current study, *Minutos* dam, the larger surveyed water body, had higher species richness (eight bat species), as well as the highest value of bat activity. These results agree with the studies that relate the increase of pond size with the increase of species richness over the water

(Taylor & Tuttle, 2007; Ruggiero *et al*., 2008; Johnson *et al*., 2010). From a relative point of view, large water bodies of large surface area are more intensively used by bats, in general (Rabe & Rosenstock, 2005), which can be explained by the manoeuvrability of these mammals. When drinking, bats need a free “swoop zone” to manoeuvre. So, flight characteristics will define the minimum pond size they can use. Smaller and maneuverable bats are able to drink in smaller ponds (Ciechanowski, 2002; Rabe & Rosenstock, 2005; Tuttle *et al*., 2006; Taylor & Tuttle, 2007). Medium and large ponds provide space to the less maneuverable species for drinking and feeding (Rabe & Rosenstock, 2005; Tuttle *et al*., 2006; Taylor & Tuttle, 2007). Bigger ponds may act as backups of small ones in the landscape, which are susceptible to drying earlier in summer (Taylor & Tuttle, 2007). Moreover, they may provide the partitioning of the pond surface, allowing bats more or less maneuverable to drink and to forage near the water surfaces (Razgour *et al*., 2010). Kalko & Schnitzler (1989) also suggested that larger water surfaces provide space to bats meander and loop in group for longer time periods, while they have to fly alone in constrained areas, making occasional narrow turns. That can be the reason for the higher number of *M. daubentonii* calls in larger ponds. Furthermore, it frequently forages in groups and creates group territories to do so (Zukal & Řehák, 2006), what can explain the higher sampling in large ponds. The observable presence of Daubenton’s bat in a small pond can be related to the fact that it is one open pond, with space to maneuvers.

4.3.2. Bat species preferences according to vegetation cover

Concerning to *Pipistrellus* spp. the higher preference for forest areas agrees with their preference to a clutter structure to forage (Downs & Racey, 2006; Ciechanowski *et al*., 2011) over arable habitats (Vaughan *et al*., 1997). This higher bat activity in forest areas, comparing to agricultural areas, can occur because of the opportunistic behavior of Pipistrelles. During pregnancy and lactation these bats can unselectively forage on Nematocera, the most abundant flying insects (Hoare, 1991 *in* Bartonička & Řehák, 2004). Flying near vegetation also provides wind shelter (Bartonička & Řehák, 2004).

In our results the preference for forest habitats was clearer to the most generalist species of the Pipistrelles, than to the *P. pygmaeus*. In spite of their morphological overlap, which is often linked to similar flight performance and habitat use (Norberg & Rayner, 1987; Davidson-Watts *et al*., 2006), Pipistrelles have differences in habitat selection (Davidson-Watts *et al*., 2006). Soprano pipistrelle is known to prefer semi-close habitats rather than the open ones (Bartonička & Řehák, 2004). Also, this bat is more specific about habitat requirements, remaining in its optimal habitat (Sattler *et al*., 2007), what can explain this lack of preference, reinforcing the inclination only for riparian habitats. Same explanation can be attributed to *M. daubentonii*, which do not show any preference for forest or agricultural area.

Although *P. pipistrellus* is referenced to prefer open areas rather than forest (Bartonička & Řehák, 2004), being tolerant to deviations from its optimum habitat (Sattler *et al*., 2007) and visiting a higher number of foraging sites (Davidson-Watts *et al*., 2006), in the Mediterranean region this bat shows a greater preference for aquatic habitats (Lisón & Calvo, 2011). Nevertheless, the observed higher presence of Commom Pipistrelle in forest areas, compared to agricultural, can relate to its preference for wind sheltered areas, usually flying near trees (Verboom & Huitema, 1997).

4. 4 Conservation implications

Many bats are threatened by habitat loss (Rainho & Palmeirim, 2011) and to conserve their populations we have to identify and prioritize the potentially important sites to protect, evaluating important bat habitat features on a wider landscape level (Taylor, 2010).

Larger ponds support higher biodiversity levels (Oertli *et al*., 2002; Ruggiero *et al*., 2008; Razgour *et al*., 2010) and, often, small ponds are ignored from the management point of view, because, apparently, they do not have any use to humans, like fishing or recreation (Schwartz & Jenkins, 2000). However, several studies showed the importance of these ponds to aquatic and terrestrial wildlife species, particularly in arid regions and during spring and summer (*e.g.* Nicolete, 2001; Ciechanowski, 2002; Oertli *et al*., 2002; Razgour *et al*., 2010; Gioria, 2013). In general, water bodies built by land managers become an essential resource to many wildlife species in a local, regional and national level, particularly in drought prone regions that show a decline in natural water bodies distribution and abundance (Ruggiero *et al*., 2008; Taylor, 2010; Gioria, 2013). In addition, being ecological structures with high insect prey densities, these water bodies have a critical importance for bats (Warren *et al*., 2000). Therefore, a high number of microhabitats within each pond, *i.e.* spatial heterogeneity, is important to maintain a diverse bat community (Razgour *et al*., 2010).

Water quality is likely another significant factor influencing bat activity over ponds. Although Pocock & Jennings (2008) suggest that management practices such as agrochemical use are threat but less important to bats than habitat loss, other studies showed a negative influence of polluted waters in bat activity (Biscardi *et al*., 2007; Gioria, 2013). So it is also important to encourage the conservation of the existing ponds by controlling the use of fertilizers, herbicides and pesticides in the surrounding area (Russo & Jones, 2003; Taylor & Tuttle, 2007; Gioria, 2013). The use of fences to prevent cattle from directly drinking is also needed to prevent high concentrations of organic matter in the water (Taylor & Tuttle, 2007). Also, the temperature increase has impacts in water quality, through dissolved organic matter, and micropollutants and pathogens rise in concentration or number (Delpla *et al*., 2009).

Several studies also emphasize the importance of habitats conservation like *montado*, with scattered trees, in order to preserve bat biodiversity (Rainho 2007; Rebelo & Rainho 2008). A cover mosaic, in a local scale, can favour several species, particularly the edge-specialists (in roosts and foraging). Generalist species can better adapt to changes in land use, but the ones with specific habitat requirements may not fit or resist to these transformations and forest fragmentation, decreasing in the landscape, or even geographical distribution (Wickramasingue *et al*., 2003; Biscardi *et al*., 2007; Johnson *et al*., 2008). So, forest conservation is essential to specialist success in areas where urban expansion or agricultural intensification occurs (Wickramasingue *et al*., 2003; Johnson *et al*., 2008).

Summarily, during the summer, the Iberian typical Mediterranean landscape provides an optimal habitat for bats forage. Although, as a result of acceleration of global warming and consequent summer dryness, prey and water availability can be temporarily limited, persuading bats to use intensively the few available water sources that persist in the landscape in these harsh conditions. Models predict an intensification of the situation in the future, with a probable increase of dry and water stress (Meehl & Tebaldi, 2004; Schär *et al*. 2004; Alcamo *et al*., 2007), so the preservation of this landscape, dominated by oak-woodland and several scattered and vegetated water bodies should be highly encouraged (Russo & Jones, 2003; Lumsden & Bennett, 2005; Rainho, 2007; Rainho & Palmeirim, 2011; Sherwin *et al*., 2012) to promote a diverse community composed of large populations of bats.

5. References

Adams, R. A. & Hayes, M. A. (2008). Water availability and successful lactation by bats as related to climate change in arid regions of western North America. *Journal of Animal Ecology*, 77: 1115 – 1121.

Ahlén, I. (2004). Heterodyne and time-expansion methods for identification of bats in the field and through sound analysis. *In*: R. M., Brigham; E. K. V., Kalko; G. G., Jones; S. Parsons; H. J. G. A., Limpens (eds.). *Bat Echolocation Research: Tools, Techniques, and Analysis*. Austin, TX: Bat Conservation International: 72 – 79.

Alcamo, J.; Flörke, M.; Märker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrological Sciences Journal*, 52(2): 247 – 275.

Arlettaz, R.; Christe, P.; Lugon, A.; Perrin, N.; Vogel, P. (2001). Food availability dictates the timing of parturition in insectivorous mouse-eared bats. *OIKOS*, 95: 105 – 111.

Avila-Flores, R. & Fenton, M. B. (2005). Use of spatial features by foraging insectivorous bats in a large urban landscape. *Journal of Mammalogy*, 86 (6): 1193 – 1204.

Bartonička T. & Řehák Z. (2004). Flight activity and habitat use of *Pipistrellus pygmaeus* in a floodplain forest. *Mammalia*, 68 (4): 365 – 375.

BCT (2010a). Daubenton's bat: *Myotis daubentonii*. Bat Conservation Trust. Accessed in: 08.2013. Available in: http://www.bats.org.uk/data/files/Species_Info_sheets/commonpipistrelle_11.02.13.pdf.

BCT (2010b). Common pipistrelle: *Pipistrellus pipistrellus*. Bat Conservation Trust. Accessed in: 08.2013. Available in: http://www.bats.org.uk/data/files/Species_Info_sheets/commonpipistrelle_11.02.13.pdf.

BCT (2010c). Soprano pipistrelle: *Pipistrellus pygmaeus*. Bat Conservation Trust. Accessed in: 08.2013. Available in: http://www.bats.org.uk/data/files/Species_Info_sheets/commonpipistrelle_11.02.13.pdf.

Biscardi, S.; Russo, D.; Casciani, V.; Cesarini, D.; Mei, M.; Boitani, L. (2007). Foraging requirements of the endangered long-fingered bat: the influence of micro-habitat structure, water quality and prey type. *Journal of Zoology*, 273: 372 – 381.

Blondel, J. & Aronson, J. (2004). *Biology and Wildlife of the Mediterranean Region*. Oxford Univ. Press, Oxford.

Bontadina, F.; Schmied, S. F.; Beck, A.; Arlettaz, R. (2008). Changes in prey abundance unlikely to explain the demography of a critically endangered Central European bat. *Journal of Applied Ecology*, 45, 641 – 648.

Borcard, D.; Gillet, F.; Legendre, P. (2011). *Numerical Ecology with R*. Springer, New York.

Borcard, D.; Legendre, P.; Drapeau, P. (1992). Partialling out the Spatial Component of Ecological Variation. *Ecology*, 73(3): 1045 – 1055.

Boyles, J. G.; Cryan, P. M.; McCracken, G. F.; Kunz, T. H. (2011). Economic Importance of Bats in Agriculture. *Science*, 332: 41 – 42.

Burles, D. W.; Brigham, R. M.; Ring, R. A.; Reimchen, T. E. (2009). Influence of weather on two insectivorous bats in a temperature Pacific Northwest rainforest. *Canadian Journal of Zoology*, 87: 132 – 138.

Burnham, K. P. & Anderson, D. R. (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. 2nd ed., Springer, New York.

Burnham, K. P.; Anderson, D. R.; Huyvaert, K. P. (2011). AIC model selection and multimodel inference in behavioral ecology: some background, observations, and comparisons. *Behav. Ecol. Sociobiol.*, 65: 23 – 35.

Burnie, D.; Birdlife International; Hoare, B. (2007). *Bird: The Definitive Visual Guide*. Dorling Kindersley Limited, Londres.

Cabral, M. (coord.); Almeida, J.; Almeida, P.; Dellinger, T.; Almeida, N. F.; Oliveira, M.; Palmeirim, J.; Queiroz, A.; Rogado, I.; Santos-Reis, M. (eds.). (2006). *Livro Vermelho dos Vertebrados de Portugal*. 2nd ed., Instituto da Conservação da Natureza. Assírio & Alvim, Lisboa.

Chruszcz, B. J. & Barclay, R. M. R. (2002). Thermoregulatory ecology of a solitary bat, *Myotis evotis*, roosting in rock crevices. *Functional Ecology*, 16: 18 – 26.

Ciechanowski, M. (2002). Community structure and activity of bats (Chiroptera) over different water bodies. *Mammalian Biology*, 67: 276 – 285.

Ciechanowski, M.; Kubic, W.; Rynkiewicz, A.; Zwolicki, A. (2011). Reintroduction of beavers *Castor fiber* may improve habitat quality for vespertilionid bats foraging in small river valleys. *Eur. J. Wildl. Res*., 57: 737 – 747.

Cleveland, C. J.; Betke, M.; Federico, P.; Frank, J. D.; Hallam, T. G.; Horn, J.; López Jr., J. D.; McCracken, G. F.; Medellín, R. A.; Moreno-Valdez, A.; Sansone, C. G.; Westbrook, J. K.; Kunz, T. H. (2006). Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. *Front. Ecol. Environ*., 4(5): 238 – 243.

Costa, J C.; Aguiar, C.; Capelo, J. H.; Lousã, M.; Neto, C. (1998). Biogeografia de Portugal Continental. *Quercetea*, 0: 5 – 56.

Crawley, M. J. (2007). *The R Book*. John Wiley & Sons Ltd., England.

Davidson-Watts, I.; Walls, S.; Jones, G. (2006). Differential habitat selection by *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus* identifies distinct conservation needs for cryptic species of echolocating bats. *Biological Conservation*, 133: 118 – 127.

Delpla, I.; Jung, A.-V.; Baures, E.; Clement, M.; Thomas, O. (2009). Impacts of climate change on surface water quality in relation to drinking water production. *Environment International*, 35: 1225 – 1233.

Denzinger, A.; Siemers, B. M.; Schaub, A.; Schnitzler, H.-U. (2001). Echolocation by the barbastelle bat, *Barbastella barbastellus*. *J. Comp. Physiol. A*., 187: 521 – 528.

DK Publishing (2010). *The Natural History Book: The ultimate visual guide to everything on Earth*. Dorling Kindersley Limited, Londres.

Downs, N. C. & Racey, P. A. (2006). The use by bats of habitat features in mixed farmland in Scotland. *Acta Chiropterologica*, 8(1): 169 – 185.

Dytham, C. (2011). Choosing and Using Statistics: A Biologist's Guide. *3rd ed., Wiley-Blackwell, UK.*

Ehrlich, P. R. (2010). Human population and conservation. *In*: Sodhi, N. S. e Ehrlich, P. R. (eds.). *Biodiversity for all*. Oxford University Press: 2 – 3.

ESRI (2011). *ArcGIS Desktop: Release 10*. Redlands, CA: Environmental Systems Research Institute.

Federico, P.; Hallam, T. G.; McCracken, G. F.; Purucker, S. T.; Grant, W. E.; Correa-Sandoval, A. N.; Westbrook, J. K.; Medellín, R. A.; Cleveland, C. J.; Sansone, C. G.; López Jr., J. D.; Betke, M.; Moreno-Valdez, A.; Kunz, T. H. (2008). Brazilian free-tailed bats as insect pest regulators in transgenic and conventional cotton crops. *Ecological Applications*, 18(4): 826 – 837.

Fenton, M. (1999). Describing the echolocation calls and behavior of bats. *Acta Chiropterologica*, 1: 127 – 136.

Flaquer, C.; Torre, I.; Ruiz-Jarillo, R. (2006). The value of bat-boxes in the conservation of *Pipistrellus pygmaeus* in wetland rice paddies. *Biological Conservation*, 128: 223 – 230.

Frey-Ehrenbold, A.; Bontadina, F.; Arlettaz, R.; Obrist, M. K. (2013). Landscape connectivity, habitat structure and activity of bat guilds in farmland-dominated matrices. *Journal of Applied Ecology*, 50: 252 – 261.

Frick, W. F; Reynolds, D. S.; Kunz, T. H. (2010a). Influence of climate and reproductive timing on demography of little brown myotis *Myotis lucifugus*. *Journal of Animal Ecology*, 79: 128 – 136.

Frick, W. F.; Pollock, J. F.; Hicks, A. C.; Langwig, K. E.; Reynolds, D. S.; Turner, G. G.; Butchkoski, C. M.; Kunz, T. H. (2010b). An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species. *Science*, 329: 679 – 682.

Galantinho, A. & Mira, A. (2009). The influence of human, livestock, and ecological features on the occurrence of genet (*Genetta genetta*): a case study on Mediterranean farmland. *Ecological Research*, 24(3): 671 – 685.

Gioria, M. (2013). Freshwater Biodiversity in the Irish Agricultural Landscape: The Significance of Ponds. *STRIVE* (*Science, Technology, Research & Innovation for the Environment*), Report nº 80.

Heikkinen, R.; Luoto, M.; Virkkala, R.; Rainio, K. (2004). Effects of habitat cover, landscape structure and spatial variables on the abundance of birds in agricultural-forest mosaic. *Journal of Applie Ecology*, 41: 824 – 835.

Hooi, T. K.; Akbar, Z.; Kunz, T. H.; Ahmad, Y. (1996). Landscaping and Bat Conservation. *The Malayan Naturalist*: 38 – 39. Available in: http://www.bu.edu/cecb/files/2009/08/tanlandscaping1996.pdf.

Horn, J. W.; Arnett, E. B.; Kunz, T. H. (2008). Behavioral Responses of Bats to Operating Wind Turbines. *Journal of Wildlife Management*, 72(1): 123 – 132.

ICN (2006a). *Plano Sectorial da Rede Natura 2000: Myotis bechsteinii*. Instituto da Conservação da Natureza. Accessed in: 08.2013, Available in: http://www.icn.pt/psrn2000/caracterizacao_valores_naturais/FAUNA/mamiferos/Myotis%20bechsteini.pdf.

ICN (2006b). *Plano Sectorial da Rede Natura 2000: Myotis emarginatus*. Instituto da Conservação da Natureza. Accessed in: 08.2013. Available in: http://www.icn.pt/psrn2000/caracterizacao_valores_naturais/FAUNA/mamiferos/Myotis%20emarginatus.pdf.

ICN (2006c). *Plano Sectorial da Rede Natura 2000: Monfurado*. Instituto da Conservação da Natureza. Accessed in: 08.2013, Available in: http://www.icn.pt/psrn2000/fichas_sitios/Sitio_MONFURADO.pdf

ICNB (2008). *Tenho morcegos em casa, o que devo fazer? (Guia de apoio a situações de coabitação e exclusão de morcegos em edifícios)*. Instituto da Conservação da Natureza e da Biodiversidade, ICNB, Lisboa. [not published].

IM (2008). *Normais Climatológicas – 1981-2010 (provisórias) – Évora*. Instituto de Meteorologia. Accessed in: 24.11.2012. Available in: http://www.meteo.pt/pt/oclima/normais.clima/1981-2010/007/

IUCN (2013). *The IUCN Red List of Threatened Species*. International Union for Conservation of Nature and Natural Resources. Accessed in: 08.2013. Available in: http://www.iucnredlist.org/

Jenkins, E. V.; Laine, T.; Morgan, S. E.; Cole, K. R.; Speakman, J. R. (1998). Roost selection in the pipistrelle bat, *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae), in northeast Scotland. *Animal Behaviour*, 56: 909 – 917.

Jensen, M. E. & Miller, L. A. (1999). Echolocation signals of the bat *Eptesicus serotinus* recorded using a vertical microphone array: effect of flight altitude on searching signals. *Behav. Ecol. Sociobiol.*, 47: 60 – 69.

Johnson, J. B.; Gates, J. E.; Ford, W. M. (2008). Distribution and activity of bats at local and landscape scales within a rural–urban gradient. *Urban Ecosyst.*, 11: 227 – 242.

Johnson, J.; Ford, W. M.; Edwards, J. W.; Menzel, M. A. (2010). Bat community structure within riparian areas of northwestern Georgia, USA. *Folia Zool.*, 59(3): 192 – 202.

Jones, G.; Jacobs, D. S.; Kunz, T. H.; Willig, M. R.; Racey, P. A. (2009). Carpe noctem: the importance of bats as bioindicators. *Endangered Species Research*, 8: 93 – 115.

Kalko, E. K. (1995). Insect pursuit, prey capture and echolocation in pipistrelle bats (Microchiroptera). *Animal Behaviour*, 50: 861 – 880.

Kalko, E. K. V. & Schnitzler, H.-U. (1989). The echolocation and hunting behavior of Daubenton's bat, *Myotis daubentoni*. *Behav. Ecol. Sociobiol.*, 24: 225 – 238.

Kunz, T. H.; Gauthreaux Jr, S. A.; Hristov, N. I.; Horn, J. W.; Jones, G.; Kalko, E. K. V.; Larkin, R. P.; McCracken, G. F.; Swartz, S. M.; Srygley, R. B.; Dudley, R.; Westbrook, J. K.; Wikelski, M. (2008).

Aeroecology: probing and modelling the aerosphere. *Integrative and Comparative Biology*: 48(1): 1 – 11.

Kusch, J. & Schotte, F. (2007). Effects of fine-scale foraging habitat selection on bat community structure and diversity in a temperate low mountain range forest. *Folia Zool*., 56(3): 263 – 276.

Kusch, J.; Weber, C.; Idelberger, S.; Koob, T. (2004). Foraging habitat preferences of bats in relation to food supply and spatial vegetation structures in a western European low mountain range forest. *Folia Zoo*., 53(2): 113 – 128.

Lacasa, V. R. G.; García-Abad, C. S.; Martín, R. P.; Rodríguez, D. J. B.; Garrido, J. A. P.; de La Varga, M. E. A. (2010). Small game water troughs in a Spanish agrarian pseudo steppe: visits and water site choice by wild fauna. *Eur. J. Wildl. Res*., 56: 591 – 599.

Lentini, P. E.; Gibbons, P.; Fischer, J.; Law, B.; Hanspach, J.; Martin, T. G. (2012). Bats in a Farming Landscape Benefit from Linear Remnants and Unimproved Pastures. *PLoS ONE*, 7(11): e48201. doi:10.1371/journal.pone.0048201.

Lesiński, G.; Kowalski, M.; Wojtowicz, B.; Gulatowska, J.; Lisowska, A. (2007). Bats on forest islands of different size in an agricultural landscape. *Folia Zool*., 56(2): 153 – 161.

Lisón, F. & Calvo, J. F. (2011). The significance of water infrastructures for the conservation of bats in a semiarid Mediterranean landscape. *Animal Conservation*: 1 – 9. doi:10.1111/j.1469-1795.2011.00460.x

Lisón, F. & Calvo, J. F. (2013). Ecological niche modelling of three pipistrelle bat species in semiarid Mediterranean landscapes. *Acta Oecologica*, 47: 68 – 73.

Lloyd, A.; Law, B.; Goldingay, R. (2006). Bat activity on riparian zones and upper slopes in Australian timber production forests and the effectiveness of riparian buffers. *Biological Conservation*, 129: 207 – 220.

Lovejoy, T. E. (2010). Climate change. *In*: Sodhi, N. S. e Ehrlich, P. R. (eds.). Biodiversity for all. Oxford University Press: 153 – 162.

Lučan, R. K.; Hanák, V.; Horáček, I. (2009). Long-term re-use of tree roosts by European forest bats. *Forest Ecology and Management*, 258: 1301 – 1306.

Lumsden, L. F. & Bennett, A. F. (2005). Scattered trees in rural landscapes: foraging habitat for insectivorous bats in south-eastern Australia. *Biological Conservation*, 122: 205 – 222.

MAMAOT (2013). *Relatório de Balanço da Seca 2012*. Ministério da Agricultura, Mar, Ambiente e Ordenamento do Território. Access in: 22.08.2013. Available in: http://www.portugal.gov.pt/media/916024/Relatorio_Balanco_GTSeca2012_v1.pdf.

Marques, J. T. (2011). *Tutorial de análise de som de morcegos com o Audacity*. Versão 1, July 2011.

Mathias, M. L.; Santos-Rei, M.; Palmeirim, J.; Ramalhinho, M. G. (1998). *Mamíferos de Portugal*. Edições INAP, Lisboa.

Mazzoni, D. & Dannenberg, R. (2000). *Audacity*. Accessed in: 03.2012. Available *in*: http://audacity.sourceforge.net/

McCain, C. M. (2007). Could temperature and water availability drive elevational species richness patterns? A global case study for bats. *Global Ecology and Biogeography*, 16: 1 – 13.

McDonald, J. H. (2008). *Handbook of Biological Statistics*. Sparky House Publishing, Baltimore, Maryland. Available in: http://udel.edu/~mcdonald/HandbookBioStat.pdf.

Meehl, G. A. & Tebaldi, C. (2004). More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century. *Science*, 305: 994 – 997.

Menzel, J. M.; Menzel, M. A.; Kilgo, J. C.; Ford, W. M.; Edwards, J. W.; McCracken, G. F. (2005). Effect of habitat and foraging height on bat activity in the coastal plain of South Carolina. *Journal of Wildlife Management*, 69(1): 235 – 245.

Mickevièiene, I. & Mickevièius, E. (2001). The importance of various habitat types to bats (chiroptera: *vespertilionidae*) in Lithuania during the summer period. *Acta Zoologica Lituanica*, 11(1): 3 – 14. ISSN: 1392 – 1657.

Mickleburgh, S. P.; Hutson, A. M.; Racey, P. A. (2002). A review of the global conservation status of bats. *Oryx*, 36(1): 18–34.

Nicolete, P. (2001). Temporary ponds in the UK: a critical biodiversity resource for freshwater plants and animals. *Freshwater Forum*, 17(1): 16 – 25.

Norberg, U. M. & Rayner, J. M. V. (1987). Ecological morphology and flight in bats (Mammalia; Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. *Phil. Trans. Roy. Soc. Lond. Ser. B.*, 316: 335 – 427.

Obrist, M. K.; Boesch, R.; Flückiger, P. F. (2004). Variability in echolocation call design of 26 Swiss bat species: consequences, limits and options for automated field identification with a synergetic pattern recognition approach. *Mammalia*, 68(4): 307 – 322.

Oertli, B.; Joye, D. A.; Castella, E.; Juge, R.; Cambin, D.; Lachavanne, J-B. (2002). Does size matter? The relationship between pond area and biodiversity. *Biological Conservation*, 104: 59 – 70.

Owen, S. F.; Menzel, M. A.; Edwards, J. W. (2004). Bat activity in Harvested and Intact Forest Stands in the Allegheny Mountains. *Northern Journal of Applied Forestry*, 21(3): 154 – 159.

Papadatou, E.; Butlin, R. K.; Altringham, J. D. (2008). Identification of bat species in Greece from their echolocation calls. *Acta Chiropterologica*, 10(1): 127 – 143.

Parsons, S. & Jones, G. (2000). Acoustic identification of twelve species of echolocating bat by discriminant function analysis and artificial neural networks. *The Journal of Experimental Biology*, 203: 2641 – 2656.

Pfalzer, G. & Kusch, J. (2003). Structure and variability of bat social calls: implications for specificity and individual recognition. *J. Zool., Lond*., 261: 21 – 33.

Pinto-Correia, T. & Vos, W. (2004). Multifunctionality in Mediterranean landscapes – past and future. *In*: Jongman R. (Ed.). *The New Dimensions of the European Landscape*, Wageningen EU Frontis Series, Springer: 135-164.

Pocock, M. J. O. & Jennings, N. (2008). Testing biotic indicator taxa: the sensitivity of insectivorous mammals and their prey to the intensification of lowland agriculture. *Journal of Applied Ecology*, 45: 151 – 160.

Pough, F. H.; Janis, C. M.; Heiser, J. B. (2008). *A Vida dos Vertebrados*. 4thed. Atheneu Editora, São Paulo Ltda.

Preatoni, D. G.; Nodari, M.; Chirichella, R.; Tosi, G.; Wauters, L. A.; Martinoli, A. (2005). Identifying bats from time-expanded recordings of search calls: comparing classification methods. *Journal of Wildlife Management*, 69(4): 1601 – 1614.

QGIS Development Team (2012). *QGIS Geographic Information System*. Open Source Geospatial Foundation Project. Available in: http://qgis.osgeo.org

R Core Team (2013). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Available in: http://www.R-project.org/.

Rabe, M. J. & Rosenstock, S. S. (2005). Influence of water size and type on bat captures in the Lower Sonoran Desert. *West. N. Am. Nat*., 65: 87 – 90.

Rainho, A. (2007). Summer foraging habitats of bats in a Mediterranean region of the Iberian Peninsula. *Acta Chiropterologica*, 9(1): 171 – 181.

Rainho, A. & Palmeirim, J. M. (2011). The Importance of Distance to Resources in the Spatial Modelling of Bat Foraging Habitat. *PLoS ONE*, 6(4): e19227. doi:10.1371/journal.pone.0019227.

Rainho, A.; Amorim, F.; Marques, J. T.; Alves, P.; Rebelo, H. (2011). *Chave de identificação de vocalizações dos morcegos de Portugal continental*. Electronic version of 05.07.2011.

Razgour, O.; Korine, C.; Saltz, D. (2010). Pond characteristics as determinants of species diversity and community composition in desert bats. *Animal Conservation*, 13: 505 – 513.

Rebelo, H. & Rainho, A. (2008). Bat conservation and large dams: spatial changes in habitat use caused by Europe's largest reservoir. *Endangered Species Research*, doi: 10.3354/esr00100.

Rebelo, H.; Tarroso, P.; Jones, G. (2010). Predicted impact of climate change on European bats in relation to their biogeographic patterns. *Global Change Biology*, 16: 561 – 576.

Robinson, W. D.; Bowlin, M. S.; Bisson, I.; Shamoun-Baranes, J.; Thorup, K.; Diehl, R. H.; Kunz, T. H.; Mabey, S.; Winkler, D. W. (2009). Integrating concepts and technologies to advance the study of bird migration. *Front. Ecol. Environ.*, 8(7): 354 – 361.

Rogers, D. S.; Belk, M. C.; González, M. W.; Coleman, B. I. (2006). Patterns of habitat use by bats along a riparian corridor in northern Utah. *The Southwestern Naturalist*, 51(1): 52 – 58.

Ruggiero, A.; Céréghino, R.; Figuerola, J.; Marty, P.; Angélibert, S. (2008). Farm ponds make a contribution to the biodiversity of aquatic insects in a French agricultural landscape. *C. R. Biologies*, 331: 298 – 308.

Russo, D. & Jones, G. (2002). Identification of twenty-two bat species (Mammalia: Chiroptera) from Italy by analysis of time-expanded recordings of echolocation calls. *J. Zool., Lond*., 258: 91 – 103.

Russo, D. & Jones, G. (2003). Use of foraging habitats by bats in a Mediterranean area determined by acoustic surveys: conservation implications. *Ecography*, 26: 197 – 209.

Russo, D.; Cistrone, L.; Jones, G. (2012) Sensory Ecology of Water Detection by Bats: A Field Experiment. *PLoS ONE*, 7(10): e48144. doi:10.1371/journal.pone.0048144

Rydell, J.; Miller, L. A.; Jensen, M. E. (1999). Echolocation constraints of Daubenton's Bat foraging over water. *Functional Ecology*, 13: 247 – 255.

Sattler, T.; Bontadina, F.; Hirzel, A. H.; Arlettaz, R. (2007). Ecological niche modelling of two cryptic bat species calls for a reassessment of their conservation status. *Journal of Applied Ecology*: 1 – 12. doi: 10.1111/j.1365-2664.2007.01328.x

Schär, C.; Vidale, P. L.; Lüthi, D.; Frei, C.; Häberli, C.; Liniger, M. A.; Appenzeller, C. (2004). The role of increasing temperature variability in European summer heatwaves. *Nature*, 427, 332 – 336.

Schwartz, S. S. & Jenkins, D. G. (2000). Temporary aquatic habitats: constraints and opportunities. *Aquat. Ecol*., 34: 3 – 8.

Sherwin, H. A.; Montgomery, W. I.; Lundy, M. G. (2012). The impact and implications of climate change for bats. *Mammal Review*, doi: 10.1111/j.1365-2907.2012.00214.x

Tabachnick, B. G. & Fidell, L. S. (2001). Using multivariate statistics. 5th ed. Pearson Education. Inc.

Taylor, D. (2010). Bats & Water: Landscape Level Conservation – Final report. *Bat Conservation International*, New Mexico Dept. Game & Fish.

Taylor, D. A. R. & Tuttle, M. D. (2007). *Water for wildlife: a handbook for ranchers and range managers*. Bat Conservation International. Available at http://www.fs.fed.us/pnw/lwm/aem/docs/olson/bciwaterforwildlife.pdf.

Tuttle, S. R.; Chambers, C. L.; Theimer, T. C. (2006). Potential effects of livestock water-troughs modifications on bats in Northern Arizona. *Wildl. Soc. Bull.*, 34: 602 – 608.

Vaughan, N.; Jones, G.; Harris, S. (1997). Habitat Use by Bats (Chiroptera) Assessed by Means of a Broad-Band Acoustic Method. *The Journal of Applied Ecology*, 34(3): 716 – 730.

Verboom, B. & Huitema, H. (1997). The importance of linear landscape elements for the pipistrelle *Pipistrellus pipistrellus* and the serotine bat *Eptesicus serotinus*. *Landscape Ecology*, 12(2): 117 – 125.

Verboom, B.; Boonman, A. M.; Limpens, H. J. G. A. (1999). Acoustic perception of landscape elements by the pond bat (*Myotis dasycneme*). *J. Zool., Lond*., 248: 59 – 66.

Walther, G.-R.; Post, E.; Convey, P.; Menzel, A.; Parmesank, C.; Beebee, T. J. C.; Fromentin, J.-M.; Hoegh-Guldberg, O.; Bairlein, F. (2002). Ecological responses to recent climate Change. *Nature*, 416: 389 – 395.

Warren, R. D.; Waters, D. A.; Altringham, J. D.; Bullock, D. J. (2000). The distribution of Daubenton's bats (*Myotis daubentonii*) and pipistrelle bats (*Pipistrellus pipistrellus*) (Vespertilionidae) in relation to small-scale variation in riverine habitat. *Biological Conservation*, 92: 85 – 91.

Webb, P. I.; Speakman, J. R.; Racey, P. A. (1995). Evaporative water loss in two sympatric species of vespertilionids bat, *Plecotus auritus* and *Myotis daubentoni*: relation to foraging mode and implications for roost site selection. *Journal of Zoology*, 235: 269 – 278.

Wickramasingue, L. P.; Harris, S.; Jones, G.; Vaughan, N. (2003). Bat activity and species richness on organic and conventional farms: impact of agricultural intensification. *Journal of Applied Ecology*, 40: 984 – 993.

Zukal, J. & Řehák, Z. (2006). Flight activity and habitat preference of bats in a karstic área, as revealed by bat detectors. *Folia Zool*., 55(33): 273 – 281.

Zuur, A. K.; Ieno, E. N.; Smith, G. M. (2007). Analysing Ecological Data. 1st ed. Springer, United States of America.

Considerações finais

As alterações climáticas e a deterioração de habitat estão actualmente a ocorrer a uma escala sem precedentes (Jones *et al.*, 2009). São vários os estudos que se têm focado nos efeitos destas alterações, demonstrando um aumento de risco para a biodiversidade (Walther *et al.*, 2002; Adams & Hayes, 2008; Frick *et al.*, 2010b). Como tal, a combinação da aceleração do aquecimento global com o clima mediterrânico, caracterizado por um período quente e seco (Blondel & Aronson, 2004), resulta numa tendência para a diminuição do tamanho e disponibilidade de corpos de água que dependam de eventos anuais de inundação (Razgour *et al.*, 2010). A água torna-se, assim, um factor limitante para muitas espécies, entre as quais os morcegos (Rainho, 2007; Basto *et al.*, 2011; Rainho & Palmeirim, 2011; Sherwin *et al.*, 2012). Foi neste âmbito que se inseriu o presente estudo, de forma a avaliar a influência da distância aos corpos de água na actividade e diversidade de morcegos e ainda as consequências de um ano de seca severa nestes parâmetros, comparando-os entre um ano extremamente seco (2012) e um ano "normal" (2011).

No presente estudo foram identificadas 12 espécies de morcego na proximidade das massas de água. As quatro espécies mais amostradas encontram-se entre as mais comuns em Portugal: *P. pygmaeus*, *P. pipistrellus*, *P. kuhlii* e *M. daubentonii* (Cabral *et al.*, 2006), constituindo o género *Pipistrellus* mais de metade da amostra (66,6%). Apesar de pouco representadas, foram também evidenciadas espécies com estatuto de ameaça ou pouco conhecidas, como *Myotis escalerai*, *Barbastella barbastellus* ou *Rhinolophus ferrumequinum*.

Globalmente os nossos resultados corroboram os estudos que realçam a importância dos habitats das zonas húmidas para as populações de morcegos (Vaughan *et al.*, 1997; Verboom *et al.*, 1999; Russo & Jones, 2003; Bartonička & Řehák, 2004; Rainho, 2007; Rebelo & Rainho, 2008), verificando-se uma elevada concentração da actividade nos corpos de água. Esta preferência mostrou-se significativamente maior no ano 2012, o que reflete uma necessidade premente destes mamíferos em procurar estes locais, num ano de seca severa (Lacasa *et al.*, 2010; Lisón & Calvo, 2011; Rainho & Palmeirim, 2011). Da mesma forma foi também observada uma maior actividade no Verão: época mais quente e com maior escassez de fontes de água.

Foi observado um declínio significativo na atividade dos morcegos em função da distância aos corpos de água, o que atesta a importância directa (disponibilidade de água) e indirecta (maior disponibilidade de presas) deste recurso para este grupo faunístico. Por outro lado, a relação entre a actividade de morcegos e as características locais foi evidente e a área dos corpos de água foi a variável mais significativa na explicação da actividade, verificando-se um aumento desta nas massas de água maiores, tal como documentado noutros estudos (Rabe & Rosenstock, 2005; Downs & Racey, 2006; Lloyd *et al*., 2006; Razgour *et al*., 2010). A albufeira dos Minutos é o maior corpo de água amostrado e, consequentemente, onde se verifica a maior actividade e riqueza específica. Os corpos de água maiores proporcionam mais espaço para beber e caçar e podem ser usados por espécies com diferentes estratégias de vôo e de caça (Rabe & Rosenstock, 2005; Tuttle *et al*., 2006; Taylor & Tuttle, 2007; Razgour *et al*. 2010). Além disso, tendem a ser mais persistentes ao contrário dos charcos menores que estão propensos a secar no final da época seca.

A existência de montado nas áreas envolventes às massas de água também promoveu a atividade dos morcegos nestas, uma vez que este sistema florestal é particularmente favorável para este grupo (Avila-Flores & Fenton, 2005; Lumsden *et al*., 2005; Lentini *et al*., 2012). Com efeito, a estrutura diversa do montado, com áreas abertas intercaladas com diferentes densidades de árvores, proporciona áreas de caça a diferentes guildas de morcegos (Kusch *et al*., 2004; Kusch & Schotte, 2007; Lentini *et al*., 2012); aumenta a disponibilidade de insectos que se abrigam e se alimentam neste habitat (comparativamente com as áreas agrícolas) (Warren *et al*., 2000; Rainho, 2007); e as árvores oferecem aos morcegos locais de abrigo e protecção, perante os predadores e o vento (Jenkins *et al*., 1998).

Assim, o nosso estudo sugere uma relação directa entre a disponibilidade hídrica no ambiente e a intensidade de uso dos morcegos das massas de água. Contudo, para além desta relação de índole mais quantitativa, será também importante investigar o efeito da qualidade da água. Com efeito, para além de resultar numa limitação da disponibilidade hídrica, o aumento da temperatura influência também a qualidade da água, através da dissolução da matéria orgânica e aumento da concentração ou do número de micro-poluentes e patogénicos (Delpla *et al*., 2009). No presente contexto de alterações climáticas, esta questão ganha uma relevância particular, na medida em que é conhecido que a actividade dos morcegos sobre estes corpos hídricos é também afectada pela qualidade da água (Mickleburgh *et al*., 2002; Rainho, 2007; Horn *et al*., 2008; ICNB, 2008; Pocock & Jennings, 2008; Jones *et al*., 2009; Frick *et al*., 2010a). Esta componente em relação à atividade e diversidade dos morcegos deverá merecer alguma atenção no futuro uma vez que, apesar de existirem dados preliminares, é uma área muito pouco explorada e é espectável uma deterioração da qualidade da água, especialmente nas regiões que passam por secas prolongadas com tendência a acentuar-se, como o Mediterrâneo.

Referências bibliográficas

Adams, R. A. & Hayes, M. A. (2008). Water availability and successful lactation by bats as related to climate change in arid regions of western North America. *Journal of Animal Ecology*, 77: 1115 – 1121.

Alcamo, J.; Flörke, M.; Märker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrological Sciences Journal*, 52(2): 247–275.

Avila-Flores, R. & Fenton, M. B. (2005). Use of spatial features by foraging insectivorous bats in a large urban landscape. *Journal of Mammalogy*, 86 (6): 1193 – 1204.

Barclay, R. M. R. (2012). Variable Variation: Annual and Seasonal Changes in Offspring Sex Ratio in a Bat. *PLoS ONE*, 7(5): e36344. doi:10.1371/journal.pone.0036344.

Bartonička T. & Řehák Z. (2004). Flight activity and habitat use of *Pipistrellus pygmaeus* in a floodplain forest. *Mammalia*, 68 (4): 365 – 375.

Basto, M. P.; Pedroso, N. M.; Mira, A.; Santos-Reis, M. (2011). Use of small and medium-sized water reservoirs by otters in a Mediterranean ecosystem. *Animal Biology*, 61: 75 – 94.

Blondel, J. & Aronson, J. (2004). *Biology and Wildlife of the Mediterranean Region*. Oxford Univ. Press, Oxford.

Boyles, J. G.; Cryan, P. M.; McCracken, G. F.; Kunz, T. H. (2011). Economic Importance of Bats in Agriculture. *Science*, 332: 41 – 42.

Burles, D. W.; Brigham, R. M.; Ring, R. A.; Reimchen, T. E. (2009). Influence of weather on two insectivorous bats in a temperature Pacific Northwest rainforest. *Canadian Journal of Zoology*, 87: 132 – 138.

Burnie, D.; Birdlife International; Hoare, B. (2007). *Bird: The Definitive Visual Guide*. Dorling Kindersley Limited, Londres.

Cabral, M. (coord.); Almeida, J.; Almeida, P.; Dellinger, T.; Almeida, N. F.; Oliveira, M.; Palmeirim, J.; Queiroz, A.; Rogado, I.; Santos-Reis, M. (eds.). (2006). *Livro Vermelho dos Vertebrados de Portugal*. 2nd ed., Instituto da Conservação da Natureza. Assírio & Alvim, Lisboa.

Chruszcz, B. J. & Barclay, R. M. R. (2002). Thermoregulatory ecology of a solitary bat, *Myotis evotis*, roosting in rock crevices. *Functional Ecology*, 16: 18 – 26.

Cleveland, C. J.; Betke, M.; Federico, P.; Frank, J. D.; Hallam, T. G.; Horn, J.; López Jr., J. D.; McCracken, G. F.; Medellín, R. A.; Moreno-Valdez, A.; Sansone, C. G.; Westbrook, J. K.; Kunz, T. H. (2006). Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. *Front. Ecol. Environ.*, 4(5): 238 – 243.

Costa, J C.; Aguiar, C.; Capelo, J. H.; Lousã, M.; Neto, C. (1998). Biogeografia de Portugal Continental. Quercetea*, 0: 5 – 56.*

Delpla, I.; Jung, A.-V.; Baures, E.; Clement, M.; Thomas, O. (2009). Impacts of climate change on surface water quality in relation to drinking water production. *Environment International*, 35: 1225 – 1233.

DK Publishing (2010). *The Natural History Book: The ultimate visual guide to everything on Earth*. Dorling Kindersley Limited, Londres.

Downs, N. C. & Racey, P. A. (2006). The use by bats of habitat features in mixed farmland in Scotland. *Acta Chiropterologica*, 8(1): 169 – 185.

Ehrlich, P. R. (2010). Human population and conservation. *In*: Sodhi, N. S. e Ehrlich, P. R. (eds.). *Biodiversity for all*. Oxford University Press: 2 – 3.

Federico, P.; Hallam, T. G.; McCracken, G. F.; Purucker, S. T.; Grant, W. E.; Correa-Sandoval, A. N.; Westbrook, J. K.; Medellín, R. A.; Cleveland, C. J.; Sansone, C. G.; López Jr., J. D.; Betke, M.; Moreno-Valdez, A.; Kunz, T. H. (2008). Brazilian free-tailed bats as insect pest regulators in transgenic and conventional cotton crops. *Ecological Applications*, 18(4): 826 – 837.

Frick, W. F; Reynolds, D. S.; Kunz, T. H. (2010a). Influence of climate and reproductive timing on demography of little brown myotis *Myotis lucifugus*. *Journal of Animal Ecology*, 79: 128 – 136.

Frick, W. F.; Pollock, J. F.; Hicks, A. C.; Langwig, K. E.; Reynolds, D. S.; Turner, G. G.; Butchkoski, C. M.; Kunz, T. H. (2010b). An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species. *Science*, 329: 679 – 682.

Galantinho, A. & Mira, A. (2009). The influence of human, livestock, and ecological features on the occurrence of genet (*Genetta genetta*): a case study on Mediterranean farmland. *Ecological Research*, 24(3): 671 – 685.

Hooi, T. K.; Akbar, Z.; Kunz, T. H.; Ahmad, Y. (1996). Landscaping and Bat Conservation. *The Malayan Naturalist*: 38 – 39. Available in: http://www.bu.edu/cecb/files/2009/08/tanlandscaping1996.pdf.

Horn, J. W.; Arnett, E. B.; Kunz, T. H. (2008). Behavioral Responses of Bats to Operating Wind Turbines. *Journal of Wildlife Management*, 72(1): 123 – 132.

ICNB (2008). *Tenho morcegos em casa, o que devo fazer? (Guia de apoio a situações de coabitação e exclusão de morcegos em edifícios)*. Instituto da Conservação da Natureza e da Biodiversidade, ICNB, Lisboa. [not published].

IM (2008). *Normais Climatológicas – 1981-2010 (provisórias) – Évora*. Instituto de Meteorologia. Accessed in: 24.11.2012. Available in: http://www.meteo.pt/pt/oclima/normais.clima/1981-2010/007/

Jenkins, E. V.; Laine, T.; Morgan, S. E.; Cole, K. R.; Speakman, J. R. (1998). Roost selection in the pipistrelle bat, *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae), in northeast Scotland. *Animal Behaviour*, 56: 909 – 917.

Jones, G.; Jacobs, D. S.; Kunz, T. H.; Willig, M. R.; Racey, P. A. (2009). Carpe noctem: the importance of bats as bioindicators. *Endangered Species Research*, 8: 93 – 115.

Kunz, T. H.; Gauthreaux Jr, S. A.; Hristov, N. I.; Horn, J. W.; Jones, G.; Kalko, E. K. V.; Larkin, R. P.; McCracken, G. F.; Swartz, S. M.; Srygley, R. B.; Dudley, R.; Westbrook, J. K.; Wikelski, M. (2008). Aeroecology: probing and modelling the aerosphere. *Integrative and Comparative Biology*: 48(1): 1 – 11.

Kusch, J. & Schotte, F. (2007). Effects of fine-scale foraging habitat selection on bat community structure and diversity in a temperate low mountain range forest. *Folia Zool*., 56(3): 263 – 276.

Kusch, J.; Weber, C.; Idelberger, S.; Koob, T. (2004). Foraging habitat preferences of bats in relation to food supply and spatial vegetation structures in a western European low mountain range forest. *Folia Zoo*., 53(2): 113 – 128.

Lacasa, V. R. G.; García-Abad, C. S.; Martín, R. P.; Rodríguez, D. J. B.; Garrido, J. A. P.; de La Varga, M. E. A. (2010). Small game water troughs in a Spanish agrarian pseudo steppe: visits and water site choice by wild fauna. *Eur. J. Wildl*. Res., 56: 591 – 599.

Lentini, P. E.; Gibbons, P.; Fischer, J.; Law, B.; Hanspach, J.; Martin, T. G. (2012). Bats in a Farming Landscape Benefit from Linear Remnants and Unimproved Pastures. *PLoS ONE*, 7(11): e48201. doi:10.1371/journal.pone.0048201.

Lisón, F. & Calvo, J. F. (2011). The significance of water infrastructures for the conservation of bats in a semiarid Mediterranean landscape. *Animal Conservation*: 1 – 9. doi:10.1111/j.1469-1795.2011.00460.x

Lloyd, A.; Law, B.; Goldingay, R. (2006). Bat activity on riparian zones and upper slopes in Australian timber production forests and the effectiveness of riparian buffers. *Biological Conservation*, 129: 207 – 220.

Lovejoy, T. E. (2010). Climate change. *In*: Sodhi, N. S. e Ehrlich, P. R. (eds.). Biodiversity for all. Oxford University Press: 153 – 162.

Lumsden, L. F.; Bennett, A. F. (2005). Scattered trees in rural landscapes: foraging habitat for insectivorous bats in south-eastern Australia. *Biological Conservation*, 122: 205 – 222.

Lundy, M.; Montgomery, I.; Russ, J. (2010). Climate change-linked range expansion of Nathusius' pipistrelle bat, *Pipistrellus nathusii* (Keyserling & Blasius, 1839). *Journal of Biogeography*, 37: 2232 – 2242.

Mathias, M. L.; Santos-Rei, M.; Palmeirim, J.; Ramalhinho, M. G. (1998). *Mamíferos de Portugal*. Edições INAP, Lisboa.

Meehl, G. A. & Tebaldi, C. (2004). More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century. *Science*, 305: 994 – 997.

Mickleburgh, S. P.; Hutson, A. M.; Racey, P. A. (2002). A review of the global conservation status of bats. *Oryx*, 36(1): 18–34.

Newson, S. E.; Mendes, S.; Crick, H. Q. P.; Dulvy, N. K.; Houghton, J. D. R.; Hays, G. C.; Hutson, A. M.; Macleod, C. D.; Pierce, G. J.; Robinson, R. A. (2008). Indicators of the impact of climate change on migratory species. *Endangered Species Research*, 7: 101 – 113.

Pinto-Correia, T. & Vos, W. (2004). Multifunctionality in Mediterranean landscapes – past and future. *In*: Jongman R. (Ed.). *The New Dimensions of the European Landscape*, Wageningen EU Frontis Series, Springer: 135-164.

Pocock, M. J. O. & Jennings, N. (2008). Testing biotic indicator taxa: the sensitivity of insectivorous mammals and their prey to the intensification of lowland agriculture. *Journal of Applied Ecology*, 45: 151 – 160.

Pough, F. H.; Janis, C. M.; Heiser, J. B. 2008. *A Vida dos Vertebrados*. 4thed. Atheneu Editora, São Paulo Ltda.

Rabe, M. J. & Rosenstock, S. S. (2005). Influence of water size and type on bat captures in the Lower Sonoran Desert. *West. N. Am. Nat*., 65: 87 – 90.

Rainho, A. (2007). Summer foraging habitats of bats in a Mediterranean region of the Iberian Peninsula. *Acta Chiropterologica*, 9(1): 171 – 181.

Rainho, A. & Palmeirim, J. M. (2011). The Importance of Distance to Resources in the Spatial Modelling of Bat Foraging Habitat. *PLoS ONE*, 6(4): e19227. doi:10.1371/journal.pone.0019227.

Razgour, O.; Korine, C.; Saltz, D. (2010). Pond characteristics as determinants of species diversity and community composition in desert bats. *Animal Conservation*, 13: 505 – 513.

Rebelo, H. & Rainho, A. (2008). Bat conservation and large dams: spatial changes in habitat use caused by Europe's largest reservoir. *Endangered Species Research*, doi: 10.3354/esr00100.

Rebelo, H.; Tarroso, P.; Jones, G. (2010). Predicted impact of climate change on European bats in relation to their biogeographic patterns. *Global Change Biology*, 16: 561 – 576.

Russo, D. & Jones, G. (2003). Use of foraging habitats by bats in a Mediterranean area determined by acoustic surveys: conservation implications. *Ecography*, 26: 197 – 209.

Schär, C.; Vidale, P. L.; Lüthi, D.; Frei, C.; Häberli, C.; Liniger, M. A.; Appenzeller, C. (2004). The role of increasing temperature variability in European summer heatwaves. *Nature*, 427, 332 – 336.

Sherwin, H. A.; Montgomery, W. I.; Lundy, M. G. (2012). The impact and implications of climate change for bats. *Mammal Review*, doi: 10.1111/j.1365-2907.2012.00214.x

Taylor, D. A. R. & Tuttle, M. D. (2007). *Water for wildlife: a handbook for ranchers and range managers*. Bat Conservation International. Available at http://www.fs.fed.us/pnw/lwm/aem/docs/olson/bciwaterforwildlife.pdf.

Tuttle, S. R.; Chambers, C. L.; Theimer, T. C. (2006). Potential effects of livestock water-troughs modifications on bats in Northern Arizona. *Wildl. Soc. Bull.*, 34: 602 – 608.

Vaughan, N.; Jones, G.; Harris, S. (1997). Habitat Use by Bats (Chiroptera) Assessed by Means of a Broad-Band Acoustic Method. *The Journal of Applied Ecology*, 34(3): 716 – 730.

Verboom, B.; Boonman, A. M.; Limpens, H. J. G. A. (1999). Acoustic perception of landscape elements by the pond bat (*Myotis dasycneme*). *J. Zool., Lond*., 248: 59 – 66.

Walther, G.-R.; Post, E.; Convey, P.; Menzel, A.; Parmesank, C.; Beebee, T. J. C.; Fromentin, J.-M.; Hoegh-Guldberg, O.; Bairlein, F. (2002). Ecological responses to recent climate Change. *Nature*, 416: 389 – 395.

Wang, J.; Gao, W.; Wang, L.; Metzner, W.; Ma, J.; Feng, J. (2010). Seasonal variation in prey abundance influences habitat use by greater horseshoe bats (*Rhinolophus ferrumequinum*) in a temperate deciduous forest. *Canadian Journal of Zoology*, 88: 315 – 323.

Warren, R. D.; Waters, D. A.; Altringham, J. D.; Bullock, D. J. (2000). The distribution of Daubenton's bats (*Myotis daubentonii*) and pipistrelle bats (*Pipistrellus pipistrellus*) (Vespertilionidae) in relation to small-scale variation in riverine habitat. *Biological Conservation*, 92: 85 – 91.

Webb, P. I.; Speakman, J. R.; Racey, P. A. (1995). Evaporative water loss in two sympatric species of vespertilionids bat, *Plecotus auritus* and *Myotis daubentoni*: relation to foraging mode and implications for roost site selection. *Journal of Zoology*, 235: 269 – 278.