MESTRADO BIOLOGIA DA CONSERVAÇÃO

ALTERAÇÕES NO CONSUMO DE PRESAS PELA LONTRA EUROASIÁTICA (*Lutra lutra*) NUMA RIBEIRA MEDITERRÂNICA DURANTE A SECA ESTIVAL

DISSERTAÇÃO DE CARLA MARIA DAS NEVES MARQUES

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ILUSTRAÇÃO CARLA MARQUES

ORIENTADORES DR. PEDRO BEJA e PROF. ANTÓNIO MIRA

UNIVERSIDADE DE ÉVORA

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ORIENTAÇÃO
DR. PEDRO BEJA
PROF. DR. ANTÓNIO MIRA

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RESUMO

A pressão provocada pela predação por lontras sobre espécies endémicas de peixes, onde a presente dissertação de mestrado se focou, inseriu-se num projecto financiado pela Fundação para a Ciência e Tecnologia, denominado "O papel dos refúgios estivais na estruturação das comunidades piscícolas de rios Mediterrânicos".

A maioria das ribeiras e pequenos rios mediterrânicos secam ou então ficam reduzidos a uma série de pegos isolados durante o Verão, reduzindo a disponibilidade de habitats para espécies piscícolas e provocam um aumento da concentração de peixes. O objectivo deste projecto foi avaliar o papel ecológico deste tipo de refúgios na estruturação de comunidades piscícolas, durante períodos de seca e a forma como podem influenciar a sua dinâmica populacional, tendo em conta factores como risco de degradação ambiental, limitação trófica, competição e predação.

A lontra é considerada o principal predador neste tipo de habitats e poderá desempenhar um papel importante na estruturação destas comunidades, uma vez que a importância dos pegos para esta espécie nestas circunstâncias já foi demonstrada. Os habitats mediterrânicos são ideais para testar hipóteses relacionadas com as alterações a longo prazo na dinâmica populacional de algumas espécies piscícolas, tendo em conta os efeitos da predação selectiva e do risco de predação de espécies endémicas de peixes de ribeiras mediterrânicas. Não existe conhecimento de estudos que tenham avaliado este potencial risco de predação pela lontra.

O objectivo principal desta dissertação foi analisar a possibilidade de depleção de presas e se a pressão predatória sobre algumas espécies poderá contribuir para o mencionado processo, analisando a dieta da lontra, numa ribeira mediterrânica no sudoeste de Portugal, durante a seca estival. Verificou-se um decréscimo na contribuição relativa das principais presas, com um aumento máximo do índice de diversidade trófica durante Setembro e um aumento do consumo de presas menos energéticas. Os nossos resultados mostram que ocorreu um decréscimo progressivo no consumo das presas mais importantes e uma diminuição no nível de actividade das lontras desde Agosto até ao final do período seco. É discutido o papel da lontra na estruturação das comunidades piscícolas e o potencial risco de predação sobre espécies endémicas, surgindo assim a necessidade de um conhecimento aprofundado sobre mecanismos ecológicos e comportamentais adaptativos do predador e presas e são propostas futuras linhas de investigação.

SHIFTS IN PREY CONSUMPTION BY THE EURASIAN OTTER (*Lutra lutra*) IN A MEDITERRANEAN STREAM, SW PORTUGAL, DURING SUMMER DROUGHT

ABSTRACT

This study is part of a comprehensive research project "The role of summer refugia on the fish community structuring in Mediterranean rivers". Most Mediterranean streams and small rivers become dry or break into isolated ponds during the summer, reducing the availability of fish habitats, and inducing higher fish concentrations. The research goal of this project was to assess the ecological role of refugia for fish assemblages according to its spatial variability, during dry periods, and how it may influence fish community dynamics, assessing limiting factors such as environmental degradation risk, trophic limitation, competition and predation.

Otters are considered the main predator in this type of habitat and may play a part as a structuring factor, since the importance of ponds for this species in such circumstances has already been demonstrated. Mediterranean habitats are ideal to test some predictions leading to changes in the population dynamics of some fish species in the long term, taking into account prey selection effects and predation risk towards endemic fish species inhabiting Mediterranean streams. To our knowledge no studies have yet addressed this potential predation risk.

The main goal of the present study was to evaluate whether there is prey depletion and if predation pressure towards some species contribute to this mentioned process, based on the analysis of otter spraints, in a Mediterranean stream in southern Portugal, during a summer period. The study area was a 12 km stretch of stream with several encompassed ponds, and three sections within this stretch were selected to assess otter diet. There was a decrease in the relative contribution of the main species, with maximum trophic diversity in early September, and an increase in the consumption of less energetically rewarding prey items.

Our main results show evidences of a progressive decrease in the consumption of the most important prey items and a decrease in otter activity levels towards the end of the surveyed period, and we relate them to predatory behaviour and to the lower availability of food resources. The role of otters in structuring fish assemblages and endemic fish species predation risk is discussed, and future investigation studies are addressed.

INTRODUÇÃO GERAL

Na região mediterrânica, onde o clima é caracterizado por longos períodos de Verão e fortes variações na precipitação, o balanço hídrico é normalmente negativo, ocorrendo por vezes longos períodos de seca. Este tipo de *stress* hídrico é responsável por fortes irregularidades temporais nos caudais na maioria dos rios Mediterrânicos (Prenda et al., 2001).

A presente dissertação de mestrado inseriu-se num projecto financiado pela Fundação para a Ciência e Tecnologia (FCT POCI/BIA-BDE/56272/2004), denominado "O papel dos refúgios estivais na estruturação das comunidades piscícolas de rios Mediterrânicos". Este projecto de investigação baseou-se na instabilidade ambiental em climas mediterrânicos, provocada por secas estivais em rios intermitentes. Tendo em consideração que a persistência das espécies piscícolas ao longo da época seca é estritamente dependente deste tipo de refúgios estivais, existe uma potencial probabilidade de as comunidades e populações piscícolas em pequenas ribeiras serem fortemente influenciadas pela distribuição espacial e pela variabilidade deste tipo de refúgios (Magalhães et al., 2002). Pretendeu-se assim avaliar a forma como a dinâmica das populações e comunidades piscícolas é condicionada pela distribuição e variabilidade dos refúgios estivais, tendo em conta os riscos de degradação ambiental, limitação trófica, competição e predação.

Como espécie maioritariamente piscívora e semi-aquática, a Lontra Euroasiática (*Lutra lutra* L.) necessita da presença de água. Apesar de se encontrar presente em grandes rios, lagos e zonas estuarinas (Kruuk, 1995), vive também frequentemente em ecossistemas com presença de água limitada, como cursos de água com dimensões médias ou pequenas (2-15 m de largura) (Ruiz-Olmo & Jiménez, 2008).

Pode ser encontrada em lugares quase secos ou com pouca água, com a condição de que existam pegos mais ou menos dispersos e, em geral, concentra a sua presença nas zonas com mais recursos alimentares (Magalhães et al., 2002, Ruiz-Olmo et al., 2007).

Este facto influencia a sua distribuição temporal neste tipo de habitats, tanto por efeito directo, com a redução do espaço aquático disponível, como por efeito indirecto, uma vez que a escassez de chuva durante os períodos de altas temperaturas tem um efeito profundo nos padrões de disponibilidade de recursos para as lontras. Ou seja, há uma diminuição geral da biomassa total de presas disponíveis, especialmente de peixes (Ruiz-Olmo & Jiménez, 2008). Paradoxalmente, verifica-se um aumento significativo da concentração de presas, consequência da diminuição do caudal, o que provoca uma reorganização da distribuição espacial das mesmas, ficando estas restringidas a uma série de manchas de água dispersas (pegos) – *discrete patches* (Brown, 1988) – nas zonas mais profundas dos rios, e o seu decréscimo gradual pode

ser bastante condicionante tanto para a lontra (Beja, 1995, Delibes et al., 2000, Ruiz-Olmo et al., 2007) como para a população de presas.

Diversos estudos efectuados na Península Ibérica sobre o uso e selecção de habitat revelam a importância de charcos temporários e de pegos para as lontras, durante períodos de seca, em ecossistemas Mediterrânicos e sub-áridos (Basto, 2005, Delibes et al., 2000, Prenda et al., 2001, Ruiz-Olmo et al., 2007), mas apesar da abundância de dados sobre a composição da dieta de lontra, os possíveis impactes da predação sobre a ecologia e dinâmica populacional das suas presas é um aspecto pouco conhecido (Clavero et al., 2008).

Alguns estudos pretenderam avaliar evidências de depleção de presas por vários tipos de predadores, tendo por base comum a teoria denominada "Optimal Foraging Theory" (Brown, 1988). Esta teoria considera que os predadores adaptam as suas estratégias de captura de presas em função do ganho energético de um determinado tipo de presa e do gasto de energia necessário na busca, captura e manuseamento. Assim sendo, a lontra ao demonstrar modificações no seu comportamento predatório de acordo com as flutuações temporais na abundância de presas (Clavero et al., 2003) poderá indiciar que existe um decréscimo gradual das suas presas preferidas, provavelmente provocado pelo impacte da sua própria predação.

O potencial papel da predação como factor estruturante das populações de presas por parte das lontras é ainda desconhecido, existindo apenas alguns estudos empíricos de como, por exemplo, a lontra-marinha *Enhydra lutris* (L.) pode ter efeitos significativos na dinâmica populacional de ouriços-do-mar *Strongylocentrotus polyacanthus* (Estes and Duggins, 1995, Estes and Palmisano, 1974, Estes et al., 1978); ou de como aves de rapina poderão limitar as comunidades de presas (Valkama et al., 2005).

Para compreender os mecanismos pelos quais a lontra poderá influenciar a composição, distribuição e abundância das populações de presas, é necessário determinar se existe predação selectiva sobre determinadas espécies e respectivas classes dimensionais, análogo ao que já foi feito, por exemplo, com estudos sobre o papel de colónias nidificantes de aves marinhas nas comunidades piscícolas costeiras, ou seja, analisando a forma como o grau de previsibilidade de determinadas presas afecta os padrões de busca destes predadores e também como poderão levar à depleção gradual de presas junto às respectivas colónias (Elliott et al., 2009a, 2009b).

Ao comprovar-se, este processo poderá induzir uma reestruturação da comunidade piscícola (Tonn et al., 1992) nas ribeiras que, por sua vez, poderá ter efeitos decisivos na forma como as espécies conseguem recolonizar as mesmas no momento em que estas ganham conectividade após períodos de seca (Magalhães et al., 2002).

Assim sendo, a presente dissertação focou-se inicialmente na pressão provocada pela predação por lontras sobre espécies de peixes, baseando-se na importância que os pegos têm para esta espécie, na época estival, e na hipótese de que a predação preferencial poderá ser um dos factores que influencia a estruturação das comunidades piscícolas, em particular de espécies de peixes endémicas, em rios mediterrânicos (Magalhães et al., 2002).

Desta forma pretendeu-se com o presente estudo encontrar evidências de depleção de presas durante a época estival numa ribeira mediterrânica no sudoeste de Portugal, nomeadamente: 1) diminuição dos níveis de actividade das lontras ao longo da ribeira no final do período de seca 2) diminuição da contribuição relativa das principais espécies de presas, com consequente aumento da diversidade trófica na dieta das lontras; 3) alterações temporais na importância relativa do número de presas em função da classe dimensional; 4) diminuição dos comprimentos médios das presas (sendo as presas maiores substituídas pelas mais pequenas, à medida que os pegos vão sendo explorados); e por último 5) aumento do consumo de presas energeticamente menos recompensadoras.

Inicialmente existiu um outro objectivo que consistia na recuperação de dejectos de lontra com marcas electrónicas (PIT TAGS), que foram inseridas em peixes no final de Julho de 2007, no âmbito do projecto acima mencionado. Estes dispositivos implantados nos peixes ciprinídeos dariam dados sobre padrões de distribuição espacio-temporal dos mesmos (Homel and Budy, 2008, Knaepkens et al., 2004), bem como sobre o local onde cada peixe teria sido predado. Esta informação, juntamente com dados sobre o número de peixes marcados em cada pego, providenciaria uma estimativa da taxa de predação nos pegos, bem como, uma estimativa mínima da variação nas deslocações espacio-temporais das lontras durante o Verão. Contudo, os escassos resultados obtidos inviabilizaram a sua análise e, consequentemente, não foram contemplados nesta dissertação.

O presente trabalho foi apresentado em formato de artigo, segundo as regras editorais da revista *Acta Oecologica*.

ÁREA DE ESTUDO

A ribeira do Torgal é o maior afluente do rio Mira, apresentando uma extensão de 28 km e uma área de drenagem de 235 km². A ribeira do Torgal nasce na Serra do Cercal a cerca de 300 m de altitude e desagua directamente no estuário do rio Mira, aproximadamente ao nível do mar. Os seus principais tributários são as ribeiras da Capelinha (17 km, 48 km²) e de Vale de Ferro (18 km, 46 km²), localizadas na margem esquerda da ribeira (Magalhães, 2002).

Geologia e orografia

As formações geológicas que afloram na maior parte da bacia hidrográfica do rio Mira, correspondem a xistos e grauvaques.

Clima e regime hidrológico

O clima da região é Mediterrânico com influência Atlântica. Em geral a temperatura média anual no interior é inferior a 16°C, registando-se amplitudes de 10-24°C. Duma forma geral, as temperaturas médias nos meses mais quentes, Julho e Agosto, não excedem os 22°C e nos meses mais frios, Dezembro e Janeiro, registam-se temperaturas médias entre 8-11°C. A precipitação inter-anual varia entre os 298-1120 mm. A distribuição sazonal da precipitação é muito marcada, concentrando no semestre húmido (Outubro e Março) cerca de 80% da precipitação anual. No semestre seco em geral não chove durante os meses de Julho e Agosto (Magalhães et al., 2007). Os valores mais elevados de evaporação verificam-se nos meses de Julho e Agosto e os menores nos meses de Dezembro e Janeiro (Magalhães, 2002).

Os cursos de água principais apresentam, geralmente, caudais com carácter intermitente, altamente dependentes dos padrões de precipitação (Magalhães et al., 2007), com secções onde o fluxo é permanente ao longo de todo o ano e outras onde o caudal é nulo durante o período de estiagem (Julho a final de Setembro). Durante este período a água superficial restringe-se a pegos permanentes, particularmente bem desenvolvidos nas porções terminais dos cursos de água e a sectores correntes alimentados por aquíferos, que ocorrem em zonas onde as formações rochosas são mais superficiais (Magalhães, 2002).

Vegetação

Fitogeograficamente, a maior parte da região enquadra-se no sub-sector Baixo-Alentejano-Monchiquense (Costa et al. 1998). A vegetação potencial climatófila é um sobreiral umbrófilo e termófilo (*Myrto-Quercetum suberis*), cuja primeira etapa de substituição é um medronhal também termófilo e umbrófilo (*Philyreo-Arbutetum unidonis*); por degradação subsequente estabelecem-se, geralmente, matos esclerófilos dominados por esteva (*Cistus ladanifer*) e urzes (*Erica* spp.).

O uso do solo é diversificado com bosques autóctones, matagais e estevais, montados (*Quercus suber* L.) e eucaliptais *Eucaliptus globulus* Labill, nos terrenos declivosos das serras. As galerias ripícolas estão bem preservadas e são dominadas por amieiros *Alnus glutinosa* (L.). e freixos *Fraxinus angustifolia* Vahl.

Fauna

A lontra (*L. lutra*) é uma presença bastante comum e constante na ribeira do Torgal, no sudoeste de Portugal, e pode ter-se uma ideia geral da composição da sua dieta num estudo realizado por Beja (1996). As principais categorias de presas são lagostins, peixes e anfíbios. O lagostim-americano *Procambarus clarkii* Girard é uma presa bastante importante para a lontra, apresentando densidades elevadas na ribeira do Torgal (Beja 1996).

A fauna piscícola dulciaquícola nativa do sudoeste de Portugal é composta por pelo menos duas espécies endémicas com distribuições praticamente circunscritas ao sul de Portugal: o escalo-do-Mira *Squalius torgalensis* (Coelho, Bugutskaya, Rodrigues and Collares-Pereira, a boga-do-sudoeste *Iberochondrostoma almacai* (Coelho, Mesquita and Collares-Pereira), bastante abundantes; e um endemismo ibérico, o barbo-do-sul *Barbus sclateri* Günther (Leunda et al. 2009), que é menos abundante (Magalhães, 2002). A enguia *Anguilla anguilla* (L.) e a verdemã *Cobitis paludica* De Buen são também presenças comuns. Existem outras espécies pouco abundantes, como o esgana-gata *Gasterosteus aculeatus* L. Existem também espécies exóticas, gambusia *Gambusia holbrooki* Girard, perca-sol *Lepomis gibbosus* (L.) e a achigã *Micropterus salmoides* (Lacépède), sendo estas duas últimas potencialmente piscívoras, embora sejam mais raras e consumam pouco peixe (Magalhães et al., 2002).

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SHIFTS IN PREY CONSUMPTION BY THE EURASIAN OTTER (*Lutra lutra*) IN A MEDITERRANEAN STREAM, SW PORTUGAL, DURING SUMMER DROUGHT

Carla Marques[a] * and Pedro Beja[b, c]

[a] Universidade de Évora, Portugal

[b] ERENA, Rua Robalo Gouveia, Lisboa, Portugal

[c] CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, Campus Agrário de Vairão, Universidade do Porto, Vairão, Portugal

* Corresponding author present address: R. Particular, Az. F. Velha, 2, Paço do Lumiar, 1600-567 Lisboa, Portugal

  E-mail address: carla_m_marques@yahoo.com

ABSTRACT

Most Mediterranean streams and small rivers become dry or break into isolated ponds during the summer, reducing the availability of fish habitats, and inducing higher fish concentrations. Eurasian otters (*Lutra lutra* L., 1758) are considered the main predator in this type of habitat and may play a part as a limiting factor of fish assemblages, since the importance of ponds for this predator in such circumstances has already been demonstrated. Iberia is a good candidate to study aspects related to endemic fish species population structuring by otters and its response to prey depletion during summer drought periods. To our knowledge no studies have yet addressed this potential predation risk. The main goal of the present study was to find evidences of prey depletion, by analysing otter diet, in a Mediterranean stream in southern Portugal, during summer of 2007. The study area was a 12 km stretch of stream with several isolated ponds, and three sections within this stretch were selected to assess otter diet. Our main results show evidences of progressive prey depletion and a decrease in otter activity levels towards the end of the surveyed period, and we relate them to predatory behaviour and to a lower availability of food resources. Crayfish was the main consumed prey (80% of occurrences), and although chub represented about 10% of occurrences, there was evidence of depletion of larger individuals of both species. There was a decrease in the relative contribution of the main prey species, with maximum trophic diversity in early September, and an increase in the consumption of less energetically rewarding prey items. The role of otters in structuring fish assemblages and endemic fish species predation risk during the most vulnerable time of the year is discussed, and future investigation studies are addressed.

Keywords: prey depletion; diet; predation; otters; *Lutra lutra*; Mediterranean streams

1. INTRODUCTION

Most of the south western European region is affected by Mediterraneity, defined as a combination of climatic and physiognomic features (severe summer drought and mild winters; environmental heterogeneity and seasonal and temporal unpredictability; Prenda et al., 2001). Due to these environmental characteristics Iberian streams are generally characterized by significant flow variations that range from floods in autumn–spring to intermittent flows or complete dryness during summer (Prenda et al., 2001). This usually results in a patchy and heterogeneous mosaic of residual surface waters embedded in dry channels (Magalhães et al., 2002). As drying progresses, abiotic conditions tend to deteriorate, with hypoxia and high temperatures occurring in some habitat patches (e.g. Gasith & Resh, 1999). Simultaneously, concentration of fish in confined spaces – herein referred to as ponds – can increase vulnerability to both aquatic and terrestrial predators (Sostoa & Lobon-Cervia, 1989, Magalhães, 1993, Pires et al., 1999).

Eurasian otters (*Lutra lutra* L. 1758) are usually considered a semi-aquatic piscivorous species throughout their distribution range (Carss, 1995, Ruiz-Olmo and Palazón, 1997) and need the presence of water, although this resource is very scarce in Mediterranean riverine habitats. For this reason they usually go through periods of high water stress when streams dry out or water is restricted to short stretches or ponds (Prenda et al., 2001). They can be frequently found in temporary water bodies, and in almost dry medium and small sized fluvial habitats, as long as there are several disperse water ponds (Prenda et al., 2001, Ruiz-Olmo et al., 2007).

In the Mediterranean region authors consider them to be generalist predators (e.g. Clavero et al., 2003), consuming mainly aquatic and semiaquatic species (Ruiz-Olmo and Palazón, 1997), shifting their diet according to seasonal prey availability. Thus, they usually show higher trophic diversity, predating upon a larger number of prey items than those of temperate habitats (Clavero et al., 2003). So, the probability of an increase in the trophic diversity during summer periods enhances the likelihood of otters preying more often on alternative prey (e.g. Beja, 1996, Clavero et al., 2003, Delibes et al., 2000).

This implies that in situations where fish prey are scarcer, such as in Southern Iberia, where river flows are greatly reduced during dry seasons, otters can compensate by preying upon other species that in particular situations are more available and easier to capture, such as, amphibians, reptiles and aquatic invertebrates, including crayfish *Procambarus clarkii* (Beja, 1996, Clavero et al., 2003, Pedroso and Santos-Reis, 2006). Crayfish, in particular, is a very important component of otter diet in Iberian streams (Beja, 1996, Clavero et al., 2003, 2004,

2007), even though crustaceans are known for being a relatively unprofitable prey for otters because they provide little energy and require a lengthy handling time (Carss, 1995). However, they can reach very high densities, due to their reproductive success in many types of habitat, including sluggish streams, and be tolerant to low oxygen levels and high temperatures (Oliveira and Fabião, 1998). It is even suggested that otters might have greatly benefited with the introduction of crayfish, working as a buffer in otter populations against reductions in the native prey abundance (Beja, 1996).

Some studies in Spain (Ruiz-Olmo et al., 2007, Ruiz-Olmo and Jiménez 2008) tried to assess the way otters can survive these drought periods from its foraging efficiency perspective within a wider spacio-temporal scale (Delibes et al., 2000, Ruiz-Olmo et al., 2007), but did not acknowledge the possibility of a higher predation risk towards some species, namely Iberian endemic fish species. The otter can be considered the main predator in many Iberian aquatic habitats (Beja, 1996, Ruiz-Olmo et al., 2007), and by feeding selectively (Beja, 1995), this carnivore could have a strong impact on some endemic fish species, minding the possibility that there might be preferences towards some of these species (Magalhães et al., 2002).

Hence, Iberia is a good candidate to study aspects related to endemic fish species population structuring by otters and its response to prey decrease during summer (Delibes et al. 2000, Ruiz-Olmo et al. 2007).

Since food resources in drying seasonal ponds are distributed in discrete patches, one might assess the way an opportunistic predator, such as the otter, adjusts its foraging behaviour in response to the characteristics and distribution of food resources. According to the Optimal Foraging Theory, under these circumstances, a predator tends to behave in such a way as to find, capture and consume food containing the most calories, while expending the least amount of time possible in doing so (Brown, 1988).

Otters generally have linear habitat ranges (Durbin, 1998), and usually tend to move between patches through the dry river stretches. Also, during the wet period, after the rains that followed the dry period, ponds are no longer as important and are marked less frequently (Ruiz-Olmo et al., 2007). Assuming that the distribution of resources among ponds remains unchanged, since these fish species do not reproduce during drought periods (Beja, 1995) in our study area, and that in theory otters deplete these resources as they harvest patches (Brown, 1988), one could predict the appearance of several signals in the otter foraging behaviour, as this will be reflected in shifts in the diet (Delibes et al., 2000), until the end of the dry summer period.

The aim of this study is to find evidences of prey depletion, during the ponds isolation period, namely: 1) a decrease in otter activity levels along the river towards the end of the drought period; 2) a decrease in the relative contribution of the main prey species, which consequently may lead to an increase in the trophic diversity present in the diet; 3) changes in the relative importance of the number of prey items or size classes; 4) a decrease of the mean prey sizes (as ponds are being depleted of larger prey items, smaller items may gain more importance); and lastly 5) a predicted consumption of less energetically rewarding prey items.

2. MATERIALS AND METHODS

2.1 *Study area*

The study was carried out in the Torgal stream (37°38'N, 8°39'W) in Alentejo region, southern Portugal, which drains about 238 km^2 and flows from the Cercal mountains (300 m a.s.l.) for 28 km, discharging at about sea level into the estuary of the river Mira (Magalhães et al., 2002) (Fig. 1).
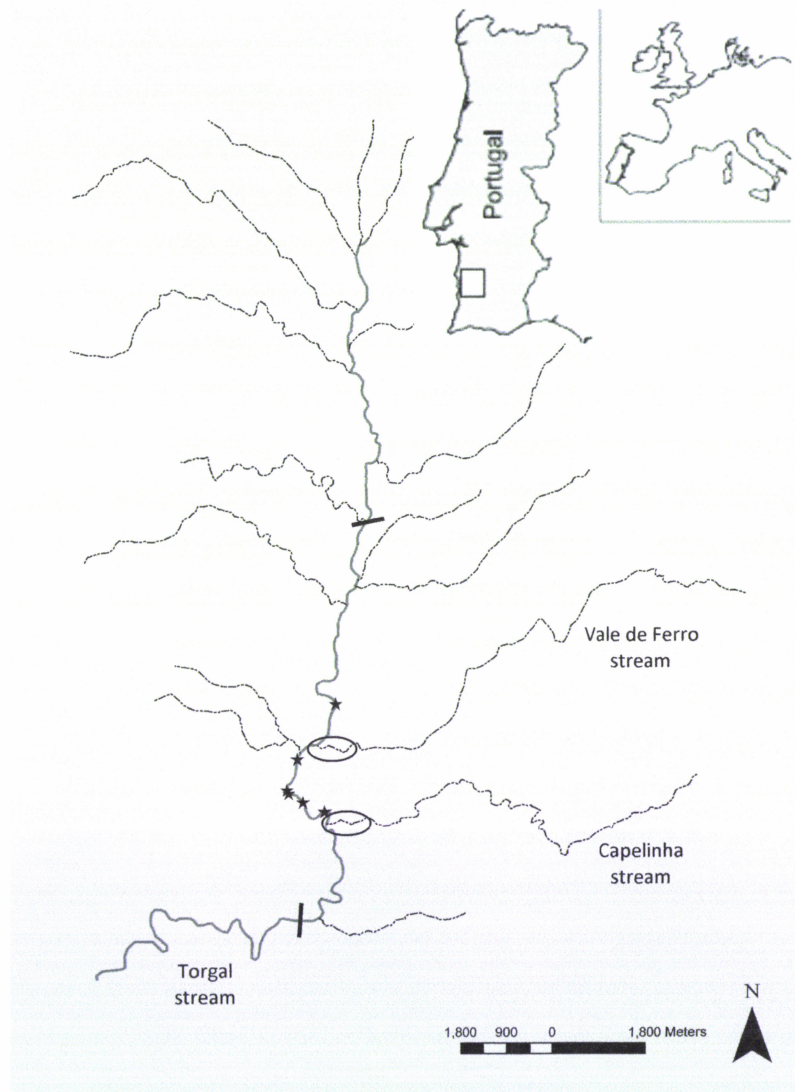

Fig. 1 Geographic location of the Torgal stream, in SW Portugal. Upstream and downstream limits (12 km) of Torgal stream prospected stretch signalled with bars; prospected stretches of the tributaries signalled with circles.

In the mainstream and some of its tributaries the surface flow is seasonally interrupted for a few months. During this period, particularly in the downstream reaches, there are well developed and deep ponds (depth >1 m) alternating with dry stream stretches (Beja, 1996). This catchment is free from urban pollution, and impoundments. Angling and other recreational activities are rare. Human settlement is sparse and land cover is primarily open cork oak *Quercus suber* L. woodland, eucalyptus *Eucaliptus globulus* Labill plantations, rough pastures and dry cereal fields. The stream valleys are largely pristine, covered with dense Mediterranean scrub and with well-developed and preserved riparian galleries dominated by alder *Alnus glutinosa* (L.) and ash *Fraxinus angustifolia* Vahl (Beja, 1996, Magalhães, 2002).

Climate is Mediterranean, with annual rainfall varying markedly from year-to-year (298–1120 mm), but following a predictable seasonal pattern. About 80% of annual rainfall occurs in the wet season (October to March) and only about 3.0% in the hot and dry season (June to August). Mean monthly temperature is 11°C in the coldest month (December) and 24°C in the hottest (August) (Magalhães et al., 2002).

Fish species inhabiting the Torgal stream comprise a few species, mostly native. Assemblages are dominated by the endemic Mira chub *Squalius torgalensis* (Coelho, Bogutskaya, Rodrigues and Collares-Pereira) and south-western arched-mouth nase *Iberochondrostoma almacai* (Coelho, Mesquita and Collares-Pereira) (Leunda et al., 2009). The eel *Anguilla anguilla* (L.) and southern Iberian spined-loach *Cobitis paludica* (De Buen) are also abundant (Beja, 1995, 1996, Magalhães et al., 2002). Other species are much less common, including barbel *Barbus sclateri* Günther and three-spined stickleback *Gasterosteus aculeatus* L., and the non-native, mosquito-fish *Gambusia holbrooki* Girard, pumpkinseed *Lepomis gibbosus* (L.) and large-mouth bass *Micropterus salmoides* (Lacépède). The otter *Lutra lutra* (L.) is the main fish predator (Beja, 1996). Although pumpkinseed and large mouth bass are potentially piscivorous, they are both rare and overall consume few fish (Magalhães et al., 2002).

Crayfish *Procambarus clarkii* Girard is a widespread and very abundant species in the study area. Other potencial otter prey categories are amphibians, in particular marsh frogs *Rana perezi* Seoane, and common toads *Bufo bufo* (L.), and also large aquatic beetles (Beja, 1996).

2.2 *Otter diet in summer*

2.2.1 *Spraint collection and analysis*

The surveys occurred during summer of 2007, every two weeks, between the end of July, when the surface flow between ponds stopped, and the beginning of October, before ponds regained their connectivity due to the beginning of the rainy season.

There is evidence that sprainting activity is a good indicator of habitat preference as it is positively correlated to the amount of time spent by otters in habitat patches (Guter et al., 2007, Kruuk, 1992). Since otters tend to have a linear home range within streams and rivers, showing a highly concentrated presence around patches with more resources and to move between ponds along the dry riverbed, during the dry periods, (Ruiz-Olmo et al., 2007), spraints collected at a site should reflect the food consumed there. The wide ranging behaviour of otters (e.g. Kruuk et al., 1993) weakens this assumption, although it may be still warranted for several reasons: rapid gut transit times (1–3 h, Carss, et al., 1998); tendency to repeatedly forage within the same habitat patch for long periods (Kruuk, et al., 1990); and the sprainting behaviour before and after foraging bouts (Kruuk, 1992). All may increase the probability of sprainting in nearby ponds, due to the highly patchy distribution of surface waters in the study area during summer. All otter spraints were thoroughly searched along the stream banks and dried streambed and collected in 24 sections, 500 m long each, within a stretch of 12 km of the Torgal stream, including the connections to two small tributaries (500 meters of each "Vale do Ferro" and "Capelinha" streams, where permanent surface water persists through the dry-season; Magalhães et al., 2002).

Three of the sections (up to 1 km apart from each other) were selected for diet analysis. Random sub-samples of 30 spraints per survey and section were used for diet analysis, using laboratorial standard procedures (e.g. Beja, 1991). Prey remains were identified using a reference collection of fish species collected at several rivers belonging to the Tagus hydrological basin (D. Freitas, unpublished data). Whenever possible, identification was made to the species level. Minimum numbers of individuals of each prey category per spraint were calculated through matching of paired diagnostic bony/skeletal structures (Hansel et al., 1988; Jacobsen & Hansen, 1996). Regression equations were used to estimate the size of prey items consumed by otters, estimating total length and weight based on the dimensions of diagnostic structures (measured to the nearest 0.01 mm) such as maxillae, premaxillae, uropods, etc. For fish species these equations were available in the literature (Prenda et al., 2002). Other

previously computed regression equations were used for other fish structures (D. Freitas, unpublished data); crayfish antennae (H. Matos unpublished data) and uropods (P. Beja unpublished data). When there were no measurable structures, it was assumed that their weights were equal to the average weight of the remaining ingested correspondent prey category, within each survey. There were no regression equations available for amphibians, insects and other minor prey. Average weights, obtained from the literature were only assigned for amphibians (Beja, 1996).

2.2.2 *Quantification of diet composition*

The importance of each prey category in the diet was estimated as percentage of occurrence (number of individuals of each prey category / sum of individuals of all prey categories · 100); as percentage of biomass (biomass of individuals of each prey category / sum of biomass of all prey categories · 100); and lastly as percentage of energy intake, which takes into account the number of prey occurrences and average weight, both per survey, and the calorific value and digestibility of each prey type (Beja, 1996). In the case of amphibians, for which regression equations were not available, their average weights were obtained from the literature (Beja, 1996). Temporal diet diversity was assessed using the Shannon index (Zar, 1999).

2.2.3 *Estimates of numbers and energetic contribution of consumed prey items*

The energetic contribution of each prey item was calculated by multiplying the number of occurrences per survey, average weight, calorific value and digestibility. The total mean energetic contribution per survey was calculated using the sum of the energetic contribution of all prey items divided by the sum of all prey occurrences per survey. Due to the sub-sampling effect, and to the fact that the analysed spraints represent an unknown fraction of an otter food intake, it is impossible to calculate directly the total number of individuals of each prey category. Thus, numbers of ingested prey items, per survey, were estimated based on the monthly energetic requirements of a non-breeding otter, using the average weight and percentage of ingested energy, and the calorific value of each prey category, (see Beja, 1996 for details). These estimated numbers were only used as a relative measure of predation over time.

2.3 *Data analysis*

During the surveyed period two weather parameters – average temperature and rainfall– were collected from a nearby weather station in the Torgal stream surrounding area.

Temporal trends over time of the number of occurrences, percentage of occurrences, percentage of biomass and average sizes for the main prey categories were tested through linear or quadratic regression analyses (Zar, 1999), to detect prey depletion, since the beginning of the ponds isolation (amphibians were excluded from size trend). Trophic diversity, energetic contributions and temporal fluctuations in the otter activity level were also assessed using linear and quadratic regression analysis. The programs EXCEL® 2003 and SPSS® 17.0 were used for computations.

3. RESULTS

3.1 *Weather conditions*

During the surveyed period the weather conditions were as shown in fig. 2. Almost no rain occurred from late July to mid September of 2007, and the temperatures were in average above 20°C until mid September, before the first autumn rainfalls began.
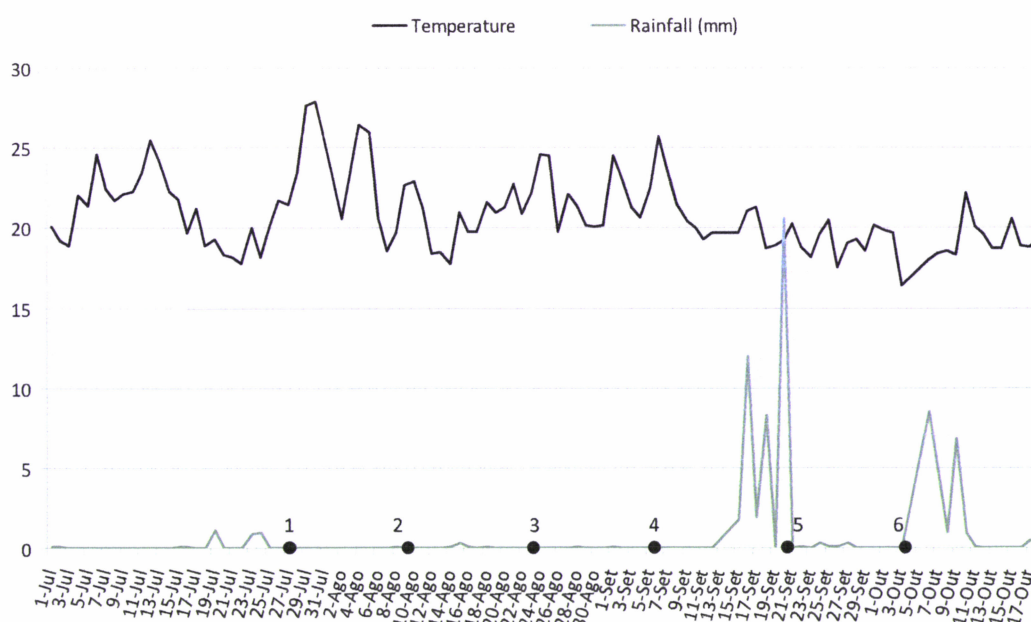

Fig. 2 Average temperature (°C) and rainfall (mm) during the surveyed period (2007), in the Torgal stream, SW Portugal. Sprint surveys are signalled with circles: 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

20

3.2 *Otter activity*

During the study, a total of 6279 otter spraints were collected along the 12 km stretch of the Torgal stream. Fig. 3 shows an overall increase in the number of spraints until late August, and then a decrease until the end (F = 2,671; d.f.= 2, 3; P = 0,216).
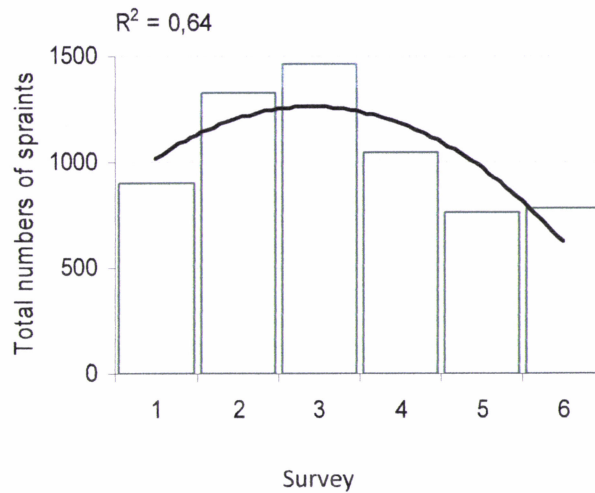

Fig. 3 Temporal variation in the total number of spraints, in Torgal stream, SW Portugal. 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

3.3 *Otter diet in summer*

A total of 523 otter spraints were analysed. Crayfish was by far the main component of otter diet at the Torgal stream, in terms of percentage of occurrences, biomass and energy (Table 1). Chub was the next most consumed prey, but represented only 10% of all occurrences. The third contribution in percentage of occurrences was eels (<6%). Amphibians only represented 2% of percentage of occurrences. The remaining species together accounted for 1.1% of percentage of occurrences and were subsequently grouped under the category *other prey*. Reptiles were almost absent; aquatic insects and other crustaceans were negligible, and therefore, excluded from the analyses, since they can also be preyed by fish.

In terms of biomass and energy, analyses revealed a different importance in rank of the main prey categories: eels ranked second after crayfish in terms of biomass and energy, and chub in third, while the rank of the rest of the species remained unchanged (Table 1).

Table 1 Composition of the diet of otters in Torgal stream, in the summer of 2007, expressed as percentage of occurrence (P.O.), percentage of biomass (P.B.), and percentage of energy (P.E.). Reptiles and other invertebrates were excluded from the analyses. All unidentified cyprinids were assumed to be one of the two identified cyprinid species, and thus assigned to the identified species in accordance to their occurrence proportions.

Prey species	P.O. (%)	P.B. (%)	P.E. (%)
Procambarus clarkii (Girard, 1852)	80.73	73.84	61.76
Squalius torgalensis (Coelho, Bogutskaya, Rodrigues & Collares-Pereira, 1998)	10.35	4.02	5.55
Anguilla anguilla (Linnaeus, 1758)	5.95	17.52	26.24
Amphibians	1.08	2.71	4.15
Lepomis gibbosus (Linnaeus, 1758)	0.77	1.68	2.05
Cobitis paludica (de Buen, 1930)	0.46	0.17	0.17
Iberochondrostoma almacai Coelho, Mesquita & Collares-Pereira, 2005	0.15	0.05	0.07
Gambusia holbrooki Girard, 1859	0.15	0.01	0.01
Barbus sclateri Günther, 1868	0.05	0	0

The estimated lengths of the main prey categories are shown in table 2. About 80% of the preyed crayfish had 50-80 mm in length (n = 1133), less than 15% were above 80 mm (n = 209), and less than 7% were under 50 mm in length (n = 90).

For Chub, 67% were under 60 mm (n = 110), and about 33% were above 60 mm (n = 54).

As for eels, almost 80% were 100-300 mm (n = 80), 12.7% were under 100 mm (n = 14), and 7.2% were above 300 mm (n = 8).

Table 2 Estimated length (mm) of the main prey categories ingested by otters during summer, in Torgal stream. Amphibians were excluded, since regression equations relating bone size to total length were unavailable.

	MEAN	S.D.	MIN-MAX	N
Procambarus clarkii	68.8	12.1	18.0 – 115.0	1432
Squalius torgalensis	50.8	28.7	19.7 – 148.9	164
Anguilla anguilla	183.4	93.8	16.1 – 585.4	77
Other fish	74.0	25.8	12.9 – 124.4	28

3.4 *Temporal changes in diet composition*

Temporal variations for the main prey categories in the summer diet of otters differed between occurrences (P.O.), biomass (P.B.) and energy (P.E.) (Fig. 4).

Crayfish was the most predominant species in terms of percentage of occurrences, although showing more or less pronounced fluctuations. In contrast, Chub showed low consumption levels, except in early September, when it had its highest consumption (Fig. 4-a). Eels' relative importance remained almost constant, until late September, and in early October showed its highest value, though no significant trend was found.

Table 3 summarises the significance of linear and quadratic regression tests for temporal trends in species number of occurrences, percentage of occurrences, percentage of biomass, and mean length.
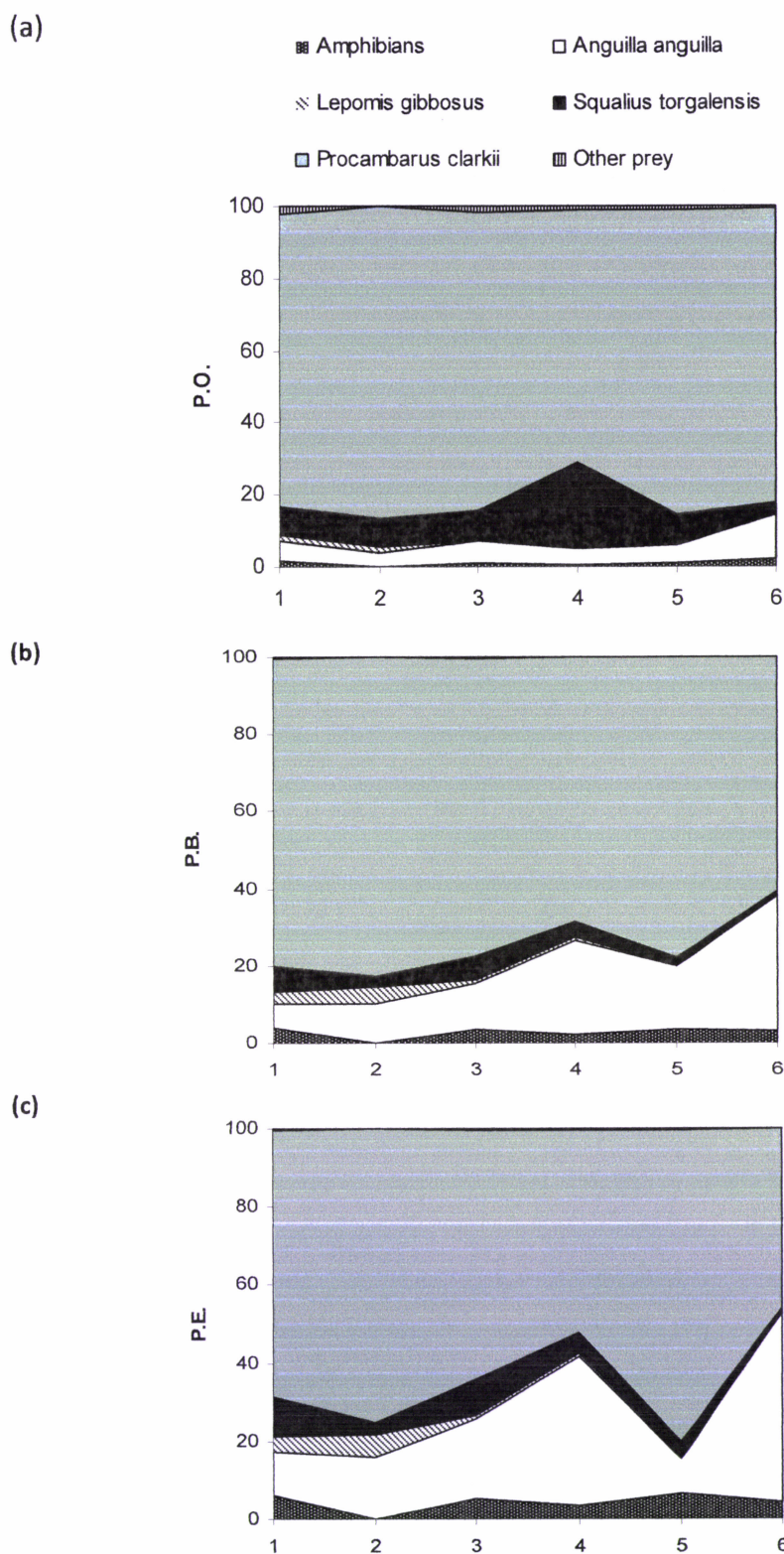
Fig. 4 Temporal variation of the relative contribution of prey categories for otters in Torgal stream, during summer of 2007, in terms of (a) P.O. – percentage of occurrences; (b) P.B. – percentage of biomass; and (c) P.E. – percentage of energy. 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

Table 3 Relationship between time and four variables: number of occurrences (NO), percentage of occurrences (PO), percentage of biomass (PB), and mean length of the main prey categories, during summer of 2007. b - slope; r^2 – coefficient of determination. Parameters refer to linear regressions from late July until early October (d.f. = 1, 4), or from late July until late September (d.f. = 1, 3); otherwise, parameters signalled with (*) refer to quadratic regressions for the same two periods: (d.f. = 2, 3) and (d.f. = 2, 2), respectively.
Values significant at P < 0.05 are shown in bold.

		Late July – early October				Late July – late September			
		F	P	b	r^2	F	P	b	r^2
PO	P. clarkii[a]	0.065	0.811	(-)0	0.02	0.176	0.703	-0.01	0.06
NO		6.492	0.063	-22.1	0.62	2.618	0.204	-21.4	0.47
NO	* 0-50 mm	2.887	0.200		0.66				
NO	* 50-80 mm	9.559	0.050		0.864				
NO	* 80-120 mm					4.209	0.192		0.808
PO	S. torgalensis[b]	0.026	0.880	(-)0	0	0.391	0.576	0.016	0.12
NO		0.089	0.780	-2.23	0.02	0.171	0.707	4.1	0.05
NO	* 0-60 mm	1.153	0.425		0.435				
NO	60-150 mm	3.923	0.119	-2.11	0.7				
PO	A. anguilla	2.038	0.227	0.01	0.34	0.184	0.697	-0.002	0.06
NO		0.423	0.551	1.26	0.09	1.079	0.335	-1.6	0.26
NO	0-300 mm	0.001	0.975	0.057	0	4.487	0.124	-2.6	0.6
NO	300-600 mm	1.714	0.261	0.4	0.3	0.214	0.675	0.2	0.07
PO	L. gibbosus	**13.65**	**0.021**	**(-)0**	**0.77**	6.953	0.078	-0.003	0.7
NO		**17.51**	**0.014**	**-1.17**	**0.81**	9.941	0.051	-1.3	0.69
PO	Amphibians	1.279	0.321	(+)0	0.24	0.052	0.834	0	0.02
NO		0.149	0.719	0.2	0.04	0.018	0.902	-0.100	0
PO	Other fish	0.771	0.429	(-)0	0.16	0.113	0.758	0	0.04
NO		1.025	0.369	-0.74	0.2	0.207	0.680	-0.5	0.06
PB	P. clarkii	5.650	0.076	-0.03	0.59	1.166	0.359	-0.018	0.28
	S. torgalensis	4.818	0.093	-0.01	0.545	1.628	0.292	-0.008	0.35
	A. anguilla	**13.87**	**0.020**	**0.05**	**0.78**	5.061	0.110	0.034	0.63
	L. gibbosus	**15.11**	**0.018**	**-0.01**	**0.79**	10.09	0.050	-0.01	0.77
	Amphibians	0.225	0.660	(+)0	0.05	0.061	0.821	0.001	0.02
	Other fish	1.370	0.307	(+)0	0.26	0.416	0.565	0	0.12
Mean Length									
	P. clarkii	0.319	0.602	0.37	0.07	**11.28**	**0.044**	**-0.74**	**0.79**
	S. torgalensis	0.067	0.809	-1.11	0.02	2.058	0.247	-6.51	0.5
	A. anguilla	1.742	0.257	8.63	0.3	0.152	0.723	3.463	0.5

[a] Size classes considered for crayfish correspond to minimal and mean sizes at sexual maturity of crayfish (82 mm mean length), for Central Portugal (Correia, 2003).

[b] Chub sexual maturity size for both sexes was between 50-60 mm (Magalhães et al., 2003).
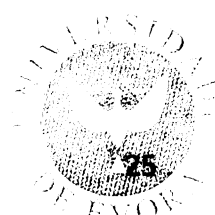
In terms of biomass and energy, the importance of crayfish decreased in early September and early October. Chub relative importance gradually decreased since the beginning of the surveyed period, although no significant trend was found (Table 3). In contrast with the slightly decrease for chub, eels showed a significant increase. The only exception was in late September when eels showed a pronounced decrease, simultaneously with the increase of crayfish importance, more relevant in terms of energy (see Fig. 4c).

Amphibians had a low but nearly steady relative importance during the surveyed period, with only a slight increase towards the end (non significant), while pumpkinseed had a relative importance only until early September, and was the only species to show a significant decrease, in terms of both percentage of occurrences and biomass (Table 3). The remaining prey items had a residual importance in the otter diet.

Shannon diversity index showed no significant linear trends throughout the survey period (F = 0.221; d.f. = 1, 3; P = 0.670), but during August and early September it showed a non significant increase. As seen in Fig. 5, the highest index value was reached during early September, and decreased afterwards.
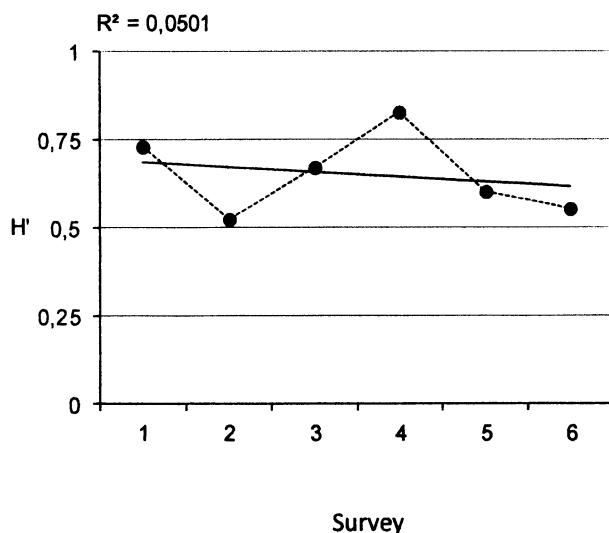

Fig. 5 Shannon diversity index temporal variation, in otter diet. 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

More detailed analyses by size classes of the three main species, show contrasting patterns. A general decrease in the number of consumed crayfish is evident (Fig. 6). The decline occurred firstly within the larger crayfish (Fig. 6c), just after the second survey and increasing enormously in early October. The remaining size classes showed a decrease, only after the third survey (more pronounced in the crayfish between 50-80 mm – Fig. 6b).
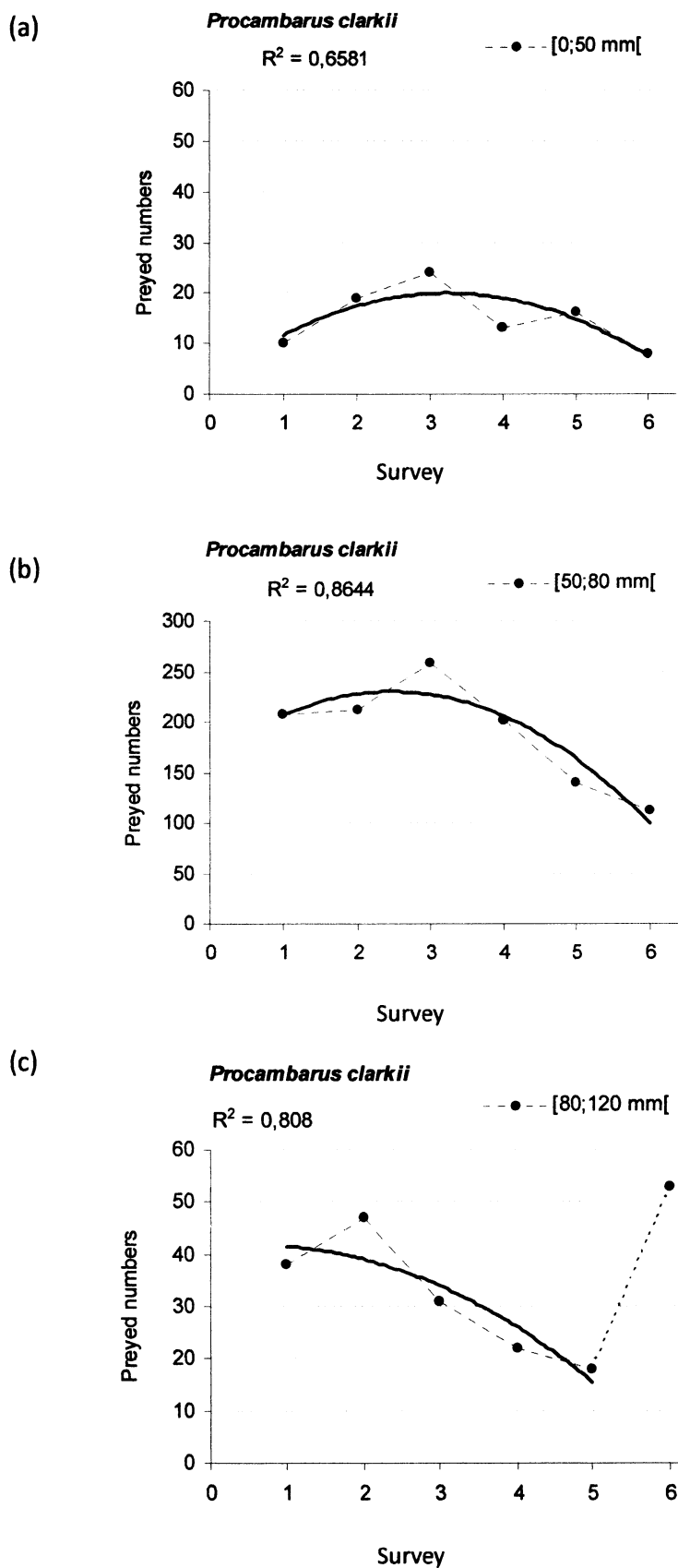
(a)

Procambarus clarkii

R² = 0,6581

--●-- [0;50 mm[

(b)

Procambarus clarkii

R² = 0,8644

--●-- [50;80 mm[

(c)

Procambarus clarkii

R² = 0,808

--●-- [80;120 mm[

Fig. 6 Crayfish (*P. clarkii*) temporal trends on number of occurrences. Lines represent quadratic regression trends. Survey #6 excluded from the regression of larger individuals (80-120 mm). 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

Regarding chub (fig. 7), only the larger individuals (60-150 mm) showed a non significant decrease (see table 3) and were less preyed upon, comparing to the higher consumption of smaller size classes, with special emphasis in the consumption of the young chub (< 30 mm; Fig. 7a), mainly in early September.
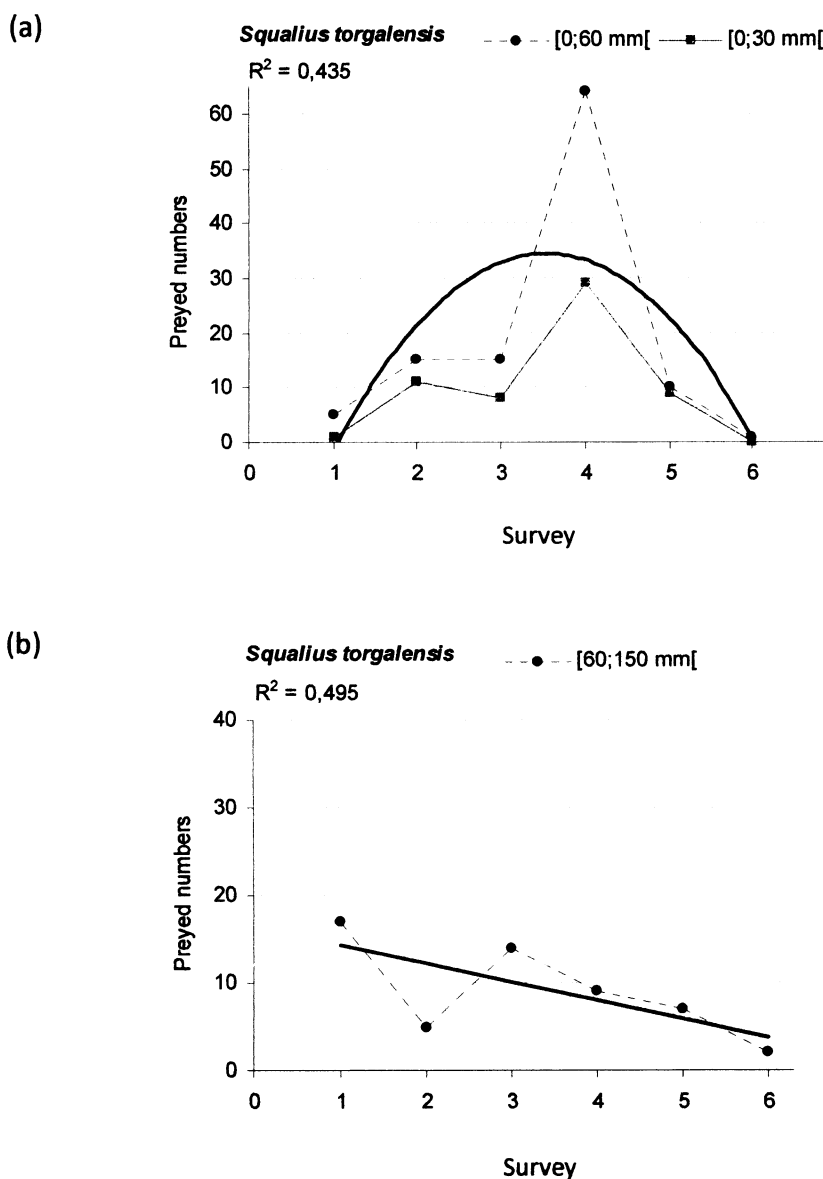
(a)

(b)

Fig. 7 Chub (*S. torgalensis*) temporal variation on number of occurrences per size class. Quadratic trend line refers only to 0-60 mm size class.

As for eels, a non significant decrease (see Table 3) was found within individuals smaller than 300 mm, during the first five surveys (Fig. 8); in fact, only eels smaller than 100 mm showed a significant decrease (F = 34.71; d.f. = 1, 3; P = 0.01; b = -0.9; r^2 = 0.92) during the same period. Contrastingly, if we were to remove the fifth survey (late September) from the linear

regression analysis, there would be a slight significant increase within the few larger individuals (300-600 mm in length) (F = 14.565; d.f. = 1, 3; P = 0.03).

(a)

Anguilla anguilla
$R^2 = 0,5993$

- - • - - [0;300 mm[

(b)

Anguilla anguilla
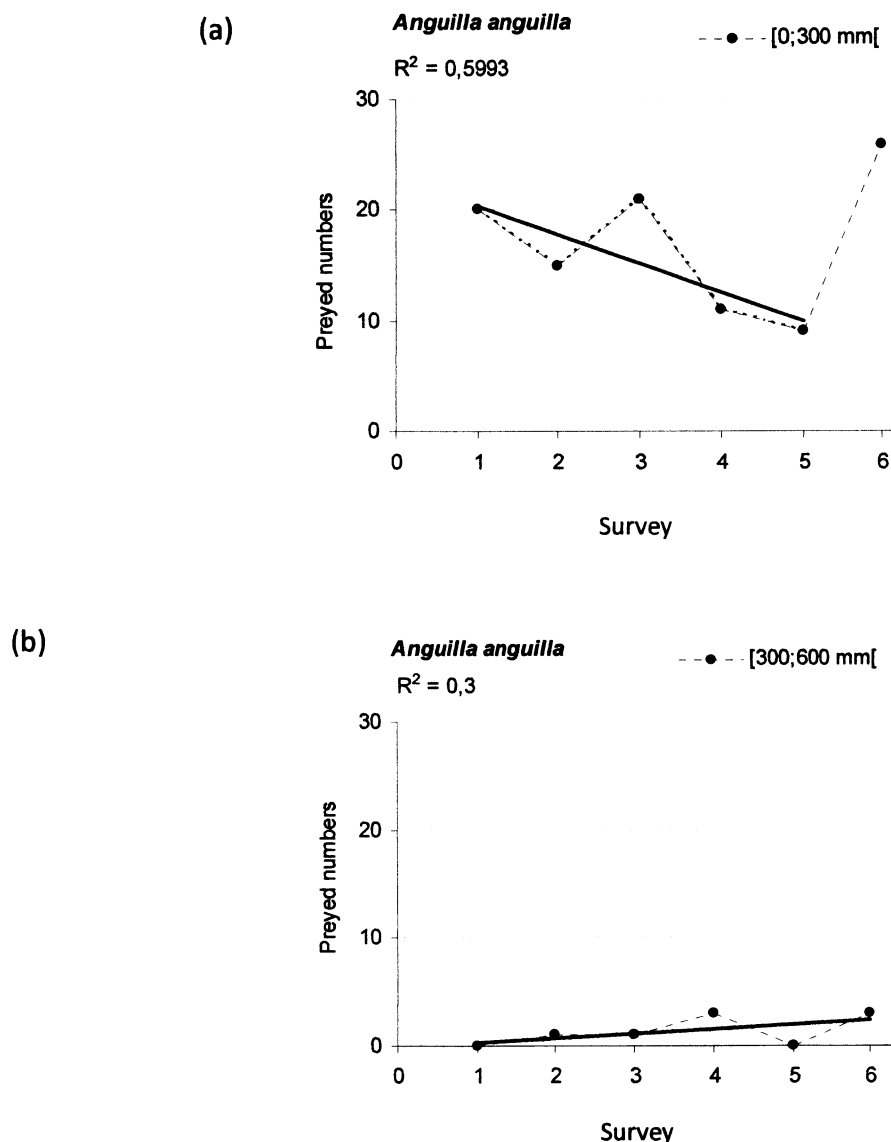$R^2 = 0,3$

- - • - - [300;600 mm[

Fig. 8 Eel (*A. anguilla*) temporal trends on number of occurrences. 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

3.5 *Temporal changes in prey mean size*

No significant temporal trends were found between the average lengths of any of the three main prey species, during the 6 surveys (Table 3). However, one common pattern between all three main prey species can be seen in Fig. 9, which showed a relative decrease during late September and an increase afterwards, in the case of crayfish and eels, to their

highest mean values. This pattern is also visible in the number of occurrences of eels (Fig. 7) and of larger crayfish (Fig. 6c). In fact, the average size of crayfish was very similar in all the surveyed period, but with a slight significant decrease (Table 3), during the first five surveys. Chub also showed a decrease, though non significant, until late September, but with pronounced fluctuations. As for eels, there was evidence of a non significant increase during the first four surveys ($F = 11.745$; $d.f. = 1, 2$; $P = 0.076$).
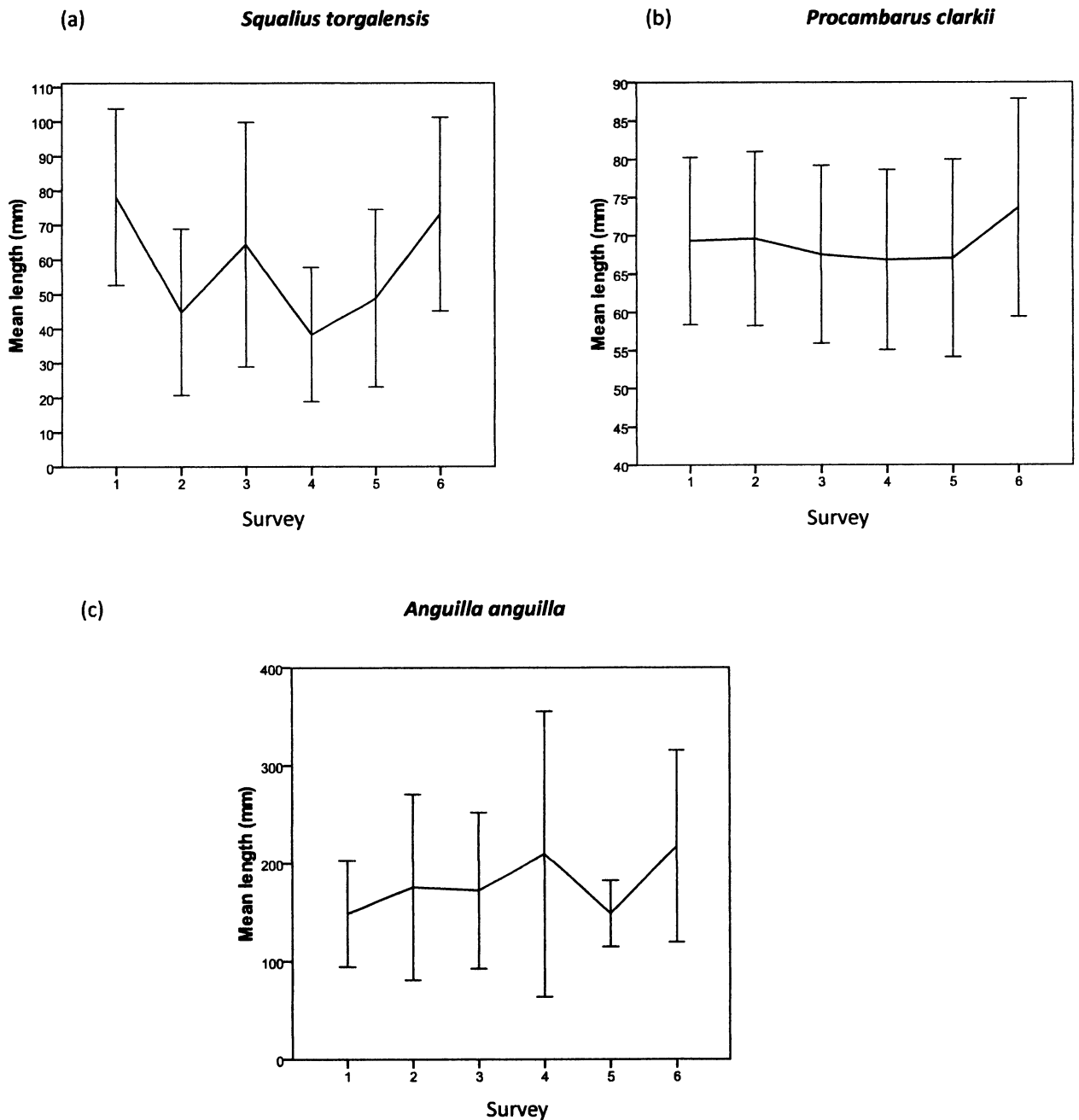

(a) *Squalius torgalensis*

(b) *Procambarus clarkii*

(c) *Anguilla anguilla*

Fig. 9 Temporal trends of the mean length for the three main species in otter diet, with median sizes ± SD for each survey sample. 1 – late July, 2- early August, 3- late August, 4- early September, 5- late September, 6 – early October.

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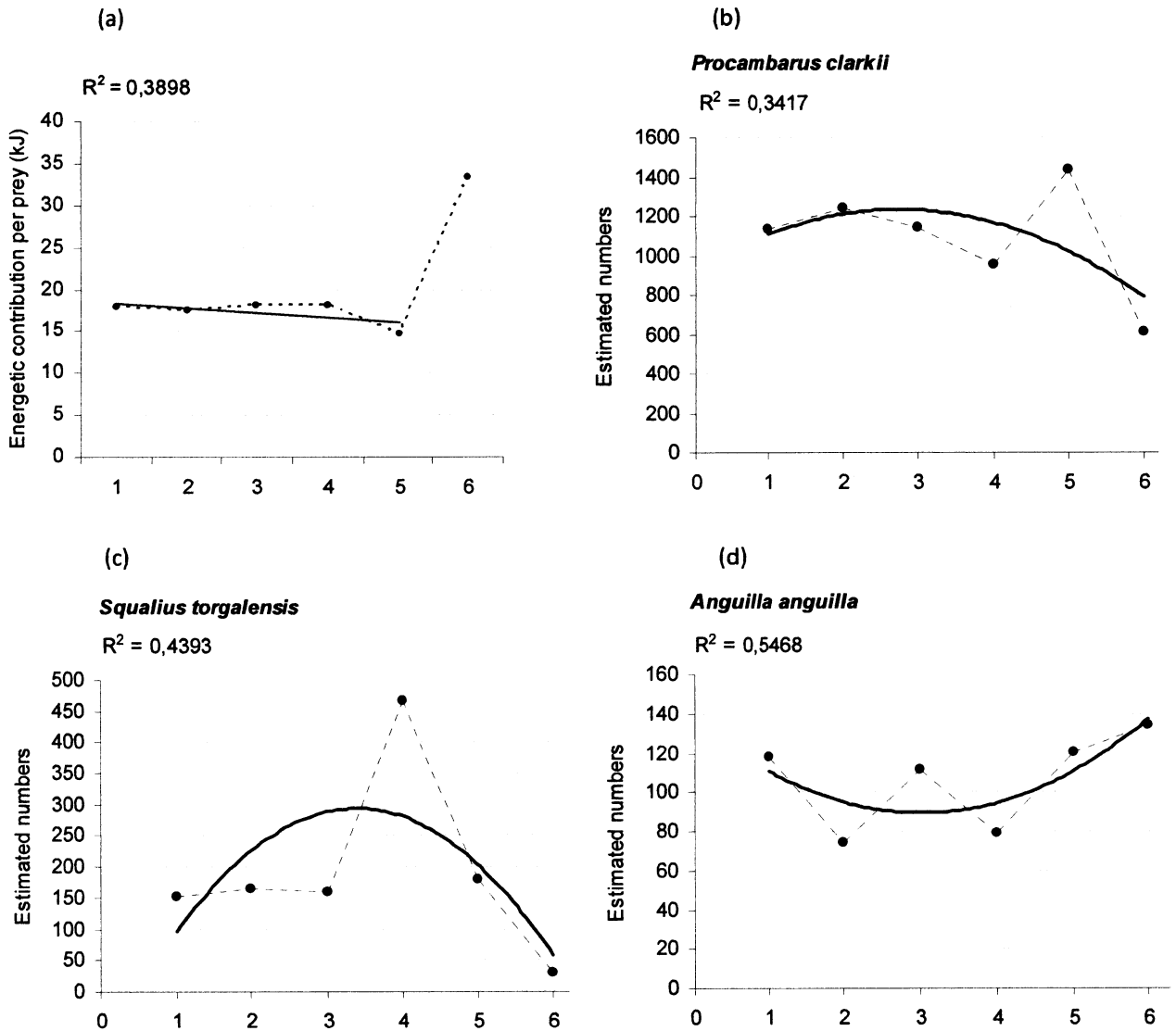## 3.6 *Energetic fluctuations and estimated prey numbers*

Fig. 10 Temporal variation of the (a) mean energetic contribution, per prey item, and estimated prey items of the three main prey species: (b) crayfish, *P. clarii*, (c) chub, *S. torgalensis*, (d) eel, *A. anguilla*, in otter energy intake. Surveys: 1 – late July, 2 – early August, 3 – late August, 4 – early September, 5 – late September, 6 – early October.

The mean energetic contribution showed no significant linear trend throughout the survey period (F = 1.769; d.f. = 1, 4; P = 0.670), but during the first five surveys it showed a non significant decrease (F = 1.917; d.f. = 1, 3; P = 0.260; r^2 = 0.62). As seen in Fig. 10-a, the lowest value was reached during late September, and increased to its highest value afterwards. The estimated prey numbers showed high fluctuations (Fig. 10b, c, d), though none was significant. Crayfish and chub estimated numbers decreased (crayfish: F = 0.779; d.f. = 2, 3; P = 0.534; r^2 = 0.34; chub: F = 1.170; d.f. = 2, 3; P = 0.421; r^2 = 0.44), but the estimated number of eels increased (F = 1.765; d.f. = 2, 3; P = 0.331; r^2 = 0.54).

4. DISCUSSION

4.1 *Methodology limitations*

Otters are considered opportunistic predators (Sostoa and Lobon-Cervia, 1989). Although some studies have shown selective predation towards some fish species (e.g. Beja, 1995), the relative contribution of different fish species is usually closely correlated with their relative proportions in the community (Sostoa and Lobon-Cervia, 1989). Otters can shift their diet whenever larger prey items are available, as long as its capture will be energetically rewarding (Brown, 1988, Clavero et al., 2007). They have been also shown to use intensely some prey items that are only seasonally available, according to their characteristic life cycle patterns (Clavero et al., 2006). However, it is often difficult to accurately assess prey availability, and therefore its seasonal changes, since different capture or censuring methods have diverse efficiency rates regarding different prey types (Beja, 1995).

The sampling results for prey availability, namely fish species, were not contemplated in our study. However, in the absence of prey abundance data, according to the evidences mentioned above, it can be assumed that the patterns presented in our diet results, regarding crayfish and other prey, may be a reflection of the real availability during the study period (Beja, 1996, Correia, 2001, Fidalgo et al., 2001).

4.2 *Otter activity*

Our results are supported by previous findings which state the highest sprainting otter activity may indicate defence of a scarce resource, rather than a high population density of otters (Kruuk, 1995). The territories of many otters may be dramatically altered between seasons, and the territory marking intensity tends to be higher in almost dry rivers, compared to rivers with relative flowing, during summer (Ruiz-Olmo et al., 2007). A literature review conducted by Carss (1995) in foraging behaviour and feeding ecology of otters revealed this species to be food-limited under certain circumstances and vulnerable to fluctuations in prey abundance (= availability). During stressful times otters may have to increase their range size, forage in different habitats, and possibly increase the consumption of 'sub-optimal' food.

Effectively, sprainting activity in Torgal river was higher during August, and then lowered towards the end of the surveyed period, suggesting that as the drying process intensified, foraging became more difficult probably due to prey depletion, and since energy costs affect foraging decisions (Brown, 1988), otters lowered their marking efforts towards the end of the summer–early autumn, probably changing their foraging area temporarily.

4.3 *Otter diet and relationships with prey abundance and behaviour*

The main prey species in otter diet – crayfish and chub – suffered a decrease in the relative importance in terms of occurrences and biomass, and also in their mean length. Although a reduction in the average sizes of crayfish and chub did not appear to be very evident as time progressed, another indirect evidence of probable prey depletion could be demonstrated through a differential decrease between prey size classes. Beja (1996) found evidences that otters had a significant preference for larger crayfish, and in the present study, larger individuals of both species – crayfish and chub – showed an earlier and greater decrease in time, than smaller individuals. More specifically, crayfish decrease occurred firstly within larger items right after the second survey (early August), and then a decrease within smaller items began just after the third survey (late August).

According to Magalhães et al. (2002), young chub are very abundant in ponds during summer periods. The highest increase recorded in our diet results regarding the numbers of small chub (mainly fish <30 mm, with only a few months old) during September could be related with the species growth, as a result of the late spawning period of this species (March to May), compared to nase (Magalhães et al., 2002). Therefore, the increasing numbers of smaller fish in the otter diet was probably related with a greater likelihood of finding shoals of young-of-the-year chub, in shallow waters, hence the temporal fluctuations in the mean length values.

Additionally, the decrease in the numbers and average length (hence, biomass) of crayfish and chub affected negatively the average energetic contribution per prey item until late September. Subsequently, the relative estimated numbers of both species implied an increase in the consumption of less energetically rewarding prey items, after September.

As for the consumption of eels, there was a different pattern. The mean size seemed to increase as time progressed, and larger eels tended to be slightly more frequent in the diet later in the season, with the exception of late September.

The fact that it is considered a much rarer species in Torgal stream, in terms of abundance comparing to crayfish or other fish, does not redraw any importance in otter diet. Many authors consider eels to be a preferential prey for otters (Carss, 1995, Miranda et al., 2006), since, compared to other fast swimming fish, it is a very slow but much energetically rewarding prey type, enabling otters to prey upon fewer individuals (Beja, 1995). In fact, proportions of different prey categories in the otter diet are also assumed to depend on other factors besides

their relative abundance, with high density prey species or slower moving species being apparently favoured. Factors like prey swimming speed, conspicuousness or detectability, and prey behaviour versus energetic reward may influence otter choice when foraging (Erlinge, 1968), leading to a positive selection towards benthic species, whereas mobile prey species may be able to rapidly escape (Kruuk, 1995).

Although there are suggestions of a probable prey depletion within the most consumed prey items, in our study, a wider spectrum of eel sizes tended to be more preyed upon throughout the surveyed period (see table 3 and Figs. 4, 6, 7 and 8). These results are also in concordance with others authors who showed that otters are not especially selective towards eels, neither in terms of abundance, nor in terms of size (Clavero et al., 2007, Delibes et al., 2000, Kruuk, 1995).

As already stated by Beja (1996), eels were quite energetically important during summer in the Torgal stream, and tended to occur simultaneously with crayfish, more than mere chance. Moreover, the author verified that otters had a higher likelihood of capturing eels, when preying on crayfish, suggesting they may be more frequently captured during the same foraging bout. Indeed, crayfish and eels can be more vulnerable to otter predation, because they both become active at night (Tesch, 1978, Mason and Macdonald, 1987), unlike cyprinids; and their benthic nature facilitates otters foraging behaviour underwater by searching in a 2-dimensional instead of a 3-dimensional space, when searching for pelagic fish (Erlinge, 1968).

The behaviour of adult eels in rivers is different regarding size, with smaller eels preferring shallower waters and larger eels preferring deeper waters (L. Costa pers. com.). In the Torgal stream, smaller eels (<30 cm) tend to be much more frequent (D. Pires pers. com.) as can be also verified by our diet results (percentage of occurrences = 80%). Smaller eels showed a decrease in occurrences during September, while the frequency of larger eels (30-60 cm), which was much lower, increased slightly as drying progressed. This suggests that the capture probability increased as water levels lowered, as eels were forced to congregate at the bottom of ponds, making them more vulnerable to otter predation.

These results could also imply a higher energetic intake towards the end of the surveyed period (Figs. 4 and 8). However, comparing the mean energetic contribution per prey (Fig. 10a) to the relative contribution of eels in otter intake energy, one can verify by the negative trend that the increasing consumption of larger eels was not enough to satisfy otters' energetic needs, until late September.

Regarding the decreasing numbers of consumed pumpkinseed until August, this could be associated with its territorial behaviour during the mating season, which may last from May to

August (Ribeiro, 2008). This means they could be more vulnerable to otter predation during this period, and if pumpkinseed depletion may indeed occur it is possible that otters can somehow control this exotic species spreading in Torgal stream.

Further indirect evidences of shifts in prey consumption was provided by the expected pattern for the summer diet variability of otters in the Torgal stream, expressed by the Shannon diversity index, which was consistent until early September. When crayfish abundance was higher (early August), the diversity index was low, as already reported by Beja (1996), and then showed an increase until early September, when crayfish values were lower and smaller chub showed a greater contribution in otter diet (Fig. 6). Consequently, one can once again infer that less-energetic items were collected later in the season.

Regarding the exceptional pattern found between late September and early October revealed by evidences of an abrupt shift – from a decrease in the consumption of crayfish and eels' to a rapid increase (see Fig. 6c, 8a and 9) –, it could simply be explained by these species burrowing behaviour, which in turn suggests an apparent renovation of its availability, even before ponds regained connectivity. Costa et al. (2008) reported that in the southern region of *A. anguilla* geographical range, the high summer temperatures, which occur in freshwater, tend to reduce eels activity, similar to the activity reduction that occurs in the winter months. Thus, eels tend to hide in the sediment at stressful periods, and become inactive almost without feeding (Costa et al., 1992; L. Costa pers. comun.).

As for crayfish, they are known for their burrowing habits when exposed to extreme temperatures and dry periods (Anastácio, 1993, Oliveira and Fabião, 1998). During autumn, larger and mature individuals are found leaving their burrows and moving towards the water making them more conspicuous to predators (Correia and Ferreira, 1995). On the other hand, during the wandering phase, breeding males can move up to 17 km in four days covering wide areas (Gherardi and Barbaresi, 2000); so crayfish may be relatively mobile on land but, although eels are known for travelling outside the water (L. Costa pers. com.), it is less likely that there was a replenishment of eels from neighboring stretches.

This may have coincided with the last survey, when smaller crayfish were immediately substituted by larger individuals in the otter diet (Fig. 5). So, crayfish and eels were less available during late September, when the ponds biophysical conditions were much more deteriorated and temperatures were still high. Subsequently, the higher numbers and average sizes of crayfish and eels in otter diet at the beginning of October were probably related to the first autumn rainfalls and the lowering of mean temperatures during late September, leading these species to become more active and available again to otters.

5. CONCLUSIONS

The main assumption in the assessment of temporal trends in the otter diet composition, in ponds during drought periods, was that prey may be initially distributed uniformly but may become depleted as a result of preferential selection of prey items (Delibes et al., 2000).

Otters can use feeding patches for long periods, until their main prey is depleted, as proven by several studies (e.g. Delibes et al., 2000, Ruiz-Olmo et al., 2007), and in the present study otter activity decreased towards the end of the surveyed period. There was also a progressive increased probability of shifting their preying behaviour towards alternative prey, and a subsequent increase in the trophic diversity index.

Crayfish was the main consumed prey (80% of occurrences), and although chub represented about 10% of occurrences, there was evidence of a decrease in the consumption of larger individuals of both species.

Despite theoretical suggestions and empirical evidences with most of all our initial hypotheses for a decrease in the consumption of the main prey items by otters in Torgal stream were supported, there are still no direct evidences suggesting that large prey items were in fact prone for depletion by foraging pressure of otters.

In conclusion, these findings are consistent with the foraging theory indicating that otters modify their prey selectivity in response to shifts in the real prey availability, which in turn is influenced by numerous environmental and ethological factors.

The fact that chub was less important in the otter diet, does not minimize predation risk. The observed predation patterns still highlight important questions. Is otter predation a significant structuring force in endemic fish species, inhabiting Mediterranean streams, during dry periods? To which extent do otters shape fish distribution and abundance in such circumstances? Therefore, further investigation is needed to shed some light into these questions. If predation risk for some endemic fish species is highest when confined in ponds during critical periods, there is a potential hypothesis that the selective pattern of otter predation among different sized ponds may influence the shaping of fish communities in the long term (among other factors). Population age and size structure may be affected, during the most vulnerable time of the year. For example, if one of the most sensitive and endemic fish species in Torgal stream – chub – shows recruitment failure in very dry years (Magalhães et al., 2003), it could have subsequent effects in the way these restructured fish assemblages recolonize streams, after dry periods (Magalhães et al., 2002), which could prevent population growth.

6. AKNOWLEDGMENTS

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CONSIDERAÇÕES FINAIS

O objectivo geral da presente dissertação foi tentar averiguar a ocorrência de depleção de presas provocada pela predação de lontra, em ribeiras mediterrânicas durante períodos de seca. Alguns estudos (Delibes et al. 2000, Ruiz-Olmo et al. 2007) revelam que a lontra pode utilizar os pegos por longos períodos, até que haja depleção das principais categorias de presas, indiciado pela modificação do seu comportamento predatório ao longo do tempo, ao surgirem determinados sinais que se reflectem na dieta da lontra. Os resultados principais do presente estudo podem ser assim resumidos, em função da escala temporal: 1) diminuição dos níveis de actividade das lontras ao longo da ribeira a partir do final de Agosto até ao final de época seca (início de Outubro); 2) diminuição da contribuição relativa, em termos de biomassa e energia consumida das principais espécies de presas – lagostim e escalo-do-Mira; 3) substituição gradual no consumo de diferentes tamanhos de lagostim e escalo-do-Mira, cujas classes dimensionais maiores foram substituídas pelas mais pequenas, à medida que os pegos foram explorados; 4) ligeira diminuição do comprimento médio dos lagostins consumidos até final de Setembro; 5) aumento da diversidade trófica na dieta das lontras entre Agosto e Setembro; 6) diminuição da contribuição energética média por presa; 7) aumento do consumo de presas energeticamente menos vantajosas.

O efeito das altas temperaturas e deterioração das condições biofísicas dos pegos condicionaram a actividade dos lagostins e enguias e consequentemente a sua diminuição da disponibilidade poderá ter tido efeitos no grau de actividade das lontras na área de estudo. Para além disso, os resultados levantam ainda questões sobre se os padrões de predação diferencial das lontras poderão ter efeitos na forma como este predador oportunista poderá moldar a distribuição e abundância de espécies de peixes, nomeadamente espécies endémicas, em ribeiras Mediterrânicas. Nestas circunstâncias torna-se necessário um conhecimento mais aprofundado sobre mecanismos adaptativos ecológicos e comportamentais das espécies envolvidas.

Futuras linhas de investigação poderão passar, por exemplo, pela manipulação experimental destes habitats, com a exclusão ou redução da actividade da lontra nos pegos e que poderia resultar no aumento das densidades de peixes ciprinídeos no final da época seca. Tal efeito teria consequências na distribuição espacial de determinadas espécies disponíveis para recolonizar a ribeira durante a época húmida (Magalhães et al. 2002). Para testar esta hipótese seria necessário recolher informação acerca das densidades de peixes e número de lontras e investigar as respectivas variações espacio-temporais.

A existência de pegos durante os períodos secos é fundamental para a conservação da lontra, bem como das espécies piscícolas, em rios Mediterrânicos. Como tal, as estratégias de conservação deveriam focar-se nos requisitos das várias espécies envolvidas. Os pegos maiores e mais profundos providenciam habitats mais estáveis, com maior variabilidade e tendem a aumentar a diversidade das comunidades piscícolas (Magalhães et al. 2002). Por sua vez, também as lontras utilizam mais frequentemente este tipo de pegos e portanto as estratégias de conservação devem ter este aspecto em consideração. Deverão ser evitadas actividades humanas que ponham em causa a heterogeneidade destes habitats, em particular actividades que diminuam o número de pegos e respectiva profundidade (Ruiz-Olmo et al. 2007).

Acima de tudo, as estratégias de conservação devem ser melhoradas, tendo em consideração todos os factores que poderão limitar as comunidades piscícolas de habitats Mediterrânicos mais ameaçadas, como por exemplo, as alterações climáticas, pois, a longo prazo, poderão provocar uma simplificação das mesmas (Magalhães et al. 2002). Estes processos são particularmente cruciais para a conservação da biodiversidade em sistemas dulciaquícolas, dada as elevadas taxas de endemismos piscícolas nesta região (Leunda et al. 2009).

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