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THE RELATIVE INFLUENCE OF RIPARIAN HABITAT STRUCTURE AND FISH AVAILABILITY ON OTTER *Lutra lutra* L. SPRAINTING ACTIVITY IN A SMALL MEDITERRANEAN CATCHMENT

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Abstract

The influence of riparian habitat structure and fish availability on otter Lutra lutra *marking activity was studied at the head of the Guadalete river (southern Spain). Otter habitat in the study area could be ordered along two gradients in structural properties (altitude, stream order, channel form, water current, bank vegetation), water quality and bankside plant species composition. Generally, higher altitude sites had more dense bankside vegetation cover and better water quality. The dominant upstream bankside plant assemblage consisted of species such as* Rubus *sp.,* Salix *spp., and* Arundo donax, *which provided secure shelter for otters. In contrast, at downstream sites the typical plant assemblage was* Tamarix africana, Nerium oleander *and* helophytes, *overall bankside cover was lower but wider and the water was more eutrophic. Otter sprainting activity was correlated with this gradient, being higher in downstream sites, especially in areas dominated by short vegetation and scarce human presence. Similarly, fish biomass was greater downstream. A strong positive correlation was observed between otter sprainting activity and larger fish size. Thus, the variability in otter marking intensity along the upper Guadalete seemed to be more dependent on fish availability, and secondly on human disturbance, than on particular riparian habitat features, including the species composition of vegetation growing on the river banks. Implications for conservation management of otters in Mediterranean areas are discussed.*

Keywords: otter conservation, Mediterranean streams, riparian habitat, riverside vegetation, water quality, human presence, Iberian peninsula.

INTRODUCTION

Otters *Lutra lutra* L. can exploit a wide array of aquatic environments, where specific habitat features such as those that provide sheltered and secluded areas are usually considered to be important. Some authors have observed a positive correlation between the amount of bank vegetation cover and sprainting activity over large areas (e.g. Adrián *et al.*, 1985; Macdonald & Mason, 1985; Rodríguez *et al.*, 1988; Delibes *et al.*, 1991). However, cover *per se* need not be an accurate predictor of marking intensity, because in certain areas, despite high cover values, such a correlation was not observed (Liles & Jenkins, 1984; Macdonald & Mason, 1985; Rodríguez *et al.*, 1988; Delibes *et al.*, 1991). Also, signs of otters have been found along most of the length of some rivers even though they had little cover (Macdonald & Mason, 1983).

Few authors have measured food availability for otters in natural environments and most (e.g. Jenkins & Burrows, 1980; Bas *et al.*, 1984; Adrián *et al.*, 1985; Macdonald & Mason, 1985) tend to assume that food supply is constant. On the other hand, Melquist and Hornocker (1983) and Kruuk *et al.* (1993) concluded that prey availability was the main factor determining abundance and distribution of otters in some North American and Scottish rivers, and Dubuc *et al.* (1990) identified four composite habitat variables predicting the occurrence of river otters *Lutra canadensis*, all of them directly or indirectly related to stream productivity.

This study describes general features of otter habitat and distinguishes the relative importance of food and habitat structure on otter marking activity along an altitudinal gradient at the head of the Guadalete river in southern Spain. Special emphasis was placed on the analysis of bank vegetation structure as potential shelter for otters, on the availability of fish, which are the main otter prey in the study area (Prenda & Granado-Lorencio, 1992), and on the conservation management implications for otter populations in the Mediterranean area.

STUDY AREA

The study area (*c.* 1500 km^2) was located in the north of Cádiz province and included two of the main tributaries of the Guadalete river, the Guadalporcún and Majaceite. It is a mountainous region rising to 1654 m.

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A large part lies within the protected area of the Parque Natural de la Sierra de Grazalema, part of the MAB Program. The area is dominated by a Mediterranean climate with Atlantic influence. Yearly average rainfall is 1400 mm (range 600–2200 mm) and is concentrated during autumn and spring. Mediterranean trees and shrubs (*Abies pinsapo*, *Quercus* spp., *Pistacia lentiscus*, *Cistus* spp., etc.), are the dominant vegetation, being more abundant at higher elevations and on poor soils and steep slopes. Low flat lands are intensively cultivated, primarily with olive trees, wheat and sunflowers. Human population density is low (48 km^{-2}) and industries are almost absent (AMA, 1987). Nomenclature for plant names follows Tutin *et al.* (1964–80).

METHODS

Otter status and habitat measurements

The study area was surveyed on 16 April, 9 May and 9 June 1991 for habitat analysis and otter status. This period was selected as the most favourable for the availability of spraints (Delibes *et al.*, 1991) and for vegetation study. Twenty-two sites were visited. At each site, 600 m of waterway were searched for signs of otters, mostly from the water. All obvious spraints and sprainting sites were counted. Sprainting activity was expressed as number of faeces per 100 m of waterway. The spraint searching method employed was considered quite accurate because most streams surveyed were very well known and in most of the sites surveyed we knew the otter sprainting sites fairly precisely. These streams were also quite small, which allowed thorough survey by five to six people, not only of sites in or near the water but of the banks distant from the main channel (20–25 m).

In each sampling site, those habitat features considered of potential importance to otters (Mason & Macdonald, 1986) were measured or estimated. These included site altitude, stream order, channel width, gradient, water current, eutrophication, bank vegetation cover, height and width, and human activity in surrounding areas. Some of these variables were estimated visually according to a qualitative scale (Table 1). For water current, and bank vegetation height and width estimates, several calibration tests on previously determined measures were made before the sampling.

Table 1. Qualitative scales used to estimate selected variables of riparian habitat

Scale	Water current	Human activity	Plant species abundance
0	No current (pool)	Lacking	—
1	Slow (0·1–0·3 m s^{-1})	Scarce/far	Present
2	Moderate (0·3–0·7 m s^{-1})	Moderate/near[a]	Scarce
3	High (> 0·7 m s^{-1})	Intense[b]	Moderate
4	—	—	Very abundant

[a]There were some human activities in the surrounding areas: buildings, intensive agricultural practices, cattle and vehicles crossing. Riparian habitat was somewhat degraded.
[b]The area was near buildings, the symptoms of degradation were evident: elimination of bank vegetation, channelization, fords, visible symptoms of water quality degradation, water extraction, etc.

Each variable was measured or estimated for approximately each 75 m of channel length, giving on average eight measures/estimates for each variable in a 600 m stretch along each bank.

At each sampling site the degree of eutrophication–pollution (0, no eutrophication; 1, low eutrophication; 2, moderate eutrophication; 3, moderate pollution) was based on previous knowledge of sampling sites (see Gallardo & Prenda, 1994). Altitude, stream order and gradient for each study site were obtained from cartographic maps (scale 1: 50,000, National Grid of Spain).

For statistical analysis, the scores for each 600 m (of independent bankside, in the case of vegetation variables) were averaged. Variables were tested for normality applying a normal probability plot or chi-square test. When necessary the data were transformed (log $[x+1]$, or arcsin $[x^{1/2}]$ for percentages).

To determine the effect of riparian habitat structure on sprainting activity, the two first components of a principal component analysis (PCA), performed on a matrix of sites*riparian habitat variables, were related to the number of spraints per 100 m.

Vegetation estimates and analysis

For each 75 m length of bank, vegetation cover was assessed by the percentage occupied by helophytes, shrubs and trees. Short grass and herbaceous vegetation was excluded because it offers little cover to otters (Mason & Macdonald, 1986; Delibes *et al.*, 1991). The relative abundance of tall plant species was independently estimated for each bank, applying the qualitative scale in Table 1, and estimates of plant species abundance at each sampling site were averaged.

To determine the importance of plant assemblages rather than dominant species, another PCA was performed on a matrix of sites*index of plant relative abundance. This index was computed by multiplying the mean relative abundance of each species by the overall percentage cover of each site divided by 4 (maximum value in the scale of plant species relative abundance). This index takes the form of relative percentage cover for individual species. The main trends in bank vegetation composition in the study area were related to otter sprainting activity. Of 52 species identified, only those present in at least seven sampling sites (> 30% of sites) were selected for PCA (20 species), to avoid chance associations.

Prey availability

To compare otter sprainting activity with prey availability, two separate intensive samplings were carried out. The first was performed between October 1988 and October 1989, when between four and nine surveys were made in eight sites along the Guadalete river. In each site, the number of otter spraints was recorded in 200 m stretches. At the same time, fish populations were surveyed by electrofishing (d.c. 220 volts, 1–2 amps). At each site, a sample of fish was caught after

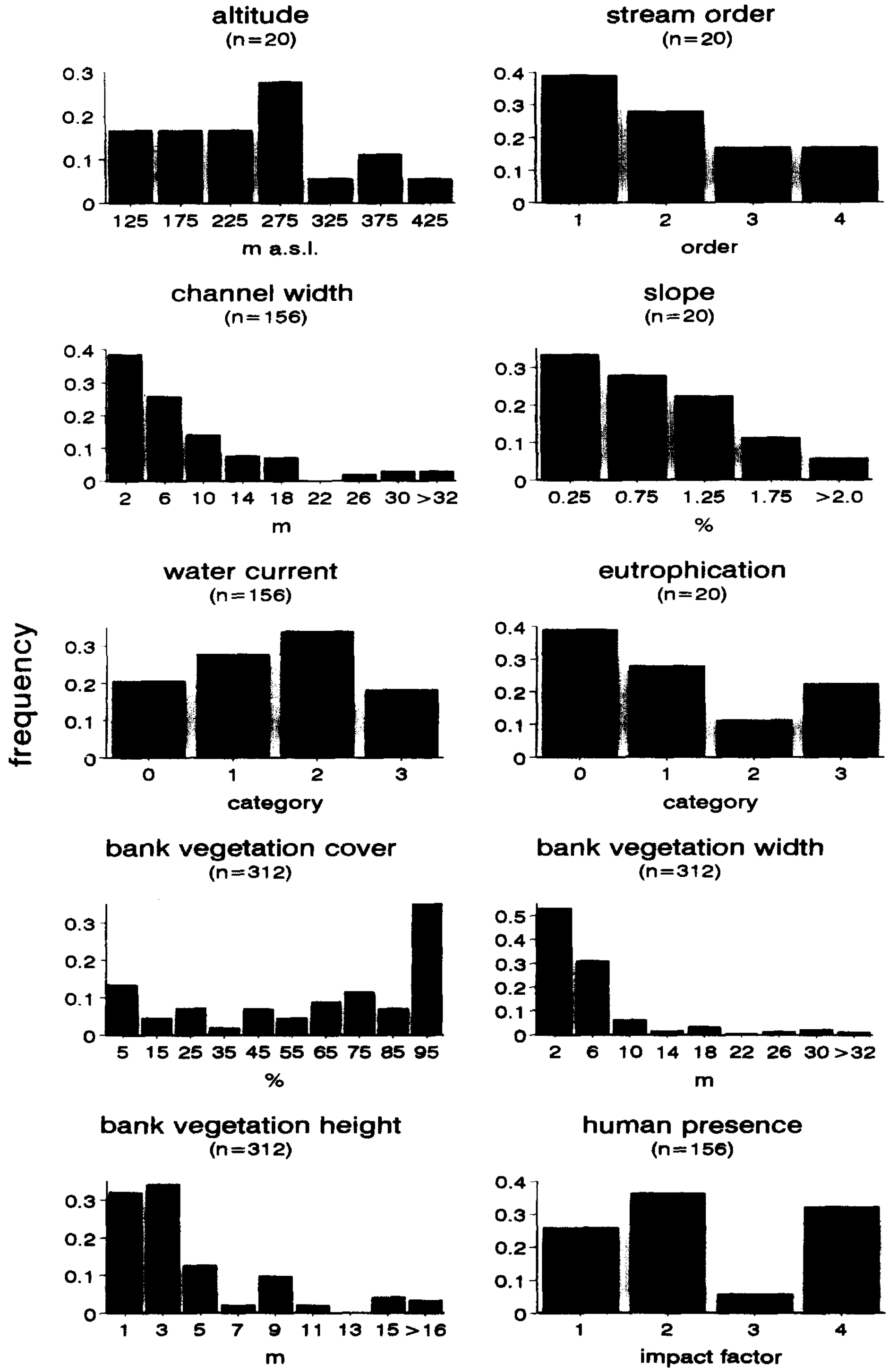

Fig. 1. Frequency distribution of selected riparian habitat features in the sites found positive for otters in the upper Guadalete catchment (Cadiz province, south Spain). See Table 1 for category units.

15–30 min of electrofishing in 100 m stretches and all fish longer than 100 mm were measured.

In the second sampling, between eight and eleven surveys of fish and otter spraints were made in two contrasting sites (each 400 m long) between December 1990 and December 1991. Site 1 was typical of headwaters and Site 2 of intermediate stretches (Prenda, 1993). Fish density (number m^{-2}) and biomass (g m^{-2}) were assessed by electrofishing at both sites. A prepositioned 12 m^2 electrofishing device was used (two copper 4 m long bars at 3 m distance) supplied with a.c. (220 V, 1–2 A) (Bain *et al.*, 1988). At each site, 20 evenly spaced locations (at 20 m intervals) were sampled, extending to a 400 m stretch that included all fish microhabitats, such as riffles, pools and runs (Prenda, 1993). All fish captured were identified and measured. Fish sampling was carried out five times: December 1990, March, June, September and November 1991. Biomass was estimated using length–weight regressions for fish fauna from the study area.

Electrofishing in the study area was considered highly efficient because of the electrical conductivity in these streams, and also through considerable prior experience on this technique in the study area.

Table 2. Pearson correlations between the habitat variables included in a PCA of riparian habitat structure and the first and second principal components

The percentage of variance accounted for each component is given in parenthesis. n=20; * $p < 0{\cdot}05$, ** $p < 0{\cdot}01$, *** $p < 0{\cdot}001$.

Habitat variables	PC1 (38·9%)	PC2 (21·5%)
Channel width	0·87***	−0·16
Stream order	0·84***	0·01
Water eutrophication	0·65**	0·04
Bankside vegetation width	0·46*	−0·70***
Slope	−0·81***	−0·23
Altitude	−0·67**	0·41
Bankside vegetation cover	−0·55*	−0·41
Water current	−0·49*	−0·33
Bankside vegetation height	−0·28	−0·91***
Human disturbance	0·25	−0·55*

The fish fauna from the upper Guadalete river comprised only three species, all Cyprinidae: Iberian barbel *Barbus sclateri*, Iberian nase *Chondrostoma polylepis willkommii* and Iberian chub *Leuciscus pyrenaicus*. Data for these were pooled because they use similar microhabitats in the study area (Prenda, 1993) and otters selected prey according to their abundance (Prenda, unpublished data).

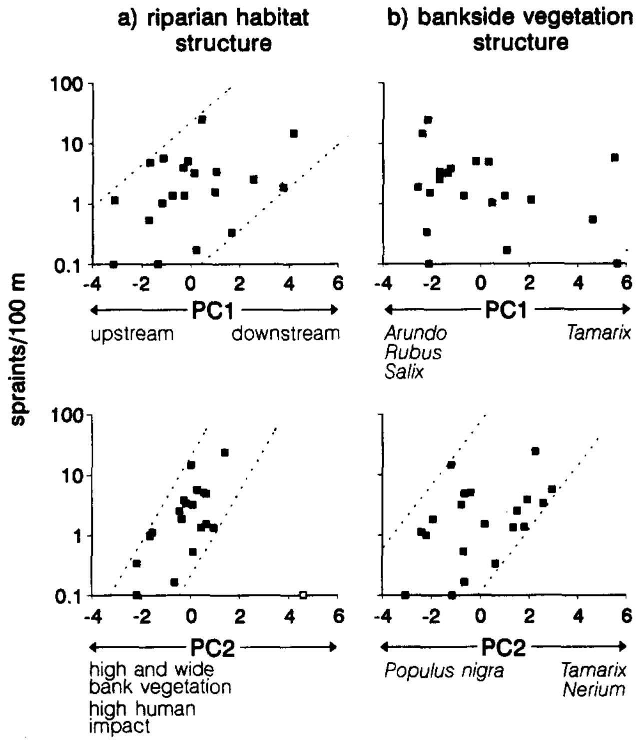

Fig. 2. Relationships between both first and second principal components (PC1 and PC2, respectively) following principal component analysis of (a) riparian habitat structure and (b) bankside vegetation structure with otter sprainting activity (spraints/100 m). The open square is considered an outlier. See Tables 2 and 3 for interpretation of principal components.

RESULTS

Riparian habitat analysis

Of the 22 sites extensively surveyed in 1991, 20 (91%) proved positive for otters. All sites surveyed intensively in 1988–89 (8) and 1990–1991 (2) also proved positive. Typically, otter habitat in the upper Guadalete basin consisted of a narrow channel, less than 12 m wide, with low to moderate water current, bankside vegetation with cover > 50%, height < 6 m and width < 8 m. Altitude was usually below 300 m and channel gradient was 0–2%. Most streams were first or second order and did not receive sewage effluent. Human presence and activities in the surrounding area ranged from low to moderate (Fig. 1).

Habitat features followed an upstream–downstream gradient (Table 2). River channels were narrower, slopes steeper and water current and bankside vegetation cover higher upstream while downstream sites tended to be more eutrophic (Table 2). A second gradient in habitat structure could be established. This was independent of altitude and was related to bankside vegetation width and height and to human impact (Table 2).

Otter sprainting activity was positively correlated to both habitat gradients (PC1: F = 3·7, p = 0·069, R^2 = 17·2%; PC2: F = 13·2, p = 0·002, R^2 = 43·7%, excluding one outlier) (Fig. 2(a)). In the case of PC1 it indicates that otter sprainting activity tended to increase downstream. For PC2 the tendency to an increase in otter signs in sites dominated by short and narrow bankside vegetation strips far from human disturbance was very strong, if we excluded the outlier site. Also, otter sprainting activity was higher in sites with turbid rather than clear water (t = 2·88, p < 0·01).

Bank vegetation structure and sprainting activity

The first component of bank vegetation composition and abundance PCA accounted for 34·5% variance and defined three groups of vegetation (Table 3). This component was strongly correlated with the PC1 obtained from the PCA of riparian habitat variables (F = 34·9, p = 0, R^2 = 66·0%). The group positively correlated with PC1 included those species more abundant in the upper catchment, mostly in streams of lower order (Table 3). A second, negatively correlated vegetation group (Table 3), corresponded to species more abundant in downstream areas (streams of order 3 and 4), where riparian habitat conditions tended to be opposite to those in the headwater (see Table 2). A third group contained those plant species which were widely distributed along the whole basin (Table 3).

The second component derived from the vegetation PCA (Table 3) was positively correlated with PC2 of riparian habitat PCA (F = 6·2, p = 0·024, R^2 = 26·6%, excluding one outlier) and determined a gradient in plant species composition between sites with low human impact dominated by short vegetation, and areas with opposite characteristics.

The number of spraints per 100 m was not related to the first component, but was positively correlated with the second (Fig. 2(b)) (F = 8·4, R^2 = 31·8%, p = 0·001, n = 20), which supported the correlation found

Table 3. Plant species associations obtained after principal components analysis of bankside vegetation structure, their Pearson correlation (r) with the first (a) and second (b) principal components and the mean value (± 1 SE) of the index of relative abundance (see Methods) at upper (stream order 1–2 or above 250 m asl) and lower (order 3–4 or below 250 m asl) sites

Species	Abundance		r
(a)	Order 1–2	Order 3–4	PC1 (34·5%)
Rosa sp.	16·6±4·9	1·8±1·3	0·93***
Arundo donax	23·9±7·2	3·7±2·3	0·88***
Ficus carica	14·9±6·2	0·1±0·1	0·88***
Rubus ulmifolius	41·4±6·3	19·8±6·2	0·85***
Salix atrocinerea	21·1±5·7	2·3±1·5	0·85***
Fraxinus angustifolia	19·3±7·1	5·3±1·9	0·73***
Populus nigra	9·2±3·9	0·8±0·6	0·70***
Smilax aspera	8·8±4·0	1·0±0·7	0·66**
Rhammnus alaternus	10·3±4·5	0·3±0·3	0·64**
Juncus spp.	5·2±1·8	2·6±1·6	0·61**
Eucalyptus camaldulensis	17·0±6·1	3·8±0·9	0·56*
Nerium oleander	23·1±5·1	19·3±4·8	0·50*
Total	210·6±46·3	60·8±15·6	0·96***
Tamarix africana	18·9±6·6	30·3±8·7	–0·46*
Phragmites australis	5·8±2·7	6·2±3·2	–0·46*
Typha spp.	8·3±5·8	9·3±4·6	–0·45*
Total	33·0±12·7	45·7±14·0	–0·53*
Crataegus monogyna	4·3±1·2	7·9±3·0	0·14
Populus alba	13·2±5·2	9·8±5·4	–0·19
Salix alba	15·4±3·5	17·7±6·9	0·25
Salix purpurea	5·1±2·8	4·9±3·4	–0·29
Scirpus holoschoenus	1·6±0·9	3·2±1·2	–0·32
Total	39·6±5·9	43·5±14	–0·01
(b)	> 250	< 250	PC2 (15·9%)
Tamarix africana	14·7±6·7	31·6±7·9	0·79***
Nerium oleander	20·0±5·2	24·3±5·7	0·63**
Eucalyptus camaldulensis	8·8±4·9	18·1±7·8	0·59**
Populus alba	9·0±4·8	16·1±6·5	0·58**
Phragmites australis	4·1±2·4	8·2±3·6	0·51*
Typha spp.	3·5±2·9	14·8±8·5	0·47*
Salix purpurea	4·2±2·8	6·1±3·4	0·45*
Total	64·3±16·6	119·3±23·9	0·93***
Populus nigra	11·7±4·7	0·5±0·4	–0·46*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Mean (± 1 SE) number of otter spraints per 100 m and mean fish biomass (kg/100 m²) and abundance (individuals/100 m²) in two contrasting sites in the upper Guadalete basin (southern Spain), assessed between December 1990 and December 1991 *t*-tests for two-sample comparisons

	Upstream (Site 1)		Downstream (Site 2)		
	Mean	*n*	Mean	*n*	*t*
Sprainting activity	2·31±0·38	8	5·41±0·82	11	–3·47**
Fish biomass	3·11±1·16	5	5·21±0·50	5	–1·79
Fish abundance	417·00±192	5	83·00±10	5	2·25*

* $p < 0.05$, ** $p < 0.01$.

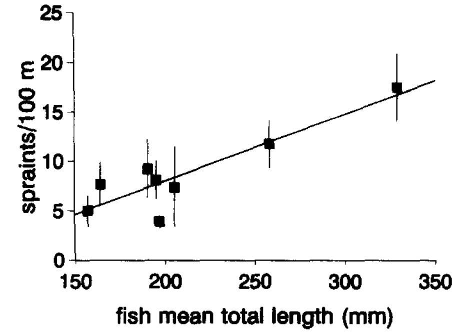

Fig. 3. Relationship between sprainting activity of otters and mean fish length in the Guadalete river. Each point represents the mean value for 4–6 sampling periods between October 1988 and October 1989, along an upstream–downstream gradient. *n* for mean fish length ranges between 259 and 1808 individuals. Regression equation for fish length: $r^2 = 0.83$, $p = 0.0042$, $y = 0.07\,x - 6.29$. Error bars represent ± 1 SE.

between otter sprainting activity and PC2 from riparian habitat PCA. These results suggested that more spraints occurred in sites dominated by the plant species assemblage positively correlated with PC2, usually more abundant downstream (see Table 3).

Prey availability and sprainting activity

Fish were the main prey for otters in the study area throughout the study period, occurring in 70% of spraints ($n = 374$) and comprising 90% abundance of otter prey items (Prenda & Granado-Lorencio, 1992). Otter sprainting activity was strongly correlated with mean fish length (Fig. 3) which was negatively correlated with altitude ($R^2 = 0.51$, $p = 0.046$, $n = 8$), i.e. larger fish occurred downstream. Comparisons of sites representative of upstream (site 1) and downstream (site 2) sections again showed significantly greater sprainting activity and fish size downstream (mean fish weights in sites 1 and 2 were 7·48 g and 62·76 g respectively) (Table 4).

DISCUSSION

The significance of otter marking intensity

Most surveys of otter habitat and status have been carried out using signs (mainly spraints) indicative of the presence of this mustelid (see Mason & Macdonald, 1986, and references therein). This technique has limitations and is a controversial issue which has stimulated intense discussions (Kruuk *et al.*, 1986; Kruuk & Conroy, 1987; Mason & Macdonald, 1987). However, with caution, sites may be related in a gross sense and from medium to large scale (from one basin to whole regions) with intensity of otter habitat use. Previous works indicate that most marking signals are concentrated in activity centres and foraging sites and that their abundance is usually enhanced as the number of individuals increase (e.g. Erlinge, 1967, 1968; Melquist & Hornocker, 1983; Green *et al.*, 1984; Conroy & French, 1987). Thus, sprainting activity can be considered as a rough index of otter habitat use. Since the final objective of this work is not to establish the number of otters present in the study area but to infer differences in habitat use in relation to habitat variability, the use of sprainting activity as an index seems to be adequate.

The effects of habitat quality and prey availability

In general, according to the descriptions made by other authors for different regions (Macdonald & Mason, 1983, 1985; Liles & Jenkins, 1984; Adrián *et al.*, 1985; Taylor *et al.*, 1988), the stream habitat of the upper Guadalete river basin was favourable or very favourable for otters and coincided with the typical otter habitat in Spain (Elliot, 1983).

According to Green and Green (1980) the preferred otter habitat comprises the slower and more productive middle and lower reaches of rivers. In the upper Guadalete catchment the riparian habitat was better for otters upstream than downstream due to higher water quality and higher bankside vegetation cover, but otter marking activity was usually higher downstream, in intensively cultivated areas, especially in sites with scarce human presence.

The increase in spraint density downstream paralleled an increase in fish mean size and biomass. Otters in the study area seemed to respond to prey availability, in the form of larger prey size, rather than to riparian floristic composition and habitat structure. The importance of prey availability on otter habitat use has been stressed by many other authors (e.g. Elliot, 1983; Green *et al.*,1984; Melquist & Hornocker, 1983; Dubuc *et al.*, 1990; Kruuk *et al.*, 1990, 1993). Kruuk *et al.* (1993) observed that in Scotland utilization of streams by otters was strongly correlated with fish biomass, which in turn was negatively correlated with stream width, probably because salmonid biomass decreased exponentially with stream width (Kruuk *et al.*, 1993). In the Guadalete catchment fish biomass was negatively correlated with altitude, but again seemed to be the factor responsible for otter habitat use.

Otter conservation in Mediterranean areas

Most of the reasons for otter decline in Spain proposed by Delibes (1990) were directly or indirectly related to prey availability. Moreover, Delibes (1990) and Rodríguez *et al.* (1988) concluded that the main factor of otter extinction was the pollution of rivers through its effects on fish populations. In Spanish rivers the main source of pollution is organic sewage effluent from urban areas, and this is considered by Elvira (1995) to be one of the main factors threatening fish populations. Thus, in most of the Iberian Peninsula, where thriving otter populations still exist, the reduction of river pollution must be the first target in otter conservation plans (Delibes, 1990).

Adrián *et al.* (1985) suggested that otter declines in southwestern Spain were partially a consequence of agricultural practices. They proposed three measures to protect otters in cultivated areas: protection of riparian vegetation, control of pesticides and reduction of water extraction from the rivers. Although all three can be very important, the protection of fish resources in streams may be the most beneficial to otter populations in areas where agricultural practices and some degradation in bankside vegetation do not seem to affect otters negatively, as in the upper Guadalete catchment. Many streams in southern Spain still have well-preserved riparian vegetation, although water quality is extremely degraded and the rivers do not hold fish populations (e.g. Guadaira river basin) (Prenda & Gallardo, 1992). This is a main difference in otter habitat conservation between Mediterranean lands and more northerly countries, where riparian cover can be more limiting than water quality. In addition, organochlorine contamination derived from agriculture does not seem to be very important, at least in the lower Guadalquivir (Delibes *et al.*, 1991). Therefore, wastewater purification in many urban areas of southern Spain is a fundamental management activity to restore fish populations and hence the recolonization and/or increase of otter populations.

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