THESES OF DOCTORAL (PhD) DISSERTATION

KAPOSVÁR UNIVERSITY
FACULTY OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
Department of Wildlife Biology and Ethology

Head of Doctorate School:
DR. KOVÁCS, MELINDA
Corresponding Member of the Hungarian Academy of Sciences

Supervisor:
DR. LANSZKI, JÓZSEF
Doctor of the Hungarian Academy of Sciences

FEEDING HABITS OF THE OTTER ON THE BASIS OF FIELD STUDIES AND *POST MORTEM* ANALYSIS

Author:
BAUER-HAÁZ, ÉVA ANITA

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1. BACKGROUND OF RESEARCH, OBJECTIVES

Background

The Eurasian otter (*Lutra lutra* Linnaeus, 1758) is a widely distributed characteristic mammalian top predator of aquatic habitats. After the population declined and became extinct in numerous parts of Europe in the second half of the 20th century, otter populations are now recovering throughout many parts of their former range due to slow improvement in habitats and protection. The population of the otter in Hungary is stable, but differences between the various regions of the country are considerable.

Since the last decades, both the number and total area of fish ponds, and ponds under management for nature conservation have also increased in Hungary. Ponds managed for conservation are buffer or shelter areas (i.e., year-round undisturbed habitats), where only the regulation of fish populations is applied. These near-natural habitats are suitable for investigating the ecological function and behaviour of piscivorous species in relation to fish farming. Although the feeding habits of the otter have been widely investigated both in natural freshwater habitats and in highly productive fish farms, little is known about prey selection by otters in semi-natural ponds managed for nature conservation.

The otter is one of the most extensively studied carnivores in Europe, partly because of this fishery conflict and it is a characteristic and environmental indicator species. Food composition and feeding habits have been studied mainly by faecal or spraint analysis, and by direct observations or by fish remains left and only rarely by examination of stomach content. Despite the differences in diet composition depending on habitat type and season the differences in feeding habits of the otter depending on sex and age are less known (*post mortem* analysis, observations on seashore) because of

difficulties in direct observations and limitations of indirect examination methods. Differences related to certain factors (e.g. body condition), can only be examined by *post mortem* analysis.

Main objective of my theses was to broaden knowledge of ecology of the otter, a keystone species of aquatic habitats, particularly its feeding habits.

I. The aim of the 4-years long field research was to analyse the feeding composition and habits of otter in a small (4 ha) pond managed for nature conservation in Csombárd Meadow Nature Conservation Area as a model pond. I examined:

(1) what is the seasonal and the annual (general) feeding composition and the niche breadth.

(2) the feeding preferences and the diet composition of otter in relation to species, weight class, habitat, and origin of fish.

(3) how the results of the dietary preference are influenced by the type of fish sampling method.

II. The aim of the study based on *post mortem* analysis of otters found dead in Hungary (from 2002) was to answer the following questions:

(1) What is the quantity (weight) and composition of stomach content, and how is it influenced by season, sex, age group, habitat type, body condition and causes of mortality?

(2) What is the composition of rectum content?

(3) What kind of relationship exists between the content of two sample types (stomach and rectum)?

(4) How close is the relationship between the different calculation methods, such as the most commonly used relative frequency of occurrence and the wet weight data, and in the case of rectum content between its data and estimated biomass composition?

2. MATERIALS AND METHODS

2.1. Field studies

Study area

The study was carried out in SW Hungary on an abandoned artificial small size fishpond (pond Csombárd, Somogy county, 4 ha). The stable presence of otters was recorded on the site. The fish management has been limited to conservation measures.

Sampling and analysis

Diet composition of the otter was determined by spraint (faecal) analysis (n= 1656 samples), collected monthly from March 2008 to January 2012 along the banks and dike of the pond on a 600-m long standard route. Fish preference of the otter within this period, during a year (from December 2010 to November 2011) was studied. Standard wet protocol of sample treatment was applied. Fish species were taxonomically identified on the basis of morphological differences of scales and bones, using atlases and reference collections both for fish and other food taxa.

Calculation methods, food item categorization

The percent composition of otter diet was expressed as relative frequency of occurrence (%O). All dry food remains were weighed and their weight multiplied by an appropriate coefficient of digestibility to obtain an estimate of the fresh biomass percentage (%B) of the food consumed. Weight category of preyed fish was back-calculated using a reference collection of bones from fish of known size. Based on these weight estimates, food items were divided into the following categories: < 100 g, 100-500 g, 501-1000 g and > 1000 g. Fish species were also grouped according to their occurrence

within the water body: littoral, metaphyton, pelagic and benthic, and origin: native and alien (or non-native).

Fish population surveys

Fish availability in the pond in a year was investigated using electrofishing and fyke nets. Electrofishing was carried seasonally, sampling was conducted along a shoreline transect. Fyke nets (n=14) were set for four consecutive days, twice and three times in each seasons on the water surface and on the bottom. Each captured fish was identified at species level, weighed, and released, except for non-native fish individuals. To avoid multiple counts, specimens > 100 g were marked by cutting a ray of the dorsal fin.

Data evaluation

The following seven main prey taxa were used in the calculations: mammals, birds, reptiles, amphibians, fish, crayfish and other aquatic invertebrates. Trophic niche breadth was calculated in accordance with Levins and standardised (B_{sta}, rating from 0 to 1). Spearman's rank correlation coefficient was applied on the number of occurrences and biomass data (food remains weight × correction factor). Ivlev's index (E_i) of preference was applied to each fish taxon and weight category. The Chi-squared test (χ^2) was used to compare raw frequency data of fish in otter diet (use) and in the environment (availability) in relation to survey method, season, fish weight class and occurrence within the water body. As our data were fitted well to a normal distribution, we used an independent sample t-test to evaluate the effect of fish survey method on the normal E_i values of different fish species, in relation to fish weight, occurrence within the water body and origin.

2.2. *Post mortem* analysis

Samples studied

Stomach and rectum samples were collected in Hungary from n = 236 *post mortem* examinations carried out on wild otters found dead. The specimens were sorted into one of the four seasons according to the date of finding, sex, age groups (adult, sub-adult juvenile), body condition (condition index with quartiles), habitat types (Lake Balaton region, other lakes or ponds, rivers, small watercourses), causes of mortality (road-kills and others).

Sampling methods and evaluation

Stomach and rectum samples were collected from the carcasses during *post mortem* analysis of otters stored frozen. Standard protocol was used during the examination of stomach and rectum contents. The identification method of food items and the weight categories of fish was the same used as in the field research. The percentage composition of food from the stomach and rectum samples were determined on the basis of both relative frequency of occurrences (%O) and wet weight of individual food remains found in the samples (%W), and in the case of rectum samples – as spraint samples – B% was calculated.

Statistical analysis

The differences in stomach content weight among the four seasons, three age groups, four habitat types and three condition index categories were determined with Kruskal-Wallis test, while among the sexes and two mortality categories the stomach content weights were evaluated with Mann-Whitney test. In the rectum, the relationship between wet and dried weight data was tested by Mann-Whitney test. Wilcoxon signed rank test on W data was used in comparative analysis of the composition of stomach and rectum contents by the seven main prey taxa and by weight category of prey

specimens. The distribution of empty and non-empty stomachs was determined for each factor studied with the Chi-square test. The χ^2 test was used for distribution analysis of the diet composition (seven main prey categories) and prey consumption on the basis of weight categories for each factor studied both in otter stomach and rectum samples. Spearman's rank correlation coefficient was calculated for the number of occurrences of each food item in stomachs and summarized weight of each food item measured, both in the case of seven main prey taxa and 20 fish taxa and size classes. Spearman's rank correlation coefficient was applied on the number of occurrences and summarized wet weights and on the number of occurrences and biomass data (food remains weight × correction factor).

3. RESULTS

3.1. Field research

General diet

According to the spraint found along the pond Csombárd (n=1656 spraints, n=2889 food items) the relative frequency of main fish species in otter diet varied by season (Chi-square test, $P<0.001$). Fish consumption was the lowest in spring (O: 64.7%, B: 82.5%), gradually increased till winter (O: 87.1%, B: 97.2%). Secondary food resource was amphibians (annual sum, O: 11.8%, B: 5.1%), third was birds (O: 3.0%, B: 1.0%), other food types were rare.

During to the high value of fish consumption– standardized trophic niche breadth (B_{sta}) was very narrow in all season (annual mean ± SE, 0.056±0.015).

In methodical point of view it is very important that the relation between results of the two dietary calculation methods (%O and %B) was close (Spearman correlation, $r_S = 0.892$, $P<0.001$).

Fish diet composition

Three fish taxa formed the bulk (O: 75.5%, B: 82.6%) of otter diet throughout the year, namely *Carassius* sp. (mainly gibel carp from spring to autumn), pumpkinseed and perch (especially in winter). Beside these species, consumption of topmouth gudgeon (particularly in autumn and winter) and of black bullhead (particularly in spring and summer) was seasonally considerable. Predation of economically important species was less important, consumption of common carp was subordinate, consumption of pike-perch, pike and other cyprinids were only occasional.

The otter preyed on small fish (<100 g) in every season frequently and in high quantitative ratios (O: 93.4%, B: 89.1%). Mainly littoral fish were eaten (gibel carp topmouth gudgeon, pike, pumpkinseed) (O: 75.1%, B: 77.3%). Main fish food of otter consisted of non-native species. (O: 76.1%, B: 79.1%)

Fish preference

The composition of fish population varied according to the type of sampling method applied (Chi-square test, $P<0.01$) and changed among seasons based on both sampling methods ($P<0.01$). Based on electrofishing, the pumpkinseed and the gibel carp being the most widespread species. According to sampling by fyke nets the most common species was the rudd, other abundant species were the topmouth gudgeon and the gibel carp, the common perch and the black bullhead. Fish weighing less than 100 g were predominant.

In different level by fish size category, the common carp, gibel carp, and perch were preferred, the topmouth gudgeon showed no preferences (was eaten by its density) according to the summarized data. Rudd, roach, tench and most size categories of pikeperch were avoided. Bullhead were preferred by otter when its availability was assessed by electrofishing (independent samples t-test, $P<0.05$), whereas pumpkinseed were preferred based on availability as assessed by fyke nets ($P<0.01$). There were no significant differences between E_i data for other fish species based on sampling methods ($P= 0.051$-0.980).

Otter consumed small-sized fish (< 100 g in weight) according to their occurrence in the environment as assessed by either electrofishing or fyke net sampling ($E_i= 0.02$ *vs*. 0.04, respectively; independent samples t-test, $P=0.648$), whereas 100-500 g fish were slightly avoided ($E_i= -0.17$ *vs*. -0.28,

P=0.550). Larger fish categories rarely occurred, but fish in the 501-1000 g category were slightly preferred (E_i= 0.31 *vs*. 0.32, P=0.881), and fish > 1000 g were avoided (E_i= -0.36 *vs*.-0.66, P=0.956). Preferences did not vary by sampling method for any size category.

Otter preferences in relation to fish habitat and origin differed according to the sampling method used to assess fish availability. Otter preferred fish occur in the shorezone (E_i= 0.44 *vs*. -0.06, P<0.05), but avoided fish living in the metaphyton (E_i= -0.35 *vs*. 0.17, P=0.051) and benthic (E_i= -0.35 *vs*. 0.81, P<0.01) when fish availability was assessed by fyke nets, but not by electrofishing. Pelagic fish were avoided according to both methods (E_i= -0.12 *vs*. -0.32, P=0.786).

Native fish species were avoided and non-native fish species were preferred when availability was based on fyke netting (E_i= -0.33 and 0.29), while no preference was pointed out by electrofishing (E_i= 0.13 and -0.03).

3.2. *Post mortem* analysis

Stomach content

The relationship between quantitative composition in the stomach (W) and the relative frequency of occurrence data (O) was significant in the case of the seven main prey taxa (Spearman's rank correlation coefficient, $r_S = 0.79$, $P < 0.05$) and also in the case of the 20 fish taxa ($r_S = 0.66$, $P < 0.01$).

There were no significant differences (Kruskal-Wallis test, P = 0.296) in the weight of stomach content by seasons as well as in occurrence of empty stomachs (Chi-square test, P = 0.302). However food composition differed significantly according to the season (Chi-square test, P < 0.001). Otters preyed most frequently on fish in winter and autumn. Consumption of amphibians (and small mammals) increased in spring, and in summer the

most frequent prey were amphibians. The quantitative diet composition showed less seasonal fluctuation. Considering the dominant fish food, in the stomach mainly *Carassius* sp. (>90% gibel carp; W: 28.8%, O: 13.4%) together with common carp (W: 21.4%, O: 5.6%) were found

In all seasons otters preyed mainly on small fish (< 100 g in weight; O: 80.0-91.3%, W: 63.6-81.4%). Relying on the weight category of the prey, the distribution of food components was non-significant among the seasons (Chi-square test, P = 0.891).

Weight of food remains measured in the stomach of males was significantly higher than that of females (Mann-Whitney test, $P < 0.05$), but there were no significant differences among sexes in the distribution of empty stomachs (Chi-square test, $P = 0.968$). The diet compositions differed significantly by sex. Males preyed more frequently and in higher quantitative ratios on fish, while females preyed more on amphibians ($P < 0.001$). In comparison to females, males preyed more frequently on larger (> 100 g) animals (11.5% *vs*. 2.4%, $P < 0.05$) and in a higher quantity ratio (W: 39.2% *vs*. 10.5%).

No significant age dependent differences were found in the weight of food remains in the stomachs (Kruskal-Wallis test, P = 0.092), as well as in occurrence of empty stomachs (Chi-square test, P =0.746). Juveniles consumed invertebrates more frequently and in higher quantitative ratios than adult and sub-adult otters ($P < 0.001$). However only non-significant differences among age groups were found when comparing prey size distributions (P = 0.565).

There were no significant differences in the mean weight of stomach content by habitat types (Kruskal-Wallis test, P =0.216), as well as in occurrence of empty stomachs (Chi-square test, P = 0.319) and in food composition (Chi-square test, P = 0.231). Otters took prey larger than 100 g more rarely on ponds ($P < 0.05$) than on other habitat types (4.5%, vs. 9.1-12.0%).

The weight of stomach contents increased (Kruskal-Wallis test, $P < 0.01$) with improvement in condition. The ratio of empty stomachs also decreased (Chi-square test, $P < 0.01$) with condition improvement.

The mean weight of stomach content of otter road kills were double (Mann-Whitney test, $P < 0.05$) that of otters from other causes of mortality. Empty stomachs were also found more frequently in otters found dead by other causes than by road-kill (44.4% *vs*. 24.6%%; Chi-square test ($P < 0.05$). Otters which died of other causes preyed on amphibians and invertebrates and otters which died by traffic preyed more frequently on fish and in higher quantitative ratios ($P < 0.01$).

Rectum content

Relying rectum contents, omitting other aquatic invertebrates, as consumed relatively frequently but in low quantity ratios food category from the evaluation, relationships among the calculation methods (W,O,B) were significant in all pairs (W-O: $r_S = 0.99$, W-B: $r_S = 0.94$, and O-B: $r_S = 0.99$, $P < 0.01$ in all cases). Relationships between the results of the three estimating methods calculated only with fish (8 taxa) were also significant (W-O: $r_S = 0.81$, $P < 0.05$, W-B: $r_S = 0.99$, $P < 0.01$, and O-B: $r_S = 0.81$, $P < 0.05$).

Differences between sample types

Considering all the samples, the composition of otter stomach and rectum content did not differ significantly on the basis of the seven main prey taxa between the wet weight data (W) of stomach and rectum contents (Wilcoxon signed rank test, $P = 0.063$). However distributions between the two sample types were different (Chi-square test, $P < 0.001$): in stomachs there was similar evidence of fish consumption and amphibians, while in rectum contents invertebrates occurred more frequently. Fish were taxonomically

identifiable more frequently from stomach than rectum samples (Chi-square test, $P < 0.05$).

Relying on the weight categories of prey, the distribution of food components did not differ significantly between the wet weight of rectum (W) and weight of stomach (W) contents (Wilcoxon signed rank test, $P = 0.068$), nor between the relevant frequency distributions (O) of the two sample types (Chi-square test, $P = 0.423$).

4. CONCLUSIONS

4.1. Main statements of field research in pond Csombárd:

4.1.1. *General dietary pattern*. In the abandoned fish pond (Csombárd) the most important food was fish in every season, which thought to be optimal food (energetically and availability point of view) for otter. This result differs remarkable from experiences found is larger but fluctuating fish population near-natural habitats (e.g. marshlands, oxbow lakes), however result shows strong similarity to found in high fish abundance fishponds.

4.1.2. Relationships between calculation methods. Efficiency of food consumption calculating methods is still actual question. There is no "one" good method. According to our examination results of the more frequently used relative frequency of occurrence (%O) and the rarely used biomass (%B) calculation were similar. These agree to the result of other dietary studies performed in Hungary. Therefore, I recommend using both calculation methods in future studies.

4.1.3. *Consumption by fish size and occurrence within the water body*. Main fish food of otter in pond Csombárd consisted of mainly small (<100g) specimens, which result is similar to found in many other European and Hungarian studies. These small fish were species judged indifferent or negative in economical point of view. Considering the small size of the pond, the relatively shallow water and the dense vegetation, otter consumed mainly fish occur in the shorezone and metaphyton and rarely consumed benthic and pelagic fish.

4.1.4. *Consumption by origin of fish*. One of the most important results of our study is that the otter consumed non-native invasive species in high ratio. Otter "helps" to maintain the native fauna, the stability and the abundance of

water habitats by consuming fish species judged to be negative in ecological and nature conservation point of view.

4.1.5. *Fish preference*. Results of our research in pond Csombárd support the opinion that the content of otter's diet reflects the composition of the fish fauna in natural or near-natural habitats. Otters are opportunistic hunter; prey on the highest density and easiest catchable fish species and specimens of the most frequent size category, and adapting to the seasonal changing of food. Results of calculation methods by fish size showed specific pattern. However, results of fish preference by fish habitats and origin differed by calculation methods.

According to our research electrofishing is more effective for catching shorezone- and metaphyton-dwelling fish, whereas fyke-nets are primarily suitable for catching benthic and diurnal fish. This means that the type of sample taking method influence the evaluating of fish preference result.

Results of our study in the abounded fish pond Csombárd can be useful in preservation of 1) otter, 2) near-natural ponds, 3) native fish fauna.

4.2. Main statements of *post mortem* analysis

4.2.1. *Stomach content, general pattern.* Composition of stomach content and spraint are similar in many respects. It is very important that according to the stomach content as well otter consumed mainly small sized and economical not important fish.

Relationship between calculation methods. It's important in methodology point of view as well, that the quantitative composition based on summarized weight of food remains detected in the stomach and the relative frequency of occurrence data based on the number of food items correlated significantly.

4.2.2. *Stomach content, differences by factors.* According to our research the larger and heavier males preyed more frequently on larger animals and in a

higher quantitative ration than females, which ate “worse quality” (less energetically value) preys e.g. amphibians, arthropods.

There was no evidence that stomach of otters found dead near fishponds contained economically important fish in higher ratios. In all habitat types consumption of small and economically not important fish was determining.

The road-killed otters, which had usually better condition, consumed larger preys and in higher quantitative ration on fish, than otters died of other causes (e.g. poisoning, dog attack), which were often in worse condition. The weight of stomach content increased, whereas the ratio of empty stomach also decreased with improvement in condition.

The age-dependent difference was also important, juveniles during learn to hunt consumed less energetically valued invertebrates than adults.

4.2.3. *Rectum content.* Correlation between basic data of the three calculation methods (W, O, B) were significant.

4.2.4. *Differences between sample types.* It’s also important in methodology point of view, that according to the *post mortem* analysis the composition of otter stomach (de facto reflects the consumed diet) and rectum content (similar to easier, non-invasive collectable spraint) was basically similar.

5. NEW SCIENTIFIC RESULTS

1. According to spraint (faecal) analysis the otter prey *mainly small and non-native (mostly invasive)* fish, consumption of larger fish and other preys (e.g. amphibians, birds) are less important in a nature conservation managed pond (pond Csombárd, Somogy county) On the basis of few relevant publications, it is generally characterised in ponds abundant in invasive (and small) fish. The otter diet composition indicates that the near-natural wetlands are also strongly "infected" by non-native fish. Otter also prey on non-native species which are avoid by other piscivor species because of e.g. shape, spine.
2. According to diet analysis based on fish population surveys otter is *an opportunistic hunter*, prey on mostly the most frequent and easiest catchable fish species *in a nature conservation managed pond.* Results of fish population survey whereas results of fish preference calculation are *influenced by the sampling method type*. Experience acquired in the pond as a model can be utilized in other similar wetlands.
3. According to *post mortem analysis* otter mostly preyed on small, economically not important (invasive) fish, which is *consisted with results of spraint analysis in pond Csombárd* (and in many other European study sites). Correlation between weight of food remains (W) and number of food items (O) detected in stomach was significant according to both the seven main prey taxa (r_s=0.79, P<0.50) and the 20 fish taxa (r_s=0.66, P<0.01).
4. *Stomach content composition differed significantly* by season (more fish consumed in autumn and winter, more amphibians in spring and summer), by sex (males consumed more fish), by age group (juveniles during learn to hunt consumed more invertebrates). Stomach of otter road-kills contained

more fish than of otters dead by other reason (e.g. dog attack, otter attack, illness), which can be in relation to hunting success.

5. *Correlations* between basic data of the three calculation methods (W, O, B, as calculated biomass composition) were *significant.* According to the *post mortem* analysis the composition of otter stomach and rectum content was *basically similar.*

6. RECOMMENDATIONS

Research

- Further defined researches need to analyse how the otter can influence the populations of invasive fish species due to different hunting strategies. It is also important in nature conservation and fish management point of view.
- Further researches need to prove the effect of the "rare consumption" on a rare prey species.
- Medical examination of fish chewed by otter near fishponds is recommended to make clear the background reason of predation on larger fish individuals (possible sanitary role).
- Spraint analysis can be use as an (cheaper) alternative in fish populations monitoring e.g. in some special cases. Otters are able to reach those fish species which cannot be detected by neither fish survey methods.
- Results found in the different sample types and food consumption calculating methods strengthen the reason for continue the cheaper, non invasive spraint analysis use in monitoring and research.

Education, preservation

- Better knowing of otter dietary habits, such as the preferred fish species, helps to reduce or avoid damages caused by otter in fish farms. The experiences acquainted widely with e.g. education in fish farming are recommended.
- Our research contributed to understand the role of artificial waters in preserve of biodiversity. Experiences can be utilized in creating and maintenance of other habitats.
- Survive of stable otter populations depends mainly on favourable actions on habitats, and better knowing and acquainting of distribution and habitats

of the species. My research can be guideline for protection of the otter, its habitats and water ecosystems.

Damage reducing

- Instead of damage compensation, prevention methods based on legal tools (e.g. electric fences around wintering ponds) for avoid and reduce the economical damage caused by piscivor species should be officially supported.

7. PUBLICATIONS ON THE SUBJECT OF THE DISSERTATION

Peer-reviewed papers published in journals

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Lanszki, J., Marler, H., Bauer-Haáz, É. A., Nagyapáti, N., Széles, L. G. 2013: A vidra elterjedése és az előfordulását befolyásoló tényezők vizsgálata a Balaton déli vízgyűjtő területén. XXXVII. Halászati Tudományos Tanácskozás. Konferencia helye, ideje: Szarvas, 2013. május 20-23, Konferencia Kötet, p. 55.

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