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ANALYSES OF THE FOOD HABITS OF THE RED FOX AND THE STONE MARTEN IN CENTRAL GREECE USING A TREE-FITTING MODEL

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ABSTRACT

The dietary habits of red fox (*Vulpes vulpes*) and stone marten (*Martes foina*) were studied in central Greece in period 2003 - 2005. The stomach contents of 219 red fox and 106 stone marten were characterised for their various prey items. The prey species were classified depending on their origin in six diet groups (mammals, birds, plants, arthropods, reptiles – amphibians and others). The samples were collected from regions where hunting is practised and in regions where hunting is not practised and classified across seasons and habitats (shrubs, agriculture, oaks). Plants, arthropods and mammals dominated the diet of the two carnivores in all seasons. The carnivores took birds and reptiles – amphibians at low levels, accounting for less than 11% of the food items for any season. Manmade items were more common in the red fox diet than for the other carnivore Using tree analysis, the only dependent variable included in the final model was “season”, indicating that “season” was the best predictor of “diet group”, while food habits were not significantly different with respect to “year”, “habitat” and “hunting”.

Keywords: Red fox, *Vulpes vulpes*, stone marten, M*artes foina*, food habits, Greece

INTRODUCTION

Dietary analysis is a frequent first step in studying an animal’s ecology because diet directly reflects resource use and can provide insight into habitat utilization and competitive interactions (Litvaitis, 2000). For carnivores, the availability and utilization of various food resources are important factors affecting population viability (Fuller and Sievert, 2001). Additionally, competitive interactions among carnivore species are common and can have major impacts upon their ecology and management (Palomares and Caro, 1999; Creel *et al.,* 2001). Such interactions usually favour the larger competitor and can result in decreased fitness for the subordinate competitor, due to direct mortality, reduced access, exclusion from preferred resources and reduced foraging and reproductive efficiency (Johnson *et al.,* 1996; Palomares and Caro, 1999; Creel *et al.,* 2001). Therefore, understanding such interactions can be critical when conservation of the subordinate competitor is a management goal.

Trees are directed graphs beginning with one node and branching to many. They are fundamental to computer science (data structures), biology (classification), psychology (decision theory), and many other fields. In the last two decades, they have become popular as alternatives to regression, discriminant analysis, and other procedures based on algebraic models. Morgan and Sonquist (1963), proposed a simple method for fitting trees to predict a quantitative variable. They called the method Automatic Interaction Detection (AID). The algorithm performs stepwise splitting for each predictor. Regression trees are parallel to regression/ANOVA modeling, in which the dependent variable is quantitative. Classification trees are parallel to discriminant analysis and algebraic classification methods. Kass (1980) proposed a modification to AID called CHAID (Chi-squared Automatic Interaction Detection) for categorized dependent and independent variables.

The primary objective of this work was to describe trends in the food habits of red fox (*Vulpes vulpes*) and stone marten (*Martes foina*) in central Greece, using a tree-fitting method. An analysis of the food habits of these two sympatric species is an important step toward their effective management.

MATERIALS AND METHODS

Study area: Red fox (*Vulpes vulpes*) and stone marten (*Martes foina*) stomachs in central Greece were collected from spring 2003 through winter 2005, for analyses. The samples were collected from zones in central Greece where hunting was practiced and where hunting was not practiced and these were classified across seasons and habitat (shrubs, agriculture, oaks).
Overall, 219 red fox and 106 stone marten stomachs were analyzed and the various prey items that participated in the diet of the two animals were determined according to the earlier methods of Litvaitis (2000). The prey species were classified depending on their origin in six diet groups (mammals, birds, plants, arthropods, reptiles – amphibians and others).
For tree analysis, Kass's algorithm CHAID (Chi-squared Automatic Interaction Detection) was used. The method incorporates a sequential merge-and-split procedure based on a chi-square test statistic (Wilkinson 1979 (20)). Breiman *et al.* (1984) showed that this method tends to yield trees with too many branches and can fail to pursue branches that can add significantly to the overall fit. They therefore advocate pruning the tree. After computing an exhaustive tree, their program eliminates nodes that do not contribute to the overall prediction. They add another essential ingredient, however - the cost of complexity. Regardless of how a tree is pruned, it is important to cross-validate it. As with stepwise regression, the prediction error for a tree applied to a new sample can be considerably higher than for the training sample on which it was constructed. Whenever possible, data should be reserved for cross-validation. Cross-validation divides the sample into a number of sub-samples, or folds. Tree models are then generated, excluding the data from each sub-sample in turn. The first tree is based on all of the cases except those in the first sample fold, the second tree is based on all of the cases except those in the second sample fold, and so on. For each tree, misclassification risk is estimated by applying the tree to the sub-sample excluded in generating it.

RESULTS

Plants, arthropods and mammals dominated the diet of the two carnivores in all seasons. The carnivores took birds and reptiles – amphibians at low levels, accounting for less than 11% of the food items for any season. Manmade items were more common in the red fox diet than for the other carnivore (Table 1).

Table 1: Frequency of occurrence (absolute and %) of diet groups used by red fox and stone marten, split to season

Diet group	Spring		Summer		Autumn		Winter	
	Red fox	Stone marten	Red fox	Stone marten	Red fox	Stone marten	Red fox	Stone marten
Mammals	77(17.11)	13(10.92)	57(27.94)	6(2.80)	87(22.48)	4(3.03)	71(24.07)	4(1.79)
Birds	11(2.44)	7(5.88)	4(1.96)	8(3.74)	14(3.62)	1(0.76)	14(4.75)	7(3.13)
Plants	80(17.78)	5(4.20)	56(27.45)	163(76.17)	206(53.23)	76(57.58)	64(21.69)	109(48.66)
Arthropods	234(52.00)	59(49.58)	62(30.39)	33(15.42)	55(14.21)	41(31.06)	113(38.31)	99(44.20)
Reptiles-Amphibians	12(2.67)	6(5.04)	5(2.45)	4(1.87)	2(0.52)	3(2.27)	5(1.69)	0(0.00)
Others	36(8.00)	29(24.37)	20(9.80)	0(0.00)	23(5.94)	7(5.30)	28(9.49)	5(2.23)
Number of stomachs	61	33	40	31	58	16	60	26

For Tree analysis, each step of the CHAID chooses the independent (predictor) variable that has the strongest interaction with the dependent variable. Categories of each predictor were merged when they were not significantly different with respect to the dependent variable. Independent variables tested were "year", "season", "habitat" and "hunting". "Prey items" was used as an influence variable. The only independent variable included in the final model was "season". In other words, using the CHAID method, "season" is the best predictor of "diet group".
The chi-square value (since the tree was generated with the CHAID method), degrees of freedom (df), and significance level (p-value) were displayed for the split in figure I. For practical purposes, interest was shown only on the significance level, which was less than 0.0001 for the split in this model. In spring, mammals, plants and arthropods dominated in red fox's diet. Since there are no child nodes below "spring", this was considered a terminal node. In summer, mammals and plants dominated, while in autumn and winter mammals dominated in red fox's diet.

Cumulative gains charts always start at 0% and end at 100% as we go from one end to the other. For a good model, the gains chart will rise steeply toward 100% and then level off. A model that provides no information will follow the diagonal reference line. The gains chart for “reptiles-amphibians” indicates that the model is a good one, compared to the other five diet groups (Figure II).

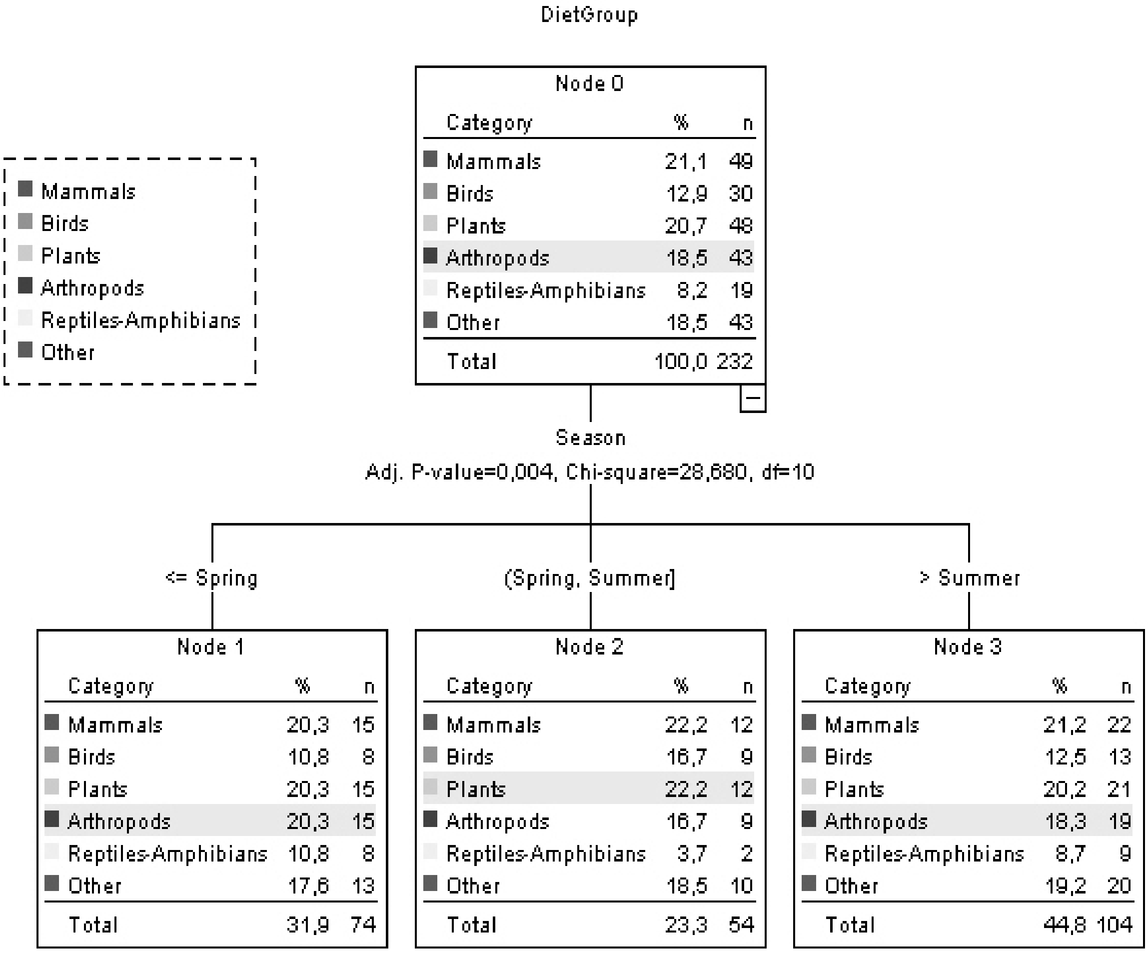

Fig. I: Tree-fitting model.

For a good model, the index value should start well above 100%, remain on a high plateau as we move along, and then trail off sharply toward 100%. For a model that provides no information, the line will hover around 100% for the entire chart. The index charts for “birds” and “reptiles-amphibians” indicated that the model was a good one, compared to the other four diet groups (Figure III).

The risk and classification statistics provide a quick evaluation of how well the model works. The risk estimate of 0.802 (with standard error 0.026) indicated that the diet group predicted by the model is wrong for 80.2% of the cases. Therefore, the risk of misclassifying a diet group is approximately 80%. The results in the classification table were consistent with the risk estimate.

Table 2 showed that the model classified approximately 19.8% of the diet groups correctly. The classification table however revealed one potential advantage with this model: for arthropods, it predicts a good rating for 79.1% of them, which means that 79.1% of arthropods were accurately classified with the diet groups.

Cross-validation allows us to assess how well our tree structure generalizes to a larger population. The risk estimate of 0.823 (with standard error 0.025) was similar to the risk estimate from the training sample.

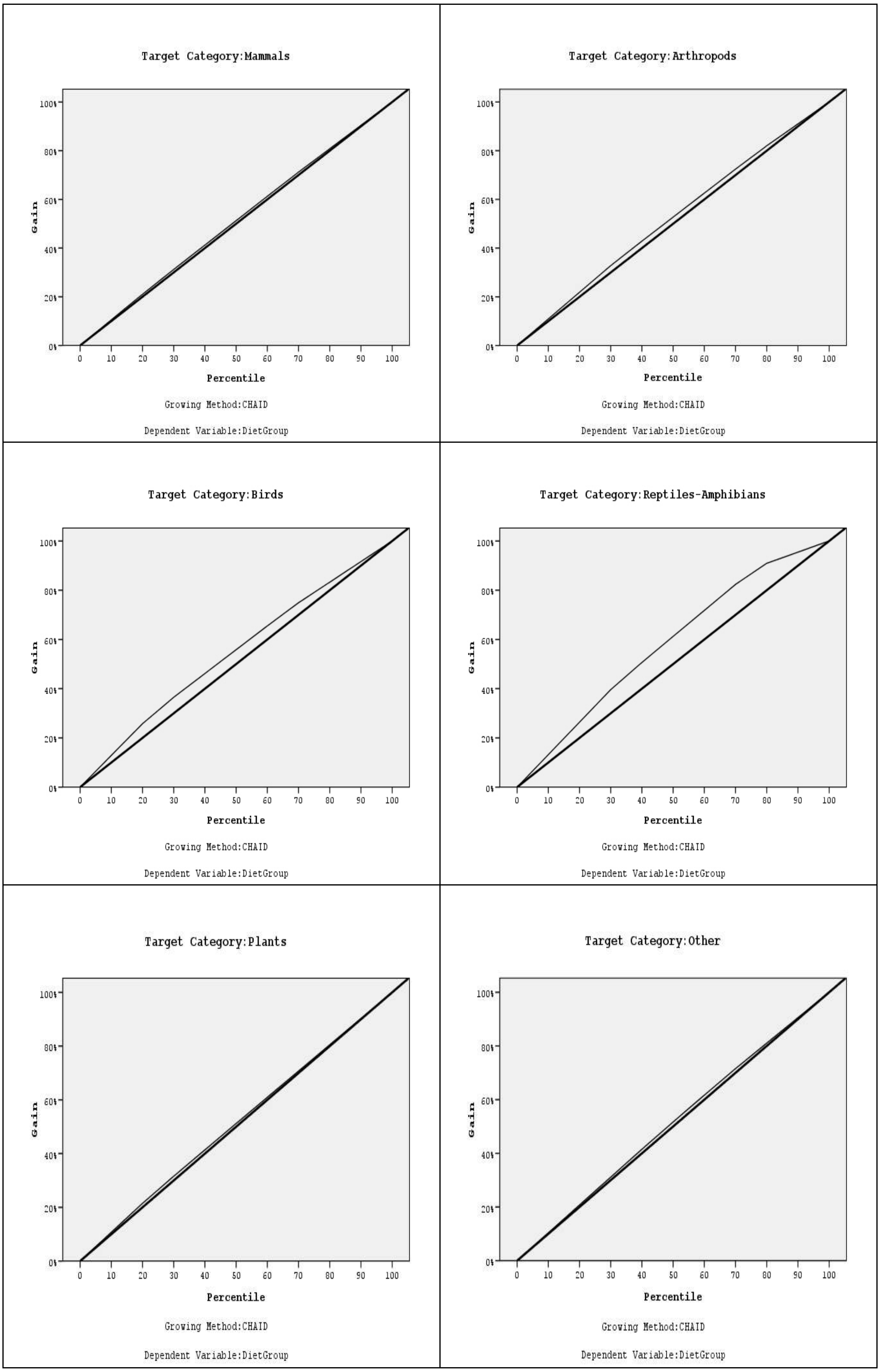

Fig. II: Gain charts for the 6 diet groups (mammals, arthropods, birds, reptiles-amphibians, plants, other).

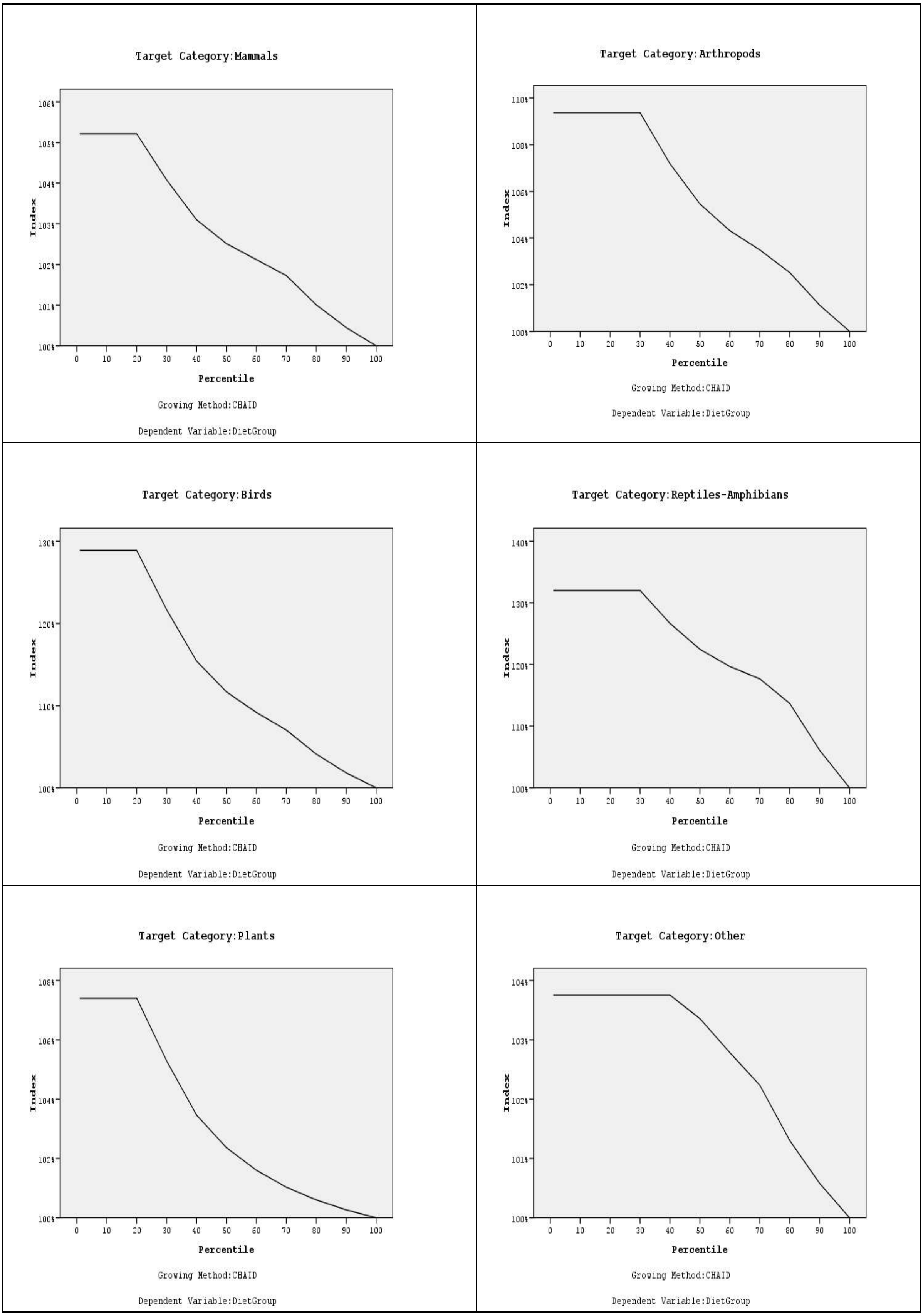

Fig. III: Index charts for the 6 diet groups (mammals, arthropods, birds, reptiles-amphibians, plants, other).

Table 2: Classification of tree-fitting method

Observed	Predicted						
	Mammals	Birds	Plants	Arthropods	Reptiles-Amphibians	Other	Percent correct
Mammals	0	0	12	37	0	0	0.0%
Birds	0	0	9	21	0	0	0.0%
Plants	0	0	12	36	0	0	25.0%
Arthropods	0	0	9	34	0	0	79.1%
Reptiles-Amphibians	0	0	2	17	0	0	0.0%
Other	0	0	10	33	0	0	0.0%
Overall percentage	0.0%	0.0%	23.3%	76.7%	0.0%	0.0%	19.8%

DISCUSSION

With a few notable exceptions, the dietary patterns of red fox and stone marten in central Greece were similar to those described in dozens of other studies of these species. Plants, arthropods and mammals dominated their diets in all seasons. The presence of reptiles – amphibians and birds usually represented a low percentage. Garbage and man made items varied by season and species. Birds and reptiles – amphibians were seasonally common in the carnivores' diets but usually accounted for a small proportion. Consumption of birds and reptiles – amphibians by red fox is likely opportunistic and much of it may represent scavenging. The two carnivores ate man made foods, although these rarely accounted for more than 10% of the food items, except during spring for stone marten (24.37%). However, human-associated foods often contain few indigestible items that would appear in the analyses, so their consumption may be underestimated in this study.

Red foxes are generally characterized as opportunistic predators and scavengers that eat a wide variety of foods depending on seasonal availability. Small and medium-sized mammals dominate the diet, with birds, insects, fruit, carrion, garbage and other foods important seasonally (Ables, 1975; Lloyd, 1980; Samuel and Nelson, 1982; Lariviere and Pasitschniak-Arts, 1996; Verts and Carraway, 1998; Nowak, 1999). The red fox diet has been extensively studied in a variety of countries and habitats (Ables, 1975; Lockie, 1977; Lariviere and Pasitschniak-Arts 1996) and in Greece (Papageorgiou *et al.,* 1986; Papageorgiou *et al.,* 1988; Vlachos et al., 2007). Previous studies showed that red fox eats predominantly rodents and lagomorphs, along with a wide variety of other vertebrate, invertebrate and plant foods as seasonally available.

Martin (1994) reviewed 22 dietary studies of marten. Mammalian preys were the primary dietary component for marten across their range. Birds, insects, and vegetation frequently occurred in scats but generally at low volumes. She concluded that martens were opportunistic generalists, taking foods as seasonally available in the environment. A recent study of marten found that they ate primarily sciurids, other rodents and birds, with insects and fruit consumed in summer and autumn (Zielinski and Duncan, 2004).

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