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FOOD HABITS OF WILD BOARS (*SUS SCROFA*) IN A MEDITERRANEAN COASTAL WETLAND

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Abstract: A population of wild boars (*Sus scrofa*) became established during the 1990s in the Natural Park of Aiguamolls de l'Empordà, a wetland on the western coast of the Mediterranean Sea (Catalonia, Spain). Between 2001 and 2004, a culling program was conducted to reduce the boar population. We collected and analyzed the contents of 142 stomachs to characterize boar diets, estimate impacts on ground-nesting birds, especially threatened species, and determine the relationships between boars and agricultural areas surrounding the park. The boar population consumed primarily plant material (94% by volume), particularly underground roots and rhizomes (33%). Agricultural (37%) and non-agricultural plants (49%) comprised very similar proportions of the diet. The primary foods were alkali bulrush (*Scirpus maritimus*) (24% by volume, and in 47% of the stomachs) and corn (*Zea mais*) (19% by volume and in 29% of the stomachs). Animal matter represented only 5.6% of the diet by volume, but occurred in 84% of the stomachs. The most important animal foods were, by volume, birds (2.3%) and crayfish (*Procambarus clarkii*) (1.7%) and, by frequency, snails (44%) and terrestrial arthropods (47%). Wild boar diets shifted seasonally between agricultural plants in summer and non-agricultural plants and acorns (*Quercus* sp.) in winter. Consumption of animal matter varied seasonally, crayfish were consumed primarily from May to October, terrestrial arthropods in May and June, and birds from March to April and September to October. Birds, especially ducks, were consumed most frequently while moulting, when vulnerable to predation. Given the high frequency of birds in the diet and the extensive rooting for underground parts of plants, the wild boar population might pose a threat to the coastal wetland ecosystem of the Natural Park of Aiguamolls de l'Empordà if allowed to become overabundant.

Key Words: acorns, arthropods, bulrush, corn, crayfish, ground-nesting birds, snails

INTRODUCTION

In the 1960s, wild boar (*Sus scrofa*) populations in Europe increased substantially (Sáez Royuela and Tellería 1986). To varying degrees, that has continued in France (Boisauvert 1997), Italy (Marsan et al.

1990), Luxembourg (Schley et al. 1998), and Spain (Leránoz and Castián 1996, Markina 1998, Rosell 1998). Wild boars now occupy a wide variety of ecosystems including high mountains (Durio et al. 1995), agroecosystems (Gerard et al. 1991), and wetlands (Garzón et al. 1984). In the Mediterranean

region of Spain, wetlands are among the most threatened habitats and the populations of many resident species are relict, small, and isolated, and thus at risk of extinction. To avoid the degradation of wetlands and to preserve habitat biodiversity and ecological function, a number of protected areas have been established in the region. In those areas, the impact of wild boar has become a concern.

Wild boars can have a wide range of impacts including bird and nest predation (Henry 1969), agricultural crop damage (Kristiansson 1985, Herrero et al. 2006), and natural vegetation alteration (Alexiou 1983, Arrington et al. 1999). Boars can eliminate some plants while foraging on underground structures and, thus, affect other species that feed on or inhabit those plants (Howe and Bratton 1976). Alternatively, boar foraging can benefit some colonizing plants (Bratton 1975).

Wild boar diets have been studied in a wide range of habitats including wetlands (Garzón et al. 1984, Dardaillon 1987), alpine environments (Durio et al. 1995, Baubet et al. 1997), forests (Groot Bruinderink et al. 1994, Valet et al. 1994, Massei et al. 1996, Irizar et al. 2004), and agroecosystems (Genov 1987, Herrero et al. 2006). Those studies indicate that diets are primarily based on plant matter, with the parts of plants being consumed varying seasonally. Some populations prefer agricultural crops to natural plants (Leránoz 1983). Typically, a consistent but limited amount of animal matter is consumed (Schley and Roper 2003). Information about the diets of wild boars in wetlands is fairly limited (Dardaillon 1984, Garzón et al. 1984). This study describes the diet of a wild boar population in a coastal Mediterranean wetland, and expands on a more limited study conducted in 2001 (Herrero et al. 2004).

STUDY AREA

Aiguamolls de l'Empordà Natural Park (ANP) is a 4,824-ha coastal Mediterranean marshland. It is a wetland of international significance, designated a Ramsar Site and an Important Bird Area (Heath et al. 2000), and is part of the Natura 2000 network (European Commission 2006). The area is located between the Fluvià and the Muga rivers, and is surrounded by a densely populated tourist area, the Gulf of Roses, in the Costa Brava (Catalonia, Spain). The delta of the Muga and Fluvià rivers is formed by Quaternary sediments, which resulted from the interaction between fluvial and marine sediments. The wetlands are slightly above sea level. Average annual precipitation is 600 mm, with most falling from September through November. Mean

annual temperature is 15°C, and the lowest and highest mean monthly temperatures are in January (8°C) and August (24°C), respectively (Gascón 2003).

ANP includes three reserves, and the study was focused in the two largest, covering 321 ha and 523 ha, respectively. The wetlands of ANP contain a wide variety of habitats including beaches with sand dunes, salt marshes, brackish or saline water lagoons with vegetative communities of glasswort (*Arthrocnemum fruticosum*), cord-grass (*Spartina versicolor*), and rush (*Juncus maritimus*), meadows bordered by tamarisk (*Tamarix gallica* and *T. Africana*), permanent and temporary river and stream channels, temporary freshwater lagoons, permanently and seasonally flooded saline and brackish marshes, and flooded freshwater meadows. Throughout the area, there are small ditches that support reed (*Phragmites australis*) and cattail (*Typha angustifolia*). The wetlands are surrounded by irrigated agricultural lands, mainly sunflower (*Helianthus annuus*), corn (*Zea mais*), barley (*Hordeum vulgare*), fruit trees, and rice (*Oryza sativa*).

ANP contains a high diversity of vertebrates including many endangered birds such as great bittern (*Botaurus stellaris*), little bittern (*Ixobrychus minutus*), night heron (*Nycticorax nycticorax*), and purple gallinule (*Porphyrio porphyrio*), and assorted ducks and geese. Common amphibians and reptiles include palmate newt (*Triturus helveticus*), Western spadefoot (*Pelobates cultripes*), stripeless tree-frog (*Hyla meridionalis*), large psammomorph (*Psammomorphus algirus*), western three-toed skink (*Chalcides striatus*), ladder snake (*Elaphe scalaris*), and viperine snake (*Natrix maura*). Introduced species include crayfish (*Procambarus clarkii*) and carp (*Cyprinus carpio*). Wild boars spread naturally into the park. Before 1990, it was an occasional visitor, but in recent years it has become a permanent resident. In response to increasing densities, park employees initiated a boar culling program in 1998.

MATERIALS AND METHODS

From February 2001 through April 2004, we collected stomachs from 154 wild boars killed during the culling program in ANP. Twelve of the 154 stomachs in the sample were empty (< 50 ml of material) or had lost much of their contents during collection; therefore, analyses were based on the other 142 stomachs. Over the three years, samples were collected in different seasons, with 54 in January/February, 12 in March/April, 17 in May/June, 17 in July/August, 18 in September/October, 23 in November/December, and one on an unknown

date. Stomachs were preserved in 5% formalin until they were examined.

To quantify stomach contents, the volume of the stomach contents was measured (± 10 ml). To eliminate gastric juices (Abáigar 1990) and fine, unidentifiable particles (Wood and Roark 1980), stomach contents were washed with water through a 1.0 mm mesh. Plant and animal items were identified by comparing them to a reference collection, using published guides and keys, and consulting experts in entomology, botany, agriculture, and ornithology. The frequency of occurrence of each of the food items was calculated by dividing the number of stomachs that contained a given item by the total number of stomachs (142). The volumes (± 0.1 ml) of each particular food item in each stomach were calculated using a graduated test tube. To calculate percentage volume, the total volume of each food type found in the entire sample of stomachs was divided by the total volume of the stomach contents. Percentage of volume of items $< 0.01\%$ were considered trace. We assessed seasonal variation in the diet by comparing foods consumed in two month periods using a Kruskal-Wallis non-parametric test. For descriptive purposes we will consider summer as May through October and winter as November through April.

RESULTS

Wild boar diets consisted primarily of plant matter (94% of total volume), which was present in all of the stomachs that contained food. Agricultural (36.7% by volume) and non-agricultural (49.5%) plants were equally important (Table 1). By frequency of occurrence, alkali bulrush (47.2% of stomachs), Graminae (39.4%), and corn (28.9%) were the most important plant food items. By volume, alkali bulrush (24%) and corn (18.6%) were the two most important plants in the diet. After combining agricultural and non-agricultural plants, we found that the above-ground portions of plants (53.3% by volume) contributed more to the diets than did underground portions (33%) (Table 1).

The relative availability of agricultural and non-agricultural plants influenced seasonal differences in the plant component of the diet of wild boars in ANP. Agricultural plants were consumed more in summer, when they were most available. Seeds from corn and sunflower were consumer primarily from July through December. When agricultural plants were less available in winter, boars consumed mostly underground parts of non-agricultural plants (Table 2).

Animal matter was a small (5.6% by volume) but frequent (84.5% of stomachs) component of the diet of the wild boar population in ANP (Table 1). By volume, crayfish (1.7%) and birds (2.3%) were the most important animal items. Vertebrates and invertebrates contributed similarly to the diet in terms of volume, but the latter occurred three times more frequently than did the former. Birds and crayfish comprised 40% and 30% of the animal matter, respectively. Snails and terrestrial arthropods were the most frequent animal food items (present in $> 40\%$ of stomachs). Amphibians, reptiles, and fish contributed little to the diet of the boars.

Wild boars consumed birds from five taxonomic Orders (Table 3). Anseriformes (ducks) and Gruiformes (coots, cranes, and rails) comprised $> 44\%$ of the total volume of birds in the diet. A common moorhen (*Gallinula chloropus*) and its nest, and the nest of a purple gallinule were found in the same stomach.

The overall amount of animal matter in the diet varied temporally, with consumption being highest between March and October. Boars consumed significantly more birds from March to April and September to October. Most crayfish and terrestrial arthropods were consumed in May and June, and mostly snails from November to December (Table 2).

DISCUSSION

Wild boars in ANP, Spain were opportunistic, omnivorous, but primarily phytophagous, consumers, which is the general pattern observed elsewhere (Vericad 1971, Jezierski and Myrcha 1975, Briedermann 1976, Leránoz 1983, Dardaillon 1984, Garzón *et al.* 1984, Venero González 1984, Abáigar 1990, Valet *et al.* 1994, Sáenz de Buruaga 1995, Rosell 1998, Schley and Roper 2003, Herrero *et al.* 2004, 2005). They consumed a wide variety but small amount of animal matter, also as elsewhere (Henry and Conley 1972, Briedermann 1976, Baettig 1980, Genov 1981, Scott and Pelton 1981, Leránoz 1983, Sjarmidi *et al.* 1992, Abáigar 1993).

Agricultural plants were consumed year-round, but primarily during summer, when their nutritional value was highest, and corn and sunflower seeds were available. Underground parts of non-agricultural plants, e.g., alkali bulrush and pignut, were an important component of the boar diet during most of the year, but less so in July and August when corn and sunflower were available. This pattern has been observed in other Mediterranean wetlands (Garzón *et al.* 1984, Venero González 1984, Dardaillon 1987). Gramineae in the stomachs of wild boars in

Table 1. Diet of a wild boar population in the Natural Park of Aiguamolls de l'Empordà, Catalonia, Spain, based on the analysis of the stomach contents of 142 animals culled from 2001–2004. +: trace (< 0.01%).

	Percentage of volume	Frequency
PLANT MATTER	94.0	98.6
Agricultural Plants	36.7	52.1
Lucerne (<i>Medicago sativa</i>)	2.4	5.6
Rice (<i>Oryza sativa</i>)	0.6	1.4
Oats (<i>Avena</i> sp.)	5.6	7.8
Barley (<i>Hordeum vulgare</i>)	0.3	3.5
Sunflower seeds (<i>Helianthus annuus</i>)	7.1	16.2
Corn (<i>Zea mais</i>)	18.6	28.9
Apple (<i>Malus</i> sp.)	1.2	7.0
Wheat (<i>Triticum sativum</i>)	0.9	5.6
Non-agricultural Plants	49.5	83.1
Above-ground Parts	16.6	64.1
Soft mast	0.1	0.7
Acorns (<i>Quercus</i> sp.)	7.4	9.9
Sea purslane (<i>Atriplex portulacoides</i>)	2.4	14.8
Hedge Bindweed (<i>Calystegia sepium</i>)	1.6	4.9
Black fruit	0.1	0.7
Gramineae	0.3	39.4
Fallen leaves	0.2	0.7
Underground Parts	33.0	57.8
Pignut (<i>Conopodium majus</i>)	6.6	10.6
Alkali bulrush (<i>Scirpus maritimus</i>)	24.0	47.2
Other roots	2.4	2.8
Unidentifiable	7.8	24.7
Brown bark	+	0.7
Stems	0.5	2.1
Wood	+	0.7
Other plant matter	7.2	20.4
Unidentifiable root	+	0.7
ANIMAL MATTER	5.6	84.5
Invertebrates	2.7	75.4
Nematoda	+	0.7
Snails	0.6	43.7
Annelidae	0.06	9.2
Crayfish (<i>Procambarus clarkii</i>)	1.7	25.4
Terrestrial Arthropoda	0.4	47.2
Vertebrates	2.9	24.6
Fish	0.30	4.2
Amphibians	+	0.7
Birds	2.30	16.2
Mammals	0.27	7.8
Unidentifiable	0.04	7.0
Coagulated blood	0.02	0.7
Bone	+	0.7
NON-ORGANIC ITEMS	+	2.1
Plastic	+	2.1

ANP occurred as balls that might serve as a purgative. Wild boars can move between refuges in the wetlands and surrounding foraging areas in cultivated fields.

In ANP, animal prey (primarily birds and crayfish) was important to wild boars. From March through October, wild boars consumed more animal

matter than they did at other times of the year, possibly because birds and crayfish were more easily obtained in summer. Of concern, a wild boar consumed some purple gallinule chicks, and this species is in danger of extinction, and was just recently reintroduced in the park. However, the vast majority of the birds found in the stomachs of wild

Table 2. Temporal variation in the relative consumption of the most important items in the diet of a wild boar population in the Natural Park of Aiguamolls de l'Empordà, Catalonia, Spain, based on the analysis of the stomach contents of animals culled in 2001–2004. Values represent annual average volumes as a percent (N = 141). *: significant $p \leq 0.05$ for Kruskal-Wallis test.

	Jan– Feb	Mar– Apr	May– Jun	Jul– Aug	Sep– Oct	Nov– Dec	Weighed average	P value
PLANT MATTER	96.4	90.2	89.5	93.5	91.3	97.9	93.1	0.08
Agricultural	17.3	20.2	57.0	67.3	64.3	35.3	43.6	0.00*
Corn	8.6	10.0	5.9	24.2	46.6	30.6	21.0	0.00*
Non corn cereals	0.0	7.1	50.2	5.1	0.0	3.4	11.0	0.00*
Sunflower seeds	0.7	0.0	0.0	38.0	17.8	0.0	9.4	0.00*
Lucerne	6.2	0.0	0.0	0.0	0.0	0.0	1.0	0.02*
Non-agricultural	69.1	51.2	32.4	13.1	22.2	61.5	41.6	0.00*
Above-ground	24.5	1.2	14.1	12.8	3.2	21.9	12.9	0.33
Acorns	17.3	0.0	0.0	0.0	0.0	4.9	3.7	0.03*
Non mast	7.2	1.2	14.1	12.8	3.2	17.0	9.2	0.43
Underground	44.6	50.0	18.3	0.3	19.0	39.6	28.6	0.00*
Alkali bulrush and pignut	43.2	50.0	18.3	0.3	4.4	39.6	26.0	0.00*
ANIMAL MATTER	3.5	9.3	10.5	6.5	8.7	2.1	6.8	0.05*
Invertebrates	0.9	0.9	10.5	4.0	2.9	1.4	3.4	0.13
Snails	0.5	0.8	0.1	0.7	0.3	1.2	0.6	0.05*
Crayfish	0.0	0.0	8.6	2.9	2.5	0.0	2.4	0.00*
Terrestrial arthropods	0.3	0.0	1.8	0.3	0.0	0.1	0.4	0.33
Vertebrates	2.7	8.4	0.0	2.4	5.8	0.7	3.3	0.03*
Birds	2.1	8.4	0.0	2.2	4.1	0.0	2.8	0.01*

Table 3. Taxonomic classification of the birds in the diet of a wild boar population in the Natural Park of Aiguamolls de l'Empordà, Catalonia, Spain, based on the analysis of the stomach contents of 142 animals culled in 2000–2004.

Taxon	Number of individuals	Frequency (%) of stomachs)	Sex or stage
ANSERIFORMES	6	22.2	
Anatidae	6	22.2	
Mallard (<i>Anas platyrhynchos</i>)	3	11.1	2 males, 1 undetermined
Teal (<i>Anas crecca</i>)	2	7.4	1 male, 1 undetermined
<i>Anas</i> sp.	1	3.7	Female
COLUMBIFORMES	1	3.7	
Columbidae	1	3.7	
Turtle Dove (<i>Streptopelia turtur</i>)	1	3.7	
GALLIFORMES	3	11.1	
Phasianidae	3	11.1	
Domestic hen (<i>Gallus gallus</i>)	2	7.4	
Pheasant (<i>Phasianus colchicus</i>)	1	3.7	
GRUIFORMES	6	22.2	
Rallidae	6	22.2	
Moorhen (<i>Gallinula chloropus</i>)	3	11.1	2 chicks, 1 egg, 1 adult
Purple gallinule (<i>Porphyrio porphyrio</i>)	3	11.1	3 chicks in the egg or with the egg opened
PASSERIFORMES	2	7.4	
NON PASSERIFORMES	5	18.6	
UNDETERMINED	4	14.8	
TOTAL	27	100	

boars were ducks, which moult into nuptial plumage in spring and into winter plumage in autumn. During moulting, ducks cannot fly and are more vulnerable to predation, and at those times, birds became more common in wild boar diets. Some birds that were consumed do not undergo a flightless moult, and these individuals might have died from other causes and were then scavenged by wild boars. However, it seems likely that wild boars are killing a significant number of birds in the ANP, which may justify continuing the culling program.

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