Spring diet of the pine marten in Sardinia, Italy

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Abstract

Spring diet of the pine marten in Sardinia, Italy.— Knowledge of a carnivore's foraging behaviour is essential to understand its ecology. The pine marten *Martes martes* is commonly defined as an opportunistic generalist predator since its diet in Europe includes mammals, fruits, birds and invertebrates. Based on faecal analyses, we evaluated spring feeding habits and trophic niche breadth of the pine marten in a Mediterranean landscape on the island of Sardinia (Central Italy). The most important source of food for the pine marten was small mammals (mainly *Apodemus sylvaticus*, *Mus musculus* and *Eliomys quercinus*), accounting for 52% of the percent mean volume. Important secondary foods were invertebrates (mainly beetles and insect larvae) and birds (almost exclusively passerines), whereas large mammals, lagomorphs, reptiles and fruits made little contribution to the diet. The diet composition and the Levins' index value suggest that the pine marten in Sardinia behaves as a facultative specialist predator, with a specialization towards small mammals.

Key words: *Martes martes*, Foraging behaviour, Scat analysis, Trophic niche breadth

Resumen

Alimentación primaveral de la marta en Cerdeña, Italia.— El conocimiento del comportamiento de alimentación de un carnívoro es esencial para entender su ecología. La marta *Martes martes* se define comúnmente como un depredador generalista oportunista, porque su dieta en Europa incluye mamíferos, frutas, aves y invertebrados. A partir del análisis de las heces, hemos descrito los hábitos alimenticios en primavera y la amplitud del nicho trófico de la marta en ambiente mediterráneo en Cerdeña (Italia central). Los pequeños mamíferos (sobre todo *Apodemus sylvaticus*, *Mus musculus* y *Eliomys quercinus*) representan la fuente más importante de alimentación de la marta, ya que constituyen aproximadamente el 52% del volumen medio. Otra fuente importante de alimentos secundarios la constituyen los invertebrados (especialmente escarabajos y larvas de insectos) y las aves (paseriformes casi exclusivamente), mientras que los grandes mamíferos, los lagomorfos, los reptiles y las frutas están poco representados en la dieta. La composición de la dieta y el valor del índice de Levins indican que la marta en Cerdeña es un depredador especialista facultativo, con una especialización en la depredación de micromamíferos.

Palabras clave: *Martes martes*, Comportamiento alimenticio, Análisis de heces, Amplitud de nicho trófico

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Introduction

The pine marten (*Martes martes* L., 1758) is a medium–sized mustelid found throughout much of Europe and northern and central Asia, from northern Portugal to western Siberia (Ruiz–González et al., 2013). In Italy, the species has a fragmented distribution in the forested areas of the peninsula, but it has recently been detected in the western part of the River Po plain, an intensively cultivated area (Proulx et al., 2004; Balestrieri et al., 2010). Insular populations also occur in Sardinia, Sicily and Elba (Masseti, 1995; Angelici et al., 2009).

In Sardinia, the pine marten is widespread, being present both in the northern and southern parts of the island (Murgia et al., 1995). The species might have been introduced on the island during Roman times or even a little earlier, but the exact period of introduction is not clear (Vigne, 1992; Masseti, 1995). At the beginning of the twentieth century, the Sardinian pine marten was described as a *Martes martes latinorum* subspecies. It was distinguished from the nominal species by the leather–yellow patch on the throat and by a lighter dominating colour; it is the same size as a Italian form of the species, except for a slightly longer tail (Murgia et al., 1995). Recently, Colli et al. (2011) described the genetic variability of Sardinian pine martens and differences between insular and Italian population. They reported two distinct clusters, corresponding to Sardinia and mainland Italy, and hypothesized the distinctiveness of the Sardinian population.

Knowledge of a carnivore's foraging behaviour is essential to understand its ecology, and to elucidate potential competitive interactions and impacts on prey populations (Litvaitis, 2000; Caryl et al., 2012). The pine marten is commonly defined as an opportunistic generalist predator. Its diet in Europe is very varied, including small and large mammals, fruits, birds and invertebrates, but its main year–round prey is generally small mammals (Helldin, 2000; Zalewski, 2004; Rosellini et al., 2008a; Balestrieri et al., 2011; Caryl et al., 2012). In the Mediterranean region, fruit, plant material and insects are important components of the diet, being consumed more frequently than in central and northern Europe (De Marinis & Masseti, 1995; Zalewski, 2004).

Feeding habits of pine martens on Mediterranean islands are poorly known. Research has been carried out only on Mallorca, Minorca and Elba islands (De Marinis & Masseti, 1993, 1995; Clevenger, 1993, 1995, 1996). In these insular environments, the pine marten shows some peculiarities in its diet: the absence of voles, for example, the main mammalian prey throughout Europe, has determined a shift towards mice (*Apodemus sylvaticus*, *Mus* sp. and *Rattus* sp.) (De Marinis & Masseti, 1995; Zalewski, 2004), and in the Balearic islands, the species shows a high level of frugivory (Clevenger, 1995, 1996) and a wider trophic niche breadth than continental populations (Clevenger, 1993).

In this paper, we provide the first description of the spring diet and trophic niche breadth for the pine marten in Sardinia and compare our results with those of Clevenger (1995) on the island of Mallorca.

Material and methods

Study area

The study was carried out in the province of Olbia–Tempio (NE Sardinia, Central Italy), which extends for 3,404 km^2 and has an altitude ranging from sea level to 1,359 m a.s.l. (Mount Limbara) (fig. 1A). The climate is Mediterranean, with the most abundant rainfalls occurring in December and the highest temperatures occurring in July. Vegetation is typically Mediterranean; the area is dominated by garrigue and low maquis with *Phillyrea* sp., lentisk (*Pistacia lentiscus*), cistus (*Cistus* spp.) and heather (*Erica arborea*), and deciduous forests, mostly including oak (*Quercus ilex, Q. suber*). Inland flat areas are characterized by arable lands and pastures.

Other mesocarnivores in the study area besides the pine marten are the red fox (*Vulpes vulpes*), the weasel (*Mustela nivalis*) and the wildcat (*Felis silvestris*). Lagomorphs present are the Sardinian hare (*Lepus capensis mediterraneus*) and the wild rabbit (*Oryctolagus cuniculus*). The community of small mammals is composed of eight species: the hedgehog (*Erinaceus europaeus*), the Etruscan shrew (*Suncus etruscus*), the North African white–toothed shrew (*Crocidura pachyura*), the wood mouse (*Apodemus sylvaticus*), the house mouse (*Mus musculus*), the garden dormouse *(Eliomys quercinus*) and rats (*Rattus rattus* and *Rattus norvegicus*). A total of 101 species of birds nest in the study area (Trainito, 2009).

Field surveys

Diet composition of the pine marten was studied by scat analysis. Scats were collected in spring (March–May) 2012 and 2013 along 80 linear transects (total length = 115.5 km, mean ± standard deviation SD = 1.4 ± 0.5 km, min. = 0.4 km, max. = 2.7 km), distributed in 34 sampling areas (15 protected areas and 19 hunting preserves) selected within the whole study area and representative of all habitat types (fig. 1B and appendix 1). Each itinerary was walked twice a season, with a 25–30 day interval between the two surveys. Faecal samples were assigned to the pine marten according to size, shape and odour (Lanszki et al., 2007; Rosellini et al., 2008b; Barrull et al., 2014). Moreover, we evaluated the proximity of scats to marten tracks and foraging signs. Scats were individually bagged, labelled with number and date of collection, and stored in a freezer at –20°C until analysis.

Diet analysis

Faecal samples were washed through two sieves of 0.5 and 0.1 mm mesh, and food remains were inspected to estimate the total numbers of each kind of food.

Prey items were categorized into eight food classes: small mammals (rodents and insectivores), lagomorphs, large mammals (wild and domestic ungulates eaten as carrion), birds, reptiles, invertebrates, fruit (berries and large fruits) and other (garbage or non–natural foods). Prey remains were identified to the lowest taxonomic level possible.

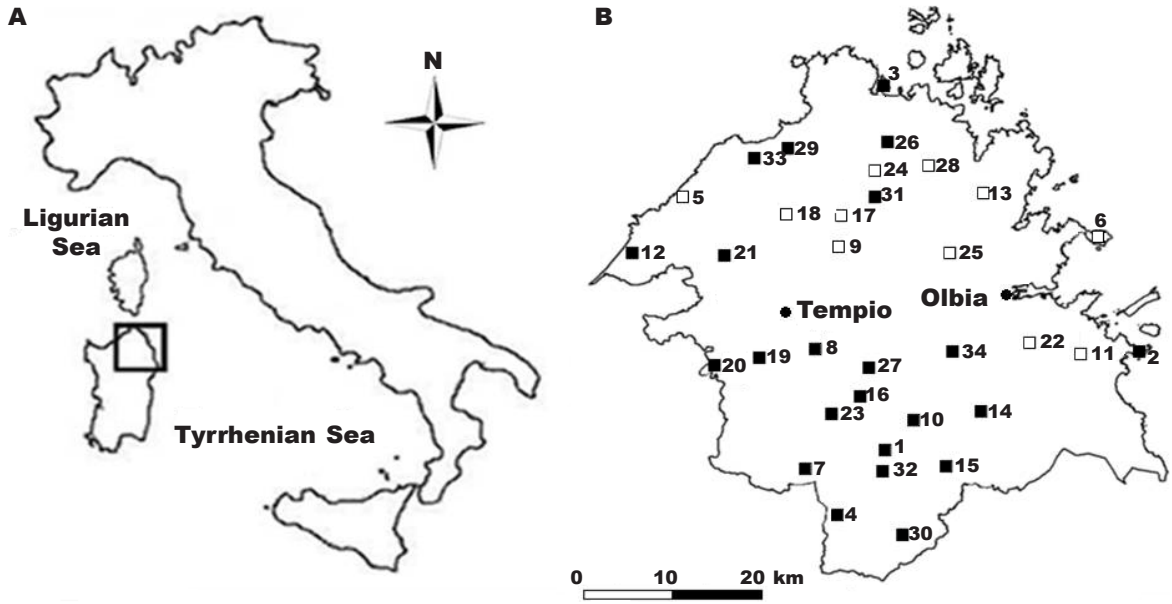

Fig. 1. Location of the study area (Province of Olbia–Tempio, Sardinia, Central Italy) (A) and location of the sampling sites (B). For the identification of sampling areas, see appendix 1: ■ Sampling areas with presence of marten scats; □ Sampling areas with no marten scats.

Fig. 1. Localización de la zona de estudio (provincia de Olbia–Tempio, Cerdeña, Italia central) (A) y localización de las áreas de muestreo (B). Para la identificación de las áreas de muestreo, véase el apéndice 1: ■ Áreas con heces de marta; □ Áreas sin heces de marta.

Mammal hairs were compared at × 10 and × 40 magnifications with the keys of Debrot et al. (1982), Teerink (1991), De Marinis & Agnelli (1993) and De Marinis & Asprea (2006). Bird feathers were identified with reference to MicrolabNW Photomicrograph Gallery (http://microlabgallery.com/Feathers.aspx). Wild or cultivated fruits (seeds) were identified with reference to Ferrari & Medici (2003) and using personal collections.

Diet composition was expressed in two ways: percent frequency of occurrence (%FO = number of faecal samples containing a specific food item/total number of faecal samples × 100) and percent mean volume (%mV = total estimated volume of each food item as ingested/total number of faecal samples). The percent volume of each food was estimated visually (Clevenger, 1995).

Based on percent mean volumes, we calculated the trophic niche breadth in accordance with Levins (Krebs, 1989):

$$B = 1/\Sigma p_i^2$$

where p_i is the relative frequency of the i^{th} food item. We standardized the B index across food items:

$$B_A = (B - 1)/(n - 1)$$

This measure ranges from 0 to 1, with higher values indicating a broader dietary niche.

Finally, we compared our results with those obtained in spring by Clevenger (1995) on Mallorca. We evaluated differences in the frequency of occurrence of seven prey categories (small mammals, lagomorphs, large mammals, birds, reptiles, invertebrates and fruit) using a χ^2–test for contingency tables (Fedriani et al., 1999).

Results

A total of 87 scats were used for dietary analysis. Scats were found in 23 of the 34 sampling areas (67.6%, fig. 1B), but about half of the scats were collected in four sampling areas: Sorilis, Monte Olia, Monte Limbara and Filigosu. The marten diet was dominated by small mammals, which represented more than half of the total percent mean volume. Three species occurred in the diet regularly: the wood mouse, the house mouse and the garden dormouse. The only insectivore species eaten by martens was the North African white–toothed shrew (table 1). Invertebrates and avian preys were important secondary foods; invertebrates comprised mainly beetles (Coleoptera) and insect larvae, while birds included predominantly passerines (table 1). Large mammals, lagomorphs, fruits and reptiles made little contribution to the pine marten diet. Both wild and domestic ungulates were

Table 1. Diet composition of the pine marten revealed through faecal analysis (n = 87): Fr. Frequency of occurrence (%); Pm. Percent mean volume (%).

Tabla 1. Composición de la dieta de la marta definida a partir del análisis de las heces (n = 87): Fr. Frecuencia de aparición; Pm. Porcentaje de volumen medio.

Food items	Fr (%)	Pm (%)
Small mammals	**58.6**	**52.2**
Rodents	55.2	49.4
Apodemus sylvaticus	24.2	21.5
Mus musculus	16.1	14.5
Eliomys quercinus	10.3	9.5
Rattus sp.	4.6	3.9
Insectivores	3.5	2.8
Crocidura pachyura	3.5	2.8
Lagomorphs	**1.1**	**1.1**
Oryctolagus cuniculus	1.1	1.1
Large mammals	**10.3**	**6.9**
Ovis aries	3.4	3.4
Bos taurus	2.3	2.3
Sus scrofa	4.6	1.2
Undetermined mammals	**4.6**	**3.7**
Birds	**17.2**	**14.0**
Passeriformes	14.8	12.2
Galliformes	1.2	1.2
Falconiformes	1.2	0.6
Invertebrates	**33.3**	**16.8**
Coleoptera	19.5	9.9
Insect larvae	11.5	5.1
Hymenoptera	1.1	0.5
Undetermined	3.5	1.3
Fruit	**10.3**	**4.6**
Juniperus spp.	4.6	1.7
Myrtus communis	1.1	1.1
Cistus spp.	1.1	0.6
Undetermined	3.5	1.2
Reptiles	**1.1**	**0.4**
Other	**1.1**	**0.3**

consumed, with a slight predominance of domestic animals. Wild rabbits were taken very occasionally, and no Sardinian hares were identified in the scats. Fruits included myrtle (*Myrtus communis*), junipers (*Juniperus* spp.) and *Cistus* spp. berries (table 1). Other foods (*i.e.* garbage) were scarcely present in the diet. The value of the standardized B index of trophic niche breadth was 0.29.

The comparison between Sardinian and Mallorcan feeding habits highlighted some significant differences; Mallorcan martens were more frugivorous ($\chi^2 = 67.63$, df = 1, $p < 0.001$) and preyed upon more reptiles ($\chi^2 = 6.76$, df = 1, $p = 0.009$) than the Sardinian martens, but consumed fewer small ($\chi^2 = 7.25$, df = 1, $p = 0.007$) and large mammals ($\chi^2 = 4.89$, df = 1, $p = 0.03$). The consumption of lagomorphs ($\chi^2 = 0.39$, df = 1, $p = 0.53$), birds ($\chi^2 = 0.26$, df = 1, $p = 0.61$) and invertebrates ($\chi^2 = 0.41$, df = 1, $p = 0.52$) did not differ significantly between the two islands (table 2).

Discussion

Our results show that small rodents were the most important food resource for the pine marten in North–Eastern Sardinia. They were found to be the main prey in spring, in agreement with the findings of other authors across the European distribution range of the species (*e.g.* Jędrzejewski et al., 1993; Ruiz–Olmo & López–Martín, 1996; Helldin, 2000; Lanszki et al., 2007; Rosellini et al., 2008a; Caryl et al., 2012). The predator mainly focused on *Apodemus sylvaticus*, an important resource for this and other medium–sized carnivores in the study area, such as the red fox (Meriggi et al., 2013). Two factors could explain the importance of the wood mouse in the marten diet; its abundance and the similar habitat requirements of both predator and prey species.

In the study area, the pine marten positively selects woodlands and shrublands (Lombardini et al., 2015). Similarly, in the Mediterranean region, the wood mouse is basically found in cork oak woodlands and areas covered by trees and shrubs (Cagnin et al., 1998; Rosalino et al., 2011). Amori et al. (2014) indicate that even in Sardinian woodlands, *Apodemus sylvaticus* is widespread and locally abundant. Furthermore, the exploitation of forested areas by the wood mouse in Sardinia could be favoured by the absence of the forest–dweller *Apodemus flavicollis*, as reported by Sarà & Casamento (1993) in Sicily.

The diet of the pine marten also comprised avian prey and invertebrates. Martens commonly feed on small birds in Europe (Posłuszny et al., 2007; Balestrieri et al., 2011; Zhou et al., 2011; Caryl et al., 2012).

Table 2. Frequency of occurrence of feeding categories in the spring diet of the pine marten in Sardinia (S, this study) and Mallorca (M, Clevenger, 1995).

Tabla 2. Frecuencia de aparición de categorías de alimentos en la dieta primaveral de la marta en Cerdeña (S, este estudio) y en Mallorca (M, Clevenger, 1995).

Food items	S (*n* = 87)	M (*n* = 130)
Small mammals	58.6	40.0
Lagomorphs	1.1	2.3
Large mammals	10.3	3.0
Birds	17.2	20.0
Invertebrates	33.3	29.2
Plant material	10.3	66.6
Reptiles	1.1	10.0
Other	1.1	1.5

The importance of birds in the spring diet is probably due to their increased vulnerability to predation during hatching and fledgling time (De Marinis & Masseti, 1995) and to the abundance of small mammals being at its lowest in spring (Jędrzejewski et al., 1993; Lanszki et al., 2007; Rosellini et al., 2008a), forcing the pine marten to exploit alternative food, such as birds (Lanszki et al., 2007; Wijsman, 2012). The pine marten preyed mostly on passerines, whereas the predation exerted on game birds was scarce and occasional. The importance of invertebrates as a secondary food resource is typical of lower latitudes. In southern Europe, in fact, characterized by warmer and more stable climates, insects are more abundant than in central and Northern Europe (Ruiz–Olmo & López–Martín, 1996; Zhou et al., 2011).

The comparison of the feeding habits of Sardinian and Mallorcan martens stresses the differences between these two insular populations. In Mallorca, the pine marten exhibited a generalist diet, with a high consumption of plant material, while in Sardinia it showed a specialization towards small mammals. In the Balearic islands, martens often eat fruit from orchards close to farmland or disturbed habitats (Clevenger, 1995). The lack of predators, in fact, may favour the exploitation of open habitats for foraging (Clevenger, 1994). On the other hand, in Sardinia, the pine marten coexists with three potential predators: the red fox, the wildcat, and the golden eagle *Aquila chrysaetos* (Lindström et al., 1995; Pedrini & Sergio, 2002; Moleón & Gil–Sánchez, 2003). For this reason, the species probably avoids open habitats in North–Eastern Sardinia (Lombardini et al., 2015). Diet results support this hypothesis, indicating the prevailing consumption of wild berries, such as myrtle, junipers and *Cistus* berries, growing in the maquis. Concerning plant foods, Clevenger (1996) indicated a predominance of the carob *Ceratonia siliqua*, found to be absent in the diet of the species in Sardinia, probably due to the rarity of the carob in the province of Olbia–Tempio (Trainito, 2009). Both in Sardinia and in Mallorca, *Apodemus sylvaticus* was the main rodent prey in spring, and consumption was similar on both islands (21% and 18% of the total percent mean volume, respectively). The significant difference in the consumption of small mammals highlighted by the analyses is linked to the higher presence in our sample of secondary rodent preys (*Mus musculus* and *Eliomys quercinus*), scarcely eaten by Mallorcan martens (Clevenger, 1995).

The relatively low Levins' index value suggests that the pine marten in Sardinia adopt an intermediate feeding strategy between that of an opportunist and that of a specialist predator (*i.e.* a facultative specialist in the predation of small mammals). A similar situation occurs in north–western Spain, where the pine marten shows no reduction in its preference for small mammals even in the seasons when they are scarce (Rosellini et al., 2008a).

Future work should test this hypothesis proposed to describe the feeding habits of the pine marten in Sardinia and should analyse the diet of the pine marten all year–round, to evaluate the existence of seasonal feeding patterns.

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Appendix 1. Environmental characteristics (% of land use categories) of sampling areas selected for scat surveys in the province of Olbia–Tempio: S. Surface (in Ha); P. Protected: F. Forest; Gg. Garrigue; Gs. Grassland; Ra. Rocky areas; Wb. Water bodies; Al. Arable lands; Ua. Urban areas.

Apéndice 1. Características ambientales (% del uso del suelo) de las áreas de muestreo seleccionadas para la recolección de las heces en la provincia de Olbia–Tempio: S. Superficie (en Ha); P. Protegida; F. Bosque; Gg. Garriga; Gs. Pradera; Ra. Áreas rocosas; Wb. Agua; Al. Tierras arables; Ua. Áreas urbanas.

Sampling areas	S (Ha)	P	F	Gg	Gs	Ra	Wb	Al	Ua
Bolostiu (1)	797	Yes	17.3	51.3	3.4	25.8	–	–	2.2
C. Coda (2)	454	Yes	20.6	14.1	21.4	23.2	3.0	3.5	14.2
Coluccia (3)	490	Yes	11.4	60.3	2.4	4.1	18.2	1.4	2.2
Conchedda (4)	2,164	Yes	25.4	59.6	4.9	7.1	0.3	0.3	2.4
Costa P. (5)	673	Yes	15.6	53.1	–	7.7	–	0.1	23.5
Figari (6)	1,524	Yes	0.8	77.7	0.3	8.5	0.2	0.6	11.9
Filigosu (7)	4,461	Yes	34.7	44.3	2.1	13.3	0.2	2.9	2.5
M. Limbara (8)	3,900	Yes	15.6	54.2	1.3	26.7	0.1	0.5	1.6
Liscia (9)	231	Yes	14.1	2.4	65.9	–	10.2	6.0	1.4
M. Olia (10)	2,171	Yes	46.3	30.8	1.3	18.8	0.1	1.0	1.7
P. S. Paolo (11)	1,181	Yes	1.5	64.9	11.6	5.6	–	6.0	10.4
M. Rotu (12)	456	Yes	8.8	38.3	25.6	–	–	19.4	7.9
Saloni (13)	418	Yes	8.0	16.9	52.4	–	5.7	7.7	9.3
Sorilis (14)	1,331	Yes	30.6	60.4	3.5	2.8	0.5	–	2.2
Terranova (15)	2,249	Yes	50.0	39.0	3.4	1.7	0.1	3.1	2.7
Campu N. (16)	654	No	22.4	2.2	45.7	–	–	27.3	2.4
Canaili (17)	587	No	43.9	34.0	9.1	1.0	–	6.3	5.7
Frassiccia (18)	827	No	22.6	50.8	3.0	17.2	–	2.5	3.9
L'Agnata (19)	551	No	42.1	49.0	2.0	2.7	–	–	4.2
Lanzinosa (20)	700	No	35.7	48.4	3.8	7.5	–	1.8	2.8
Li Parisi (21)	1,674	No	6.7	23.1	57.4	4.7	–	5.3	2.8
M. Littu (22)	685	No	4.9	26.2	49.2	0.7	–	10.9	8.1
Locheri (23)	1,034	No	22.8	14.1	43.8	1.8	–	15.0	2.5
Lu Naracu (24)	649	No	21.4	13.4	42.8	1.9	0.1	13.8	6.6
Muddizza (25)	1,179	No	19.7	48,1	19.7	6.5	–	3.2	2.8
Muntagna (26)	978	No	5.4	35.6	3.4	11.1	0.3	41.6	2.6
Nulvara (27)	824	No	42.7	23.2	16.3	1.3	–	13.7	2.8
PFG (28)	625	No	5.4	28.5	53.1	8.0	–	0.8	4.2
M. Russu (29)	1,066	No	9.5	49.5	32.2	–	–	6.4	2.4
Sa Matta (30)	2,828	No	26.4	19.6	44.0	3.4	–	3.6	3.0
S. Biagio (31)	653	No	22.4	46.5	25.1	0.3	–	2.3	4.6
Ulchi B.C. (32)	895	No	10.9	54.4	8.3	21.7	0.1	0.3	4.3
Vignola (33)	1,692	No	4.0	43.6	6.2	0.9	–	42.6	2.7
Zurria (34)	1,149	No	14.3	34.6	23.8	8.9	0.1	14.4	3.9
Total	41,750		22.4	41.6	15.7	9.2	0.5	6.6	4.0
Province	340,418		21.2	38.1	13.2	6.0	0.8	15.2	5.5