

# Grit in the gizzard of Spanish Sparrows (*Passer hispaniolensis*)

By Juan C. Alonso

## 1. Introduction

Small stones are ingested by a variety of bird species with very different qualitative diet compositions (MEINERTZHAGEN 1954, ZISWILER & FARNER 1972). It is known that grit is in them essential for optimum digestion, because it increases the motility and grinding action of the gizzard and the digestibility of hard foods (GROEBBELS 1932, FRITZ 1937, BROOKE 1957, HILL 1971). However, the literature is relatively poor in quantitative studies that relate the grit content to food parameters. Some interspecific comparisons show that the size of grit varies according to their feeding regimes (MEINERTZHAGEN 1954, GRIGERA & ALIOTTA 1976, TITUS et al. 1977), but there are very few intraspecific analyses between food and grit variables. In the present study I analyse the variations in weight, number and size of grit in Spanish Sparrows (*Passer hispaniolensis*) in relation to diet composition, number and size of the food elements, age and weight of the bird, season, and time of day.

## 2. Material and methods

Grit was examined from the stomachs of 317 Spanish Sparrows (242 ad., 43 juv. and 32 nestlings) captured at a cultivated area in Extremadura, Spain (39° 58' N / 6° 20' W), between 1978 and 1981. The stomach contents were removed as soon as possible, and the food elements were separated from the grit, oven-dried at 70 °C during 48 hours, counted, weighed to the nearest 0,0001 g and identified. All the grit samples were also oven-dried, counted and weighed. Measuring of grit particles was done on all samples of nestlings and juv., but only on a sample of 48 ad. birds (4 selected at random from each month of the year). The few particles of grit which occasionally occur in a proventriculus were included with the corresponding gizzard sample. As size of a grit particle or food element I considered its longest diameter, which was measured to the nearest 0,02 mm in grit particles larger than 0,5 mm and to the nearest 0,1 mm in grit particles smaller than 0,5 mm, and in all food elements. In the seasonal comparisons, only stomachs of birds captured after 10.00 hours were utilized, to eliminate the effect of the steep increase in the grit weight during the first hours of the day. As the weight of grit depends on the number and size of the stones (see below), the first variable was selected as indicator of the amount of grit and used in multiple correlation analyses with weight of food, weight of bird and time of day in ad. and juv. While studying the relations between pairs of variables, partial correlation analysis was utilized to eliminate the influence of other variables.

We wish to acknowledge the assistance provided by A., D. und M. RODRIGUEZ, J. ALONSO, P. CAMPOS, A. CARMENA, A. FERNANDEZ, M. FERNANDEZ, A. PASCUAL, P. PEREIRA and P. VEIGA during netting operations. We also thank the Cátedra de Vertebrados of the Complutense University of Madrid and the Ministerio de Educación for a FPI-grant.

## 3. Results

### 3.1. Grit in adult birds

The weight of grit in the gizzards of ad. sparrows varied between 0 (2.48 % of the gizzards contained no grit) and 0,2725 g, with an average of 0,0932 g (S. D. = 0,0511, n = 242). There was no significant difference in the grit weights of ♂ (0,0924 g, S. D. = 0,0441) and ♀ (0,0964 g, S. D. = 0,0613;  $t = 0,58$ ,  $p > 0,05$ ).

Table 1: Partial correlation coefficients between five variables related to grit and food in stomachs of ad. Spanish Sparrows ( $n = 242$ ). Significance levels: \* =  $p < 0,05$ ; \*\* =  $p < 0,001$ .

	Time of day	Weight of bird	Weight of grit	Weight of vegetal food	Weight of animal food
Time of day					
Weight of bird	0,13*				
Weight of grit	0,20***	0,14*			
Weight of vegetal food	0,31***	0,12	- 0,01		
Weight of animal food	0,18***	-0,03	- 0,02	- 0,10	

Partial correlation analysis between grit weight, number and mean size of particles, and size of the largest particle, with a sample of 48 stomachs (4 from each month) showed that the weight of grit depends on both the number of particles ( $r = 0,68$ , 44 df,  $p < 0,001$ ) and the size of the largest particles ( $r = 0,47$ ,  $p < 0,01$ ). On the other hand, the number of particles in a stomach is inversely correlated with their mean size ( $r = 0,42$ ,  $p < 0,01$ ) and with the size of the largest one ( $r = 0,45$ ,  $p < 0,01$ ).

The weight of grit increases significantly with time of day and weight of the bird, but is not correlated with the weight of the stomach food contents (Table 1). Bird weight and weight of the food in stomach also increase with time of day, but partial cor-

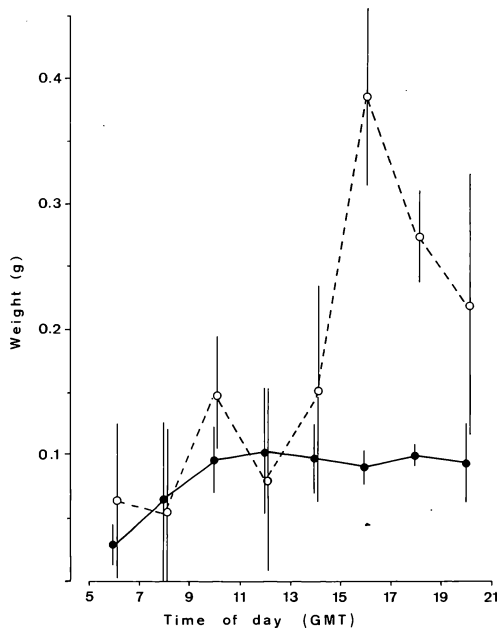


Fig. 1: Variation of grit weight (solid line) and food weight (broken line) in stomachs of ad. Spanish Sparrows with time of day. Vertical lines represent the 95 % confidence intervals. — Gewichte (in g) von Magensteinchen (ausgezogene Linie) und Nahrung (unterbrochene Linie) im Magen adulter Weidensperlinge zu verschiedenen Tageszeiten. Die vertikalen Linien kennzeichnen jeweils den 95 %- Vertrauensbereich.

relation analysis indicates that the daily increase in grit weight is independent of the other variables. In fact, the daily pattern of grit weight increase is clearly different from that of food weight increase (Fig. 1). The amount of grit is minimal in early morning (the 6 stomachs that contained no grit were collected between 6.00 and 7.00 hours), but increases rapidly before midday, remaining constant throughout the rest of the day. On the contrary, the weight of food in stomach shows two peaks along the day, the second being much higher and not correlated with an increase in grit weight.

The seasonal variation of grit weight shows peak values during winter and late spring in both sexes (Fig. 2). These are probably the result of the interaction of the seasonal patterns of grit size and number of particles: the largest grit sizes occur in late spring, decreasing then regularly to minimum values in winter (Fig. 3). This seasonal trend is positively correlated with the seasonal variation of the mean size of food elements consumed by the sparrows ( $r = 0,82$ , 10 df,  $p < 0,001$ , Fig. 3). The monthly average numbers of grit particles per stomach are inversely correlated with the grit size means ( $r = - 0,71$ , 10 df,  $p < 0,01$ ), decreasing from high numbers in winter to low numbers in summer, and positively correlated with monthly average numbers of food elements per stomach (logarithmic correlation,  $r = 0,59$ , 10 df,  $p < 0,05$ , Fig. 4).

### 3.2. Grit in juveniles

The grit weight varied in juv. birds between 0,001 g and 0,2742 g, with an average of 0,1291 g (S. D. = 0,0719,  $n = 43$ ). Partial correlation analysis shows that grit weight increases with time of day also in juveniles (Table 2). The inverse correlations between grit weight and weight of vegetal food and between bird weight and weight of animal food are surely determined by a seasonal change in the diet composition: the preponderance of animal food in the diet of recently fledged Spanish Sparrows is gradually outweighed by increasing proportions of vegetal food from June to October (own unpu-

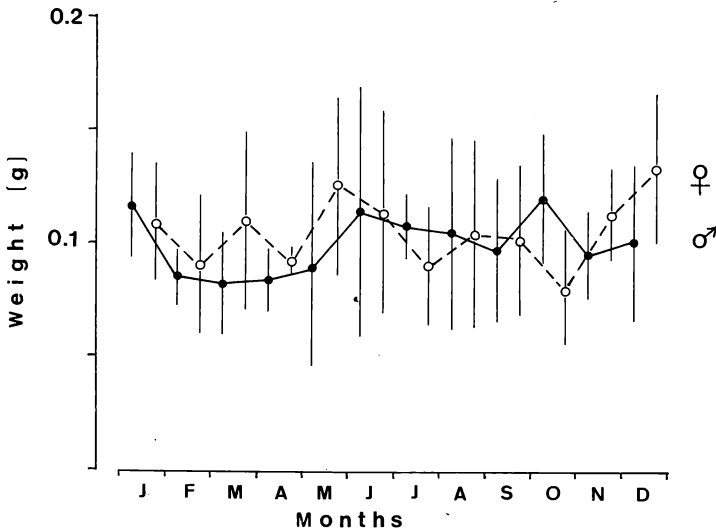


Fig. 2: Monthly variation of the grit weight in ♂ and ♀ ad. Spanish Sparrows. Vertical lines represent the 95 % confidence intervals. — Gewichte (in g) von Magensteinchen adulter ♂ und ♀ des Weidensperlings in den einzelnen Monaten.

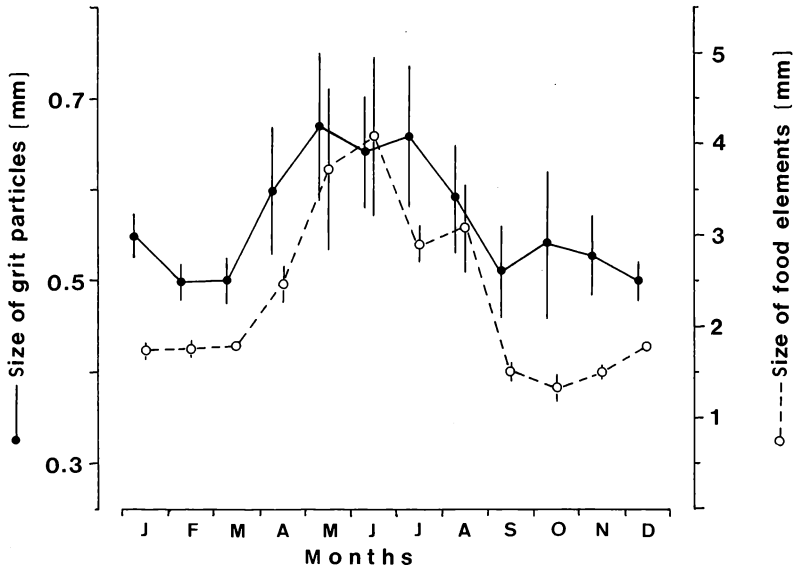


Fig. 3: Monthly variation of the mean sizes of grit particles (solid line) and food elements (broken line) in stomachs of ad. Spanish Sparrows. Vertical lines represent the 95 % confidence intervals. — Größe (in mm) von Magensteinchen (ausgezogene Linie) und Nahrungspartikeln (unterbrochene Linie) im Magen adulter Weidensperlinge in den einzelnen Monaten.

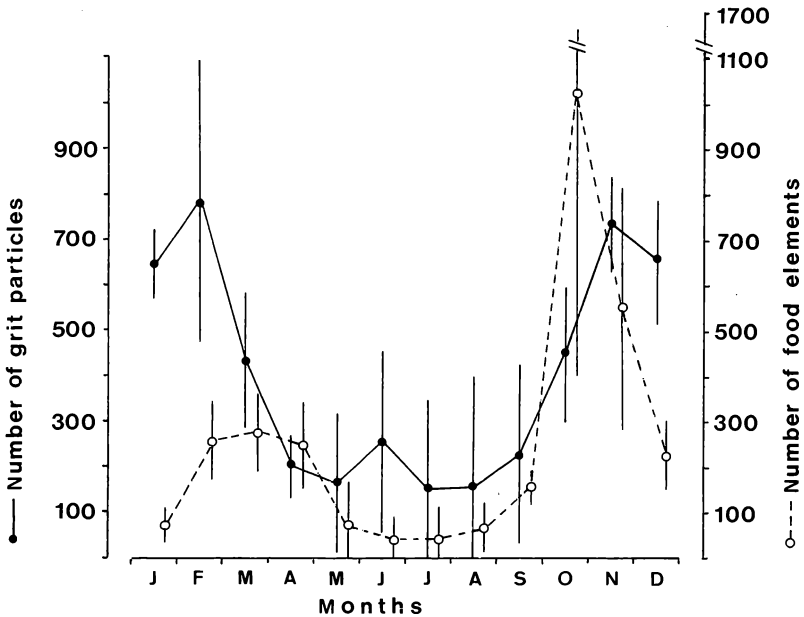


Fig. 4: Monthly variation of the mean numbers of grit particles (solid line) and food elements (broken line) per stomach of ad. Spanish Sparrows. Vertical lines = 95 % confidence intervals. — Zahl der Magensteinchen (ausgezogene Linie) und der Nahrungspartikel (unterbrochene Linie) im Magen adulter Weidensperlinge in den einzelnen Monaten.

Table 2: Partial correlation coefficients between five variables related to grit and food in stomachs of juv. Spanish Sparrows ( $n = 45$ ). Significance levels: \* =  $p < 0,05$ ; \*\* =  $p < 0,01$ .

	Time of day	Weight of bird	Weight of grit	Weight of vegetal food	Weight of animal food
Time of day					
Weight of bird	0,44**				
Weight of grit	0,33*	0,07			
Weight of vegetal food	0,27	0,25	- 0,32*		
Weight of animal food	0,22	- 0,43**	- 0,12	0,05	

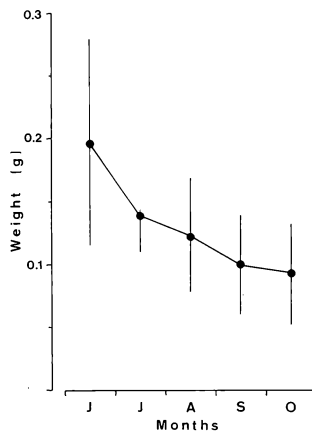


Fig. 5: Monthly variation for the grit weight in juv. Spanish Sparrows ( $n = 43$ ). Vertical lines = 95 % confidence intervals. — Gewichte (in g) von Magensteinchen juveniler Weiden-sperlinge ( $n = 43$ ) in den Monaten Juni bis Oktober.

blished data). The simultaneous increase in bird weight ( $r = 0,99$ , 5 df,  $p < 0,001$ , ALONSO 1985) and decrease in grit weight ( $r = - 0,95$ , 3 df,  $p < 0,02$ , Fig. 5) determine the existence of the inverse correlations mentioned above. The grit weight is significantly higher in juv. than in ad. in June-August ( $t = 2,15$ ,  $p < 0,05$ ) and statistically identical in September-October ( $t = 0,09$ ,  $p > 0,05$ ). The cause of the monthly decrease in grit weight is the marked decrease in the mean grit size, as indicated by the significant correlation between both variables, while the number is held constant through partial correlation analysis ( $r = 0,98$ , 2 df,  $p < 0,05$ ). The decrease in grit size is strongly correlated with a seasonal decrease in mean size of prey ingested by juv. birds ( $r = 0,99$ , 3 df,  $p < 0,01$ , Fig. 6).

### 3.3. Grit in nestlings

The weight of grit in the gizzards of young Spanish Sparrows averaged 0,2510 g (S. D. = 0,2360,  $n = 32$ ), being significantly higher than the grit weight in fledged juv. birds in June-July ( $t = 2,30$ ,  $p < 0,05$ ). The weight of grit and the size and number of particles are higher in older than in younger nestlings (Table 3). Also, the food elements are significantly larger in aged chicks.

Partial correlation analysis between age, number and mean size of grit particles, and number and mean size of food elements showed significant positive correlations between age and the other four variables ( $r = 0,70$ , 27 df,  $p < 0,001$ ;  $r = 0,55$ ,  $p < 0,01$ ;  $r = 0,37$ ,  $p < 0,05$ , and  $r = 0,37$ ,  $p < 0,05$ , respectively). Also, there were inverse correlations between number of particles and size of food elements ( $r = -0,39$ , 27 df,  $p < 0,05$ ), and between number and size of food elements ( $r = -0,66$ , 27 df,  $p < 0,05$ ).

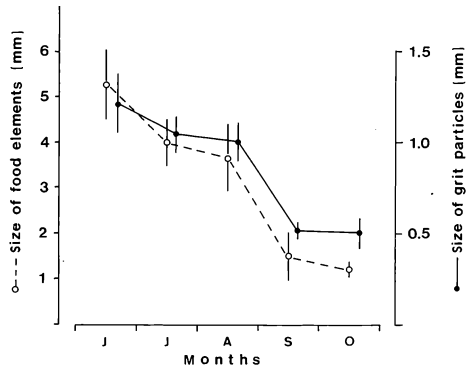


Fig. 6: Monthly variation of the mean sizes of grit (solid line) and food elements (broken line) in stomachs of juv. Spanish Sparrows. Vertical lines = 95 % confidence intervals. — Größe (in mm) von Magensteinchen (ausgezogene Linie) und Nahrungspartikeln (unterbrochene Linie) im Magen juveniler Weidensperlinge in den Monaten Juni bis Oktober.

Table 3: Grit and food parameters in stomachs of young Spanish Sparrows ( $n = 32$ ): mean  $\pm$  S. D. (range).

Age in days	1—5 ( $n = 10$ )	6—11 ( $n = 22$ )	t-test difference
Weight of grit (g)	0,0264 $\pm$ 0,0287 (0—0,0812)	0,3527 $\pm$ 0,2123 (0,01—0,7555)	4,66***
Size of grit particles (mm)	0,92 $\pm$ 0,78 <sup>a</sup> (0,3—3,34)	1,26 $\pm$ 1,12 <sup>b</sup> (0,2—7,94)	2,54*
Number of grit particles per stomach	8,25 $\pm$ 10,21 (0—80)	89,07 $\pm$ 52,06 (1—210)	4,71***
Weight of food (g)	0,1208 $\pm$ 0,0454 (0,02—0,185)	0,1307 $\pm$ 0,0761 (0,01—0,305)	0,37
Size of food elements (mm)	6,00 $\pm$ 4,68 <sup>c</sup> (2—25)	7,91 $\pm$ 8,02 <sup>d</sup> (3—40)	2,52*
Number of food elements per stomach	6,40 $\pm$ 5,41 (1—19)	12,55 $\pm$ 12,55 (1—47)	1,44

a)  $n = 48$ ; b)  $n = 239$ ; c)  $n = 64$ ; d)  $n = 276$ ;  
Significance levels: \* =  $p < 0,05$ ; \*\*\* =  $p < 0,001$

#### 4. Discussion

Ingestion of grit seems to be independent of the qualitative composition of the diet in Spanish Sparrows: grit is present in the gizzards of nestlings, which have a mainly insectivorous diet (90 % by weight), in juv. birds, who's diet contain 44 % of animal food (by weight), and in ad. in all seasons and independently of the proportions of animal and vegetal food in their diets (ALONSO 1982). Although the seasonal changes in the diet composition of ad. sparrows do not determine important variations in the weight of the grit in their stomachs, the slightly higher amounts in spring and winter could be related to the increased metabolic rates during these periods (see KENDEIGH et al. 1977). It has been shown that the amplitude of gizzard movements is greater (GROEBBELS 1932, FRITZ 1937, TITUS 1949, HILL 1971), and the rate of food passage and digestibility higher (MANGOLD 1927, BROOKE 1957) when grit is present. Higher amounts of grit have been recorded in several species during winter (WEST 1967, TAMISIER 1971, KEIL 1973, RODRIGUEZ & HIRALDO 1975, HERRERA 1977) and during periods of high energy demands in spring, like when ♀ are engaged in egg-laying (HUGHES 1972, PINOWSKA 1975). Similarly, the higher grit weights in nestlings and juv. probably favour the high digestion rates necessary for a rapid growing at these ages.

Although the effects of qualitative changes in the diet on the total grit weight in stomach are negligible, the type of foods ingested influence the characteristics of the grit particles selected throughout the year. During the spring and summer ad. sparrows capture many insects, which are rapidly available on the ground, where the birds usually search for food, and also eat a higher amount of cereal seeds (ALONSO 1982). As insects and cereal seeds are on average larger than other seeds consumed by the sparrows, the mean size of food elements increases during the summer half-year. The sparrows take then grit particles of larger size, which presumably makes digestion of large insect prey and cereals more efficient. As a larger size of grit would determine an increase in total grit weight in the stomach, birds reduce the number of stones, adjusting it probably to the optimal grit weight. During winter, when the sparrows feed mainly on small weed seeds, the size of the grit is also small, and the numbers of seeds and grit particles are higher than in summer. Thus, in spring-summer grit consists of fewer and larger particles and in winter, of more numerous and smaller particles.

Juv. birds also select the size of grit in relation to the size of food elements consumed, and the size of grit supplied to the nestlings by their parents increases with nestling age parallelly to the size of nestling food items. Thus, overall a close correlation exists between mean size of food elements and mean size of grit for the three age-classes and the different months of the year considered together ( $r = 0.88$ ,  $n = 19$ ,  $p < 0,001$ ). An interspecific relation between size of grit and size of food elements had been found by comparison of diets and grit contents of various waterfowl species (OWEN 1973, OWEN & CADBURY 1975, THOMAS et al. 1977, CAMPREDON 1984). However, in contrast to the results of these studies, in which the average sizes of food elements and grit particles were very similar, in our study average grit size was about 1/4 of average size of food elements both in ad. and juv., and about 1/6 in nestlings. These values probably represent the optimal size relations for an efficient grinding action of the grit. These results and the constancy of the parallelism between size and number of grit particles and size and number of food elements throughout the year and for different ages of the birds suggest that sparrows select the optimal number and size of grit particles, rather than swallowing them undeliberately along with the food.

A certain amount of grit is probably voided daily, as suggested by the low average amounts found in the stomachs of birds captured early in the morning. This seems to be the rule when birds have free access to grit daily (BROWN 1904, LIENHART 1953), as is the case in our study area. During the first morning hours birds ingest the amount of grit necessary to reach the „ideal“ quantity, which remains constant throughout the rest of the day, with independence of the passage of food through the gizzard.

## 5. Summary

Grit was examined from the stomachs of 317 Spanish Sparrows captured at Extremadura, Spain. The weight of grit increases with time of day independently of the increase in weight of the stomach food content. Highest grit weights occur in nestlings, decreasing in juv. birds gradually between spring and autumn. The weight of grit depends on the number and size of the grit particles, and these latter variables are correlated, respectively, with number and size of the food elements consumed by the birds. In winter, when the diet consists mainly of small weed seeds, sparrows ingest higher numbers of smaller grit particles, while in summer, when the diet includes large insects, birds ingest lower numbers of larger particles, thus probably enhancing the efficiency of the grinding action of the grit.

## 6. Zusammenfassung

Magensteinchen beim Weidensperling (*Passer hispaniolensis*).

Der Steinchengehalt im Magen von Weidensperlingen wurde an 317 in Extremadura/Spain gefangenen Individuen untersucht. Das Gewicht des Inhalts an Magensteinchen nimmt mit der Tageszeit unabhängig vom Gewicht der Nahrung im Magen zu. Die höchsten Gewichte fanden sich bei Nestlingen. Bei Jungvögeln nimmt das Gewicht des Magensteinchen-Inhalts zwischen Juni und Oktober ab, was vielleicht eine schnellere Verdauung bei ihnen erleichtert. Das Gewicht des Magensteinchen-Inhalts hängt von Anzahl und Größe der Steinchen ab, und diese Variablen sind mit der Anzahl und Größe der aufgenommenen Nahrungspartikel korreliert. Im Winter, wenn die Nahrung hauptsächlich aus kleineren Samen besteht, nehmen die Sperlinge eine höhere Anzahl kleinerer Steinchen, während sie im Sommer, wenn die Nahrung auch größere Insekten und Samen enthält, wenige, doch größere Steinchen auswählen. Diese Schwankungen können als Anpassung an ein besseres Zermahlen der Nahrungsbestandteile gewertet werden.

## 7. References

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Artikel/Article: [Grit in the gizzard of Spanish Sparrows \(\*Passer hispaniolensis\*\)  
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