

Clutch size of the Great Tit *Parus major* and the Blue Tit *Parus caeruleus* in some areas of Central Italy

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Abstract - Small values of clutch size were observed for both species in all the study stations, as compared with other European areas located at higher latitude; these results could be related to the lower seasonality of food resources in Mediterranean area. In some sites preliminary data show a high presence of youngsters among the breeders; considering also the small effect of competitive factors and predation on clutch size, a trade-off between reproduction and survival does not appear to be important. As far as clutch size variations among the study areas are concerned, habitat features, density of breeders and laying date seem to play a decisive role. Clutch size does not decrease with altitude. Food availability might produce the observed differences in breeder density.

Introduction

The significance of avian clutch size has occupied much space in the literature on evolution and ecology (Cody 1966, Klomp 1970, Ricklefs 1983, Murphy and Haukioja 1986). Although the correct estimate of heritability of this breeding parameter is not clear (Perrins and Jones 1974, van Noordwijk *et al.* 1981, Emlen 1984), clutch size is definitely an important component of individual fitness.

Among the factors affecting clutch size, Lack (1947, 1948, 1954) stressed the direct role of food availability and proposed that clutch size corresponds to the largest number of offspring that parent birds can raise. On the other hand, Ashmole (in Ricklefs 1980) stated that clutch size should increase with seasonality of food supply. Another hypothesis explained the variations of this breeding parameter with a trade-off between reproduction and survival (Cody 1971, Nur 1988) and with the unpredictable year-to-year fluctuations in selection pressures (Boyce and Perrins 1987). Finally for some authors, clutch size could be inversely related to the probability of predation (Slagsvold 1982) and to the increasing risk of brood hyperthermia (van Balen and Cavè 1970), an hypothesis with little favour. It is, however, difficult to explain the geographical variation of clutch size since many factors influence Blue Tit *Parus caeruleus* and Great Tit *Parus major* clutch size, e.g. female age, nest box size,

laying date, breeder density and altitude (Bellavita and Sorace 1991). However, some authors (Zang 1982, Krementz and Handford 1984, Hamann *et al.* 1989, Delgado *et al.* 1992), did not find altitude effects on clutch size. A decrease in clutch size as a consequence of population density increase (Kluyver 1951, Lack 1966, Dhondt and Eyckerman 1980) may represent an effect of density on food supply or an adaptation to the poorer prospects for successful rearing of young (van Balen 1973, Ashmole in Ricklefs 1980, Ekman and Askenmo 1986). Note, however, that in deciduous oak woods, Tits present the largest clutches (Perrins 1965, Orell and Ojanen 1983, Blondel *et al.* 1987) as well as the highest density (Snow 1954, Lack 1966, van Balen 1973, Perrins 1979).

The present study investigated the role of laying date, breeder density, habitat and predatory pressure on Great and Blue Tit clutch size at some sites in Central Italy. The correlation with some environmental factors may indeed help us to understand the mechanisms producing variations in demographic parameters (Ricklefs 1983). The choice of nearby sites reduces some useful information (e.g. latitude effect); on the other hand the comparison among very distant areas could raise other kinds of problems in the interpretation of the observed results (e.g. different importance of some environmental factors, Ricklefs 1985; different time and energy budget of the study populations, Cody 1966, Walsberg 1983, Bryant

and Westerterp 1983, Hussel 1985: subspecific differences, Blondel et al. 1992 b).

Study Area, Materials and Methods

This investigation was carried out in seven areas in Central Italy (Tab.1). Nest boxes (14 x 14 x 22 cm, entrance hole 3.5 cm) were placed about 3 m above the ground and about 50 m apart.

During the breeding season, the boxes were checked weekly. Laying dates were calculated assuming that females lay one egg per day (Kluijver 1951, Lack 1955). For each site, hatching success was defined as

the ratio between the observed number of chicks and eggs laid.

Taking into account the effect of laying date on clutch size and the fact that after April 30 many second clutches are usually present (Bellavita et al. 1990, Bellavita and Sorace 1991), the analysis of clutch size variations in the study area was carried out only for the first clutches laid before this date. In some cases, the observed results were validated by carrying out comparisons among different environments or sites over shorter periods when laying dates overlapped (unpublished data). For each environment of a study area, data of different years were sometimes summed:

Tab.1. Geographical coordinates, altitude, habitat features and nest-box numbers for each studied sites.

Study areas	geographical coordinates	altitude	environment (prevailing species)	nest-box number
Monte Rufeno:	42° 47' N 11° 93' E	500	deciduous wood 25-30 years old (<i>Quercus cerris</i>)	30*
			pine wood 20-25 years old (<i>Pinus halepensis</i>)	20
			Mediterranean scrub in secondary stage (<i>Quercus ilex</i>)	20
Orbetello:	42° 27' N 11° 13' E	0	pine wood 30-40 years old (<i>Pinus pinea</i>)	30
Burano:	42° 24' N 11° 22' E	0	Mediterranean low scrub with sparse plants (<i>Quercus ilex</i>)	20
Lago di Vico:	42° 20' N 12° 11' E			
S. Rocco (locality)		800	deciduous wood 40-70 years old (<i>Quercus cerris</i>)	30
M. Venere (locality)		700	beech wood 70 years old (<i>Fagus sylvatica</i>)	30
Palo:	41° 56' N 12° 05' E	0	deciduous wood 40-50 years old (<i>Quercus cerris</i>)	50
Macchia Grande:	41° 50' N 12° 13' E	0	Mediterranean scrub in primary stage (<i>Quercus ilex</i>)	38
Castelporziano:	41° 44' N 12° 24' E	0	deciduous wood 50-60 years old (<i>Quercus robur</i>)	31
			pine wood 30 years old (<i>Pinus pinea</i>)	20

* second year 40 nest boxes ° in 1990 20 nest boxes

generally, in these cases the observed results did not differ from those of single years (unpublished data). During the spring of 1991, information on breeder density was collected in each site using the Line Transect Method (Järvinen and Väisänen 1973). In the Palo woods, data were collected in the spring of 1989 (Bellavita et al. 1990), and in the L.Vico woods in the spring of 1988 (Ruvolo et al 1991).

Results

Clutch size and laying date

For all the sites in all the study years, the average clutch size varies between 6.2 and 8.2 in the Great Tit (except for the data of Orbetello, which refer to four clutches only) and between 7.0 and 8.4 in the Blue Tit (Fig.1-2). In some cases, clutch size differences among the various sites show statistical significance (Tab.2). For clutches laid up to April 30, nesting occurs between April 16 and May 20; in Rome (41°53'N, 12°27'E), over this period, the actual evapotranspiration, AE, varies between 60 and 90 mm and in autumn it is at the same level as in April (Pinna 1977).

For clutches laid before April 30, laying date comparisons between the same environment at two different sites were not significant (Mann-Whitney test). For the Great Tit, however, the mean laying date in each study area (i.e. summing data of different environments) and the relative mean clutch size are

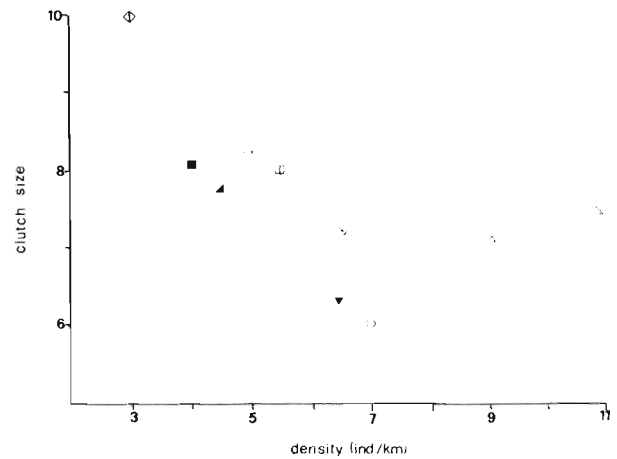


Fig.1. Great Tit density (ind/km) and clutch size in each environment of the following study areas (in brackets, study years and number of clutches for each environment): Monte Rufeno=□ (1989-91, deciduous wood n=16; pine wood n=13; Mediterranean scrub n=10); Orbetello=◇ (1990-1991, n=4); Burano=△ (1990-1991, n=6); Lago di Vico=△ (1988-89, deciduous wood n=11; beech wood n=4); Palo = (1983-84 and 1990, n=39); Macchia Grande=▽ (1990-91, n=21); Castelporziano = △ (1991, deciduous wood n=6). For each study area: empty symbol = deciduous wood; filled symbol = mediterranean scrub; barred symbol = pine wood; dotted symbol = beechwood.

positively correlated (Spearman Rank Correlation, 1-tailed, $r=0.89$, $n=7$, $p<0.01$, Fig.3), while in some areas Blue Tit data are most likely too scarce (Fig.2) to reveal possible correlations. 92.7% of Blue Tit and

Tab.2. Significance of comparisons among clutch sizes at different sites (Anova and Student t test).

Environment	species	compared areas*	year(s)	Test	significance
deciduous wood	GT	1-3-4-6	all	$F_{3,67} = 7.1$	$p<0.01$
deciduous wood	GT	1-4	all	$t_{53} = 2.5$	$p<0.02$
deciduous wood	GT	3-4	all	$t_{48} = 3.0$	$p<0.01$
deciduous wood	GT	1-3	1989	$t_9 = 3.3$	$p<0.01$
deciduous wood	BT	1-3	all	$t_{56} = 2.1$	$p<0.05$
deciduous wood+ pine wood	GT	1-6	1991	$t_{14} = 2.2$	$p<0.05$
deciduous wood+ pine wood	BT	1-6	1991	$t_{22} = 2.4$	$p<0.05$
mediterranean scrub	GT	1-2-5	1991	$F_{2,23} = 6.9$	$p<0.01$
mediterranean scrub	GT	1-5	1991	$t_{20} = 3.6$	$p<0.01$
mediterranean scrub	GT	2-5	1991	$t_{17} = 2.8$	$p<0.05$
mediterranean scrub	GT	1-5	1989-91	$t_{29} = 4.4$	$p<0.01$
mediterranean scrub	GT	2-5	1990-91	$t_{25} = 3.0$	$p<0.01$

* 1=Monte Rufeno. 2=Burano. 3=Lago di Vico. 4=Palo. 5=Macchia Grande. 6=Castelporziano.

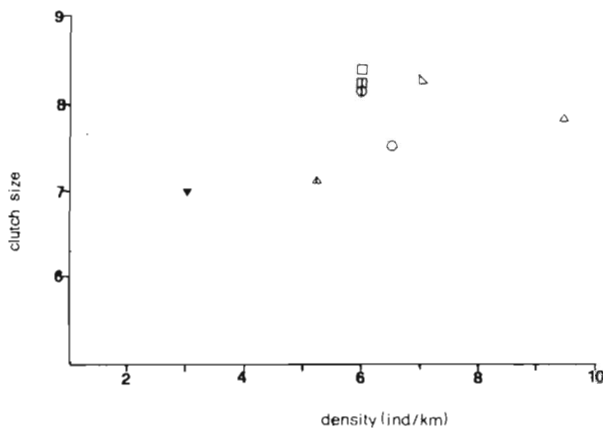


Fig.2. Blue Tit density and clutch size in each environment of the following study areas (in brackets, number of clutch for each environment): Monte Rufeno (deciduous wood n=43; pine wood n=12); Lago di Vico (deciduous wood n=15; beech wood n=13); Palo (n=3); Macchia Grande (n=2); Castelporziano (deciduous wood n=8; pinewood n=3). Symbols and study years as in Fig.1.

86.0% of Great Tit females started laying their first clutches before April 30.

Density

The density of Tits is higher in deciduous woods than in Mediterranean scrubs and, for the same environment, when density increases clutch size often decreases (Fig.1-2). The mean breeder density of Great Tits in each site and the relative mean clutch size are inversely correlated (Tab.3). Great Tit breeder density in Macchia Grande was lower in the first of the two study years (5 ind/km vs. 6.5 ind/km); clutch size decreased in the second year, but the difference was not significant ($F_{1,19}=0.4$). This result provides some useful information about the effect of breeder density on clutch size in the Mediterranean scrub.

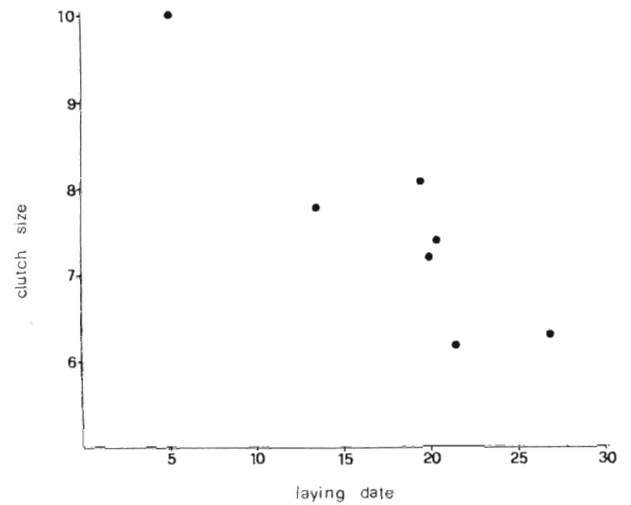


Fig.3. Relationship between clutch-size and laying date (1=March 25) for the Great Tit in each study area.

Competitive factors between the two species of Tits, however, do not seem to be important enough to produce the observed values of clutch size (Tab.3) and they are possibly only important for the more crowded stations. Some information on the avian community of the study areas shows that the lower values of clutch size (Fig.1-2) are often observed in less saturated environments. The density of all the species, as well as that of insectivores, is clearly lower in Macchia Grande (Guerrieri *et al.* in press) than in Palo (Fratlicelli and Sarrocco 1984) and Castelporziano (Bernoni *et al.* 1989); in Castelporziano it is lower in pine wood than in deciduous wood (unpublished data) and in M.Rufeno is lower in Mediterranean scrub than in deciduous and pine woods (Calvario *et al.* 1992). In 1991, four Great Tit and four Blue Tit females caught during the night

Tab.3. Significance of the correlation between breeder density and relative clutch size for each study area (average of the values of all the environments for that area; Spearman Rank Correlation, one-tailed).

Clutch	size*	density	r.	n	significance
Great	Tit	Great Tit	-0.71	7	p<0.05
Great	Tit	Blue Tit	-0.41	7	N.S.
Great	Tit	Great Tit + Blue Tit	-0.42	7	N.S.
Blue	Tit	Blue Tit	0.10	5	N.S.
Blue	Tit	Great Tit	-0.10	5	N.S.
Blue	Tit	Great Tit - Blue Tit	0.30	5	N.S.

* 1991 data; L. Vico: 1988 data; Palo: Great Tit. 1990 data; Blue Tit. 1983 data.

Tab.4. Number and percentage of unsuccessful clutches and number of preyed-upon clutches in each study area; Blue and Great Tit data summed.

	A	B	C	D	E	F	G	H	I	J
clutches unsuccessful (%)	7 (11)	12 (40)	0 -	0	6 (35)	10 (38)	4 (10)	0 —	4 (25)	4 (23)
clutches preyed-upon	0	1	-		3	2	1	—	1	0

A: M. Rufeno 1989-90; B: M. Rufeno 1991; C: Orbetello; D: Burano; E: L. Vico beech wood; F: L. Vico deciduous wood; G: Palo; H: Macchia Grande 1990; I: Macchia Grande 1991; J: Castelporziano.

in nest-boxes in the Castelporziano area, as well as four of six females caught in the night at Macchia Grande, displayed characteristics typical of young individual (Svensson 1984).

Environmental factors

With the exception of the L.Vico data, at all sites clutch size is larger in deciduous wood than in the other environments (Fig.1-2), but the differences are not statistically significant. In 1991, for the whole breeding season, Great Tit clutch size was significantly larger in the Castelporziano deciduous woods than in the Mediterranean scrub of Macchia Grande ($F_{1,33}=6.8$, $p<0.05$). This comparison was possible because clutch size in these two stations, located at similar latitude, does not seem to decrease with laying date (breeding season total: Castelporziano $\bar{X}=7.2 \pm 1.0$ $n=8$; Macchia Grande $\bar{X}=6.0 \pm 1.2$ $n=27$; see Fig.1-2 for comparison).

Altitude could have caused the low clutch size of the L.Vico deciduous wood, but beech wood in the same area did not display this effect (Fig.1-2). Likewise, the Monte Rufeno data (Fig.1-2) seem to indicate that altitude does not produce a decrease in clutch size.

Unsuccessful clutches

In the study area, the number of preyed-upon and, in general, unsuccessful clutches was generally low (Tab.4). Only in the first part of 1991, when climatic conditions in Central Italy were the worst in the last 30 years, bad weather caused low breeding success (Bellavita and Sorace in press).

The small clutch size of the L.Vico deciduous wood (Fig.1-2) could be related to the higher number of unsuccessful clutches in this environment as compared with other sites, but the same effect is not observed (Fig.1-2) in the beech woods, which exhibit a similar number of nest failures (Tab.4). Moreover,

low hatching success has generally been observed in the deciduous wood of L.Vico (Blue Tit, 1988, beech wood: 77.8%, deciduous wood: 26.2%; 1989, beech wood: 77.0%, deciduous wood 37.6%; Great Tit, 1988, beech wood: 79.7%, deciduous wood: 44.0%; 1989, beech wood: 100%, deciduous wood: 87.6%); this was not at all related to bad weather nor to other natural events (the only two cases of possible egg predation were not accounted for in these percentages). It is useful to observe that, in spite of the bad weather in the first part of the 1991 breeding season, hatching success in the M.Rufeno Reserve was 87.0% for the Great Tit and 52.6% for the Blue Tit (Bellavita and Sorace, in press).

Discussion

Clutch size in the Mediterranean area

Great and Blue Tit clutch size in the Central Italian study areas is generally lower than in other European regions at higher latitudes (Bellavita and Sorace 1991, Blondel et al. 1992 a), in spite of an earlier laying date (Bellavita and Sorace 1991) and irrespective of the study year, of the environment and of the densities. In disagreement with Lack (1966), some authors (for the Great Tit, see Orell and Ojannen 1983; for the Blue Tit, see Isenman 1987) have not found a latitudinal gradient of clutch size in Central and Northern Europe; likewise, their results do not agree with the correlation between the decrease of Tit clutch size and the length of the day in Mediterranean areas. Moreover, in this area during the nestling period, the values of AE, a parameter related to primary productivity in plants and probably with resource production (Ricklefs 1980), are equal to or higher than those reported by that author for the temperate zone. Considering that in mediterranean area the

yearly primary productivity is high (Reichle 1970), that plant growth partially occurs in autumn and that winter is generally mild (Polunin and Walters 1987), the sharp drop in Tit clutch size toward Southern Europe could be related to a reduced seasonality of food resources (Ricklefs 1980, Isenmann 1987, but see Hussel 1985).

In the study period, the effect of predation, as well as that of nest failures (Slagsvold 1984), does not appear to be decisive, although negative years such as 1991 might result in a clutch size decrease in the following year (Boyce and Perrins 1987). The low clutch size in the L.Vico deciduous wood could be partially related to a higher number of nest failures as compared with other sites, but the values of hatching success and the comparison between the two study environments of this area seem to indicate that clutch size in the L.Vico deciduous wood might be due to environmental stress (Ruvolo *et al.* 1992); in some species of Passeriformes, hatching success and clutch size were observed to decrease on account of pollutants (Kallander and Smith 1989).

In the Palo wood, Fraticelli (*in press*) has observed, in spring, a higher percentage of youngsters than in other regions of North Europe and these results seem to be confirmed by preliminary data on breeding females in the other study sites. Furthermore some observations seem to rule out effects of competitive factors on clutch size. According to the data from other Mediterranean areas (Blondel 1985, 1992 b), these results are in disagreement with the reproduction-survival trade-off hypothesis. On the other hand, the trade-off between fecundity and adult survival involves other factors, namely post-fledging survival and percentage of birds breeding as yearlings: the values of these life-history traits could both be higher in the Mediterranean area (Blondel *et al.* 1992 b). Moreover, for all the hypotheses concerning clutch size, the role of second clutches in the Mediterranean area has to be carefully examined (Bellavita and Sorace 1991).

Variations of clutch size in the Mediterranean area

Remarkable differences in habitat quality cause higher clutch size variations in the Mediterranean area than in other European regions (Blondel *et al.* 1992 a). For this area, among other factors, it has been found that clutch size in Mediterranean scrub is lower than in deciduous wood and that this breeding parameter varies among different sites according to the laying date (Blondel *et al.* 1987, Isenmann 1987, Delgado *et al.* 1992). Our results, however, suggest that breeder density may also play a central role in clutch size variations in the Mediterranean area (see also Perrins

and McCleery 1989, Perrins 1990). Considering that young woods and mountain habitats (*i.e.* M.Rufeno, Burano) should provide Tits with smaller food supplies than older woods on the plains (*i.e.* Palo, Castelporziano, Macchiagrande) (Kluijver 1951, Leclerq 1976, 1977, Perrins 1979, Kremenz and Handford 1984), breeder density, in turn, seems to be related to food availability (*e.g.* Lack 1966, van Balen 1973, Leclerq 1976, Perrins 1979, Blondel 1985). On the other hand, deciduous woods (as compared with Mediterranean scrubs), mountain habitats and open environments (*i.e.* Burano low scrub with sparse vegetation as compared with Macchia Grande mature scrub) show higher food resources seasonality (Lack and Moreau 1965, Klomp 1970, Cody 1971, Boyce 1979, Isenmann 1987; but see for mountain habitat Kremenz and Handford 1984); consequently they might exhibit larger clutch size and, due to a greater winter mortality (Ashmole in Ricklefs 1980), lower breeders density. Furthermore, in the Mediterranean area, no evident relationships between latitude and clutch size seem to exist (Blondel *et al.* 1987); in the Mediterranean scrub, Southern and Northern populations of Blue Tit lay clutches of similar size (Isenmann *et al.* 1990, Delgado *et al.* 1992). Likewise, the clutch size of this species in the L.Vico beech woods is well within the limits reported for this breeding parameter in a similar environment at same altitude in Southern France (Isenmann 1987). On the other hand, clutch size in Mediterranean scrub for the Great Tit and in deciduous wood for both species is the same as that observed in Spanish populations at similar latitude (Potti *et al.* 1988, Barba *et al.* 1988) but is lower than in areas in Southern France (Cramm 1982, Blondel *et al.* 1987, Isenmann 1987). Due to environmental factors, laying date and breeder density should be ruled out when studying this relation.

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Riassunto - In sette località del centro Italia sono stati correlati parametri ambientali con la dimensione della covata. In tutte le aree di studio la dimensione della covata appare inferiore rispetto ad aree centro e nord europee. Ciò potrebbe imputarsi alla minore fluttuazione stagionale di risorse presente nelle aree mediterranee.

La densità dei riproduttori, la data di deposizione e l'eterogeneità ambientale sembrano fattori importanti nel determinare la variabilità, tra le località, di questo parametro riproduttivo.

Non si osservano clini altitudinali mentre la disponibilità di cibo può influenzare la densità di coppie in riproduzione. In generale, le dimensioni di covata di cinciarelle e cinciallegre in centro Italia sono inferiori di quelle della Francia del Sud mentre sono simili a quelle spagnole di latitudine corrispondente.

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