THE ANNUAL CYCLE OF THE AZORES BULLFINCH, *PYRRHULA MURINA* GOLDMAN, 1866 (AVES: PASSERIFORMES)

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The annual cycle of the Azores bullfinch or Priôlo, *Pyrrhula murina*, is described. This bird breeds from June to August, when food abundance is high, and starts moulting in September. Seasonal variations in body weight and fat scores were small. The annual mortality is probably less than 60%. The median monthly group size was always one or two. Overall, it presents a strong seasonal pattern similar to that of western European *Pyrrhula*, but with slight variations. These should be an environmental correlate of the oceanic temperate climate of S. Miguel island.

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Descreve-se o ciclo anual do Priôlo, *Pyrrhula murina*. Esta ave nidifica de Junho a Agosto, quando a abundância de alimento é elevada, e começa a muda de penas em Setembro. O peso e o indíce de gordura apresentaram variações sazonais reduzidas. A mortalidade anual é provavelmente menos de 60%. O grupo de aves observadas em cada mês apresentou sempre uma mediana de um ou dois. De um modo geral, o Priôlo apresenta um padrão sazonal semelhante ao de outros *Pyrrhula* da Europa Ocidental, embora com ligeiras variações. Tal facto deverá estar relacionado com o clima temperado oceânico de S. Miguel.

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INTRODUCTION

Physiognomically, Azorean cloud forests resemble tropical montane forests (HAGGAR 1988) and seasonal variations in temperature and water regime are small (SJÖGREN 1984). MOREAU (1950) and SERLE (1981) observed that breeding is seasonal in tropical montane forests. For lowland forests, however, they were not able to define an universal breeding season, although most families had a preferred nesting season. No information is available on the ecology of Azorean cloud forest passerines. For example, it is not known whether their annual cycle resembles that of tropical montane forest birds. This may not be expected because, for instance, seasonal variations of daylength in the Azores are much more pronounced than those of the tropics. The evaluation of this question would provide a primary step in understanding the ecology of terrestrial birds in these native forests.

Here, the annual cycle of the Azores (or S. Miguel) bullfinch or Priôlo, *Pyrrhula murina*, is reported. This species is the only endemic bird species of the archipelago (RAMOS 1993). It is also of crucial importance on practical grounds because this bird, with a population of about 100 pairs (BIBBY & CHARLTON, 1991), is restricted to the native cloud forest in eastern S. Miguel (BIBBY & CHARLTON 1991; BIBBY *et al.* 1992; RAMOS in press a). The results reported here are part of a wider research programme on the ecology of the Azores bullfinch carried out between 1991 and 1993.

Both breeding and moulting are energetically costly and are expected to occur when food is abundant (LACK 1966; PERRINS 1970). Although insular habitats can be regarded as relatively equable throughout the year when compared with similar mainland areas, these activities still often present a strong seasonal component (SNOW & SNOW 1964; DIAMOND 1980; GREIG-SMITH 1980; BROOKE 1985). Generally, the distribution and abundance of food are expected to influence overall seasonal rhythms of birds (WIENS 1989) and will be used here as a basis for an examination of seasonal activity patterns.

This paper provides information on annual cycle events and, to a lesser extent, the population dynamics of the Azores bullfinch. The following questions were asked: (1) Do breeding and moulting show seasonal occurence and are they correlated with food abundance? (2) Are mortality levels related with food resource abundance?

METHODS

The study area is described in full elsewhere (BIBBY & CHARLTON 1991; BIBBY et al. 1992; RAMOS 1993). It is a mountainous district in eastern S. Miguel with densely vegetated steep ground; native forests being present above 400-500 m.

Mist netting was carried out at several sites both within and at the edge of the Laurel forest. Nets were placed at feeding sites, especially on patches of *Polygonum capitatum* and *Leontodon filii*, up to four days a week.

Birds were examined for differences between male and female plumage, for presence of a brood patch, presence or absence of primary moult, fat score (0 to 4 according to SPENCER 1975), odd marks or injuries and presence or absence of throat pouches. They were also colour-ringed, weighed with a 50 g Pesola spring balance and measured for wing-length, tail-length, bill-length, bill-depth, tarsus and total head, according to SVENSSON (1984).

Sexes were indistinguisable in the field. In hand, some birds could be sexed by colour differences. In males the abdomen and flanks were suffused with a reddish-tawny tinge as stated by GOODWIN (1985) and there was never a brood patch. When these criteria were used for sexing, a sample size of 22 males (with reddish tinge) and 28 females (with brood patch) where obtained. A further 23 birds could not be sexed by these methods. From these 23 birds, 12 could be sexed because they were seen paired with ringed birds of known sex. The traditional method of ageing bullfinches, *Pyrrhula pyrrhula*, colour differences in their greater coverts (NEWTON 1966a) was difficult to apply to the Azores bullfinch because adults have buffish edged coverts too, unlike the more grey mainland bullfinches. Therefore, for the analysis of overall mortality rates, it was not attempted to distinguish between first years and older birds.

Recruitment into the population was estimated by counting the number of juveniles (with brown heads) during walks along routes (marked in the main distribution area of the bird) made every ten days. To assess mortality rates, colour-ringed birds were sought widely along all marked routes.

Plant species in the study area were examined every month and their phenologies noted. Changes in the abundance of foods taken by the Azores bullfinch (see also RAMOS in press a) were evaluated by counting the number of seed heads or fruits of individual food plants in 40 x 5m transects at the stations of three routes, at low (300 m), mid (500 m) and high (700 m) altitude.

RESULTS

Breeding and moult. The first female with a brood patch was caught on the 10th of June, about three weeks after fresh *P.capitatum* seeds (a preferred herbaceous seed in summer, BIBBY et al. 1992; RAMOS in press a) became available. The birds' behaviour in late April, May and early June indicated pre-breeding activity. The male's dance and bill caressing (HINDE 1955; NICOLAI 1965) were common in May and early June; a twig display was observed in late April and courtship feeding (see NEWTON 1972) was commonly seen in late May and early June. In the last week of May two birds were seen flying with dry twigs in their beaks.

In 1992 two nests were found. The first, on the 6th of July, was being built. Two birds were watched for two hours on two consecutive days. They were seen to be carrying twigs, stems of dry grass and moss. No eggs were laid in this nest. The second, found on the 26 of July, had one chick of approximately 10-12 days old. Twelve faecal sacs (see NEWTON 1967) were present on the edge of the nest. The first nest was located within a short plantation (< 5 m height) of *Cryptomeria japonica* and the second within *Clethra arborea* and native forest but both were placed on a *C. japonica* tree at about 3 m height. Nests were alike, consisting of an outer layer of twigs of *C. arborea* and *Erica azorica* and an inner layer of rootlets, grass and a few bits of moss.

Although breeding commenced in June a significantly higher proportion of birds started only in July (χ^2=10.06 P<0.001, df=1 with Yates' correction) (Fig. 1). There were positive correlations between the percentage of the breeding population breeding in a particular summer month and food abundance, as indicated by (1) the number of plant species providing food (rs=0.975, P<0.05) and (2) the number of seed heads and fruits in transects (rs=0.8, P<0.10; Fig. 2). This indicates that the Azores bullfinch bred when food abundance was high. The relatively extended time period that females were found with brood patches (Fig. 1) e.g. one captured on

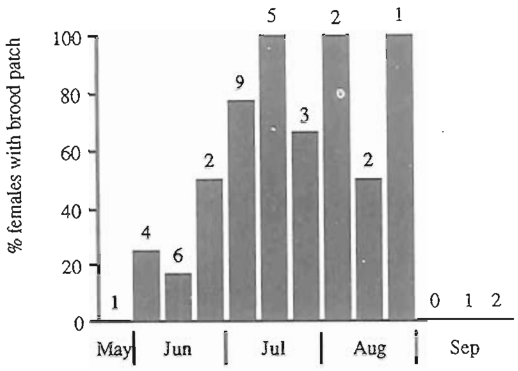

Fig. 1. Seasonal pattern of nesting, shown by the percentage of females with brood patch in 10 day periods. Numbers above bars indicate the total number of females caught. Data from 1991 and 1992 were combined. It should be noted that birds were difficult to sex (see text). This may be important to explain the decrease in the percentage of females with brood patch in July, when, presumably, the whole population should be breeding. Some of these birds could actually be males.

the 10th of June with a brood patch, and again on the 3rd of August still with a brood patch, perhaps suggests a second breeding attempt by some birds. A small proportion of birds could still be breeding in early September, but no adults were caught which verified this (Fig. 1).

The progressive appearance of juveniles into the population (% of juveniles seen during route walks) is shown in figure 3. Juveniles reached 50% of the birds by the last ten days of August in 1991 and by the first ten days of September in 1992. However, this figure could be biased in September owing to the fact that adults, undergoing a full body moult, were probably less likely to be seen than juveniles. Nevertheless, breeding productivity seemed relatively low: about two young per pair.

Adult moulting followed breeding (Fig. 4). Also, two juveniles caught in September were moulting head feathers and, some juveniles were

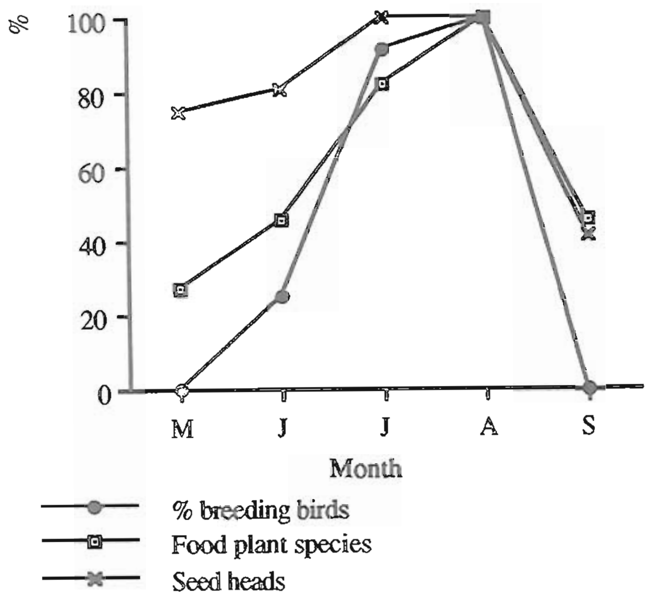

Fig. 2. Relation between the number of breeding birds (% of females with brood patch) and the degree of food abundance (from transect counts). Food abundance is presented as follows: the highest monthly record was given a value of 100% and the rest were scaled accordingly (GRANT & GRANT, 1980).

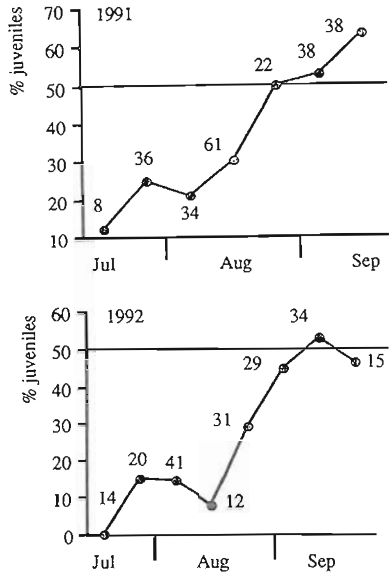

Fig. 3. Proportion of juveniles seen during route walks in 1991 and 1992. Sample sizes are indicated beside the points.

observed from late August to October with partially black caps.

Body weight and fat scores. Overall, the mean monthly weight of Azores bullfinches varied from 29.6 g in August to 31.4 g in January, a difference of 1.8 g (Fig. 5). Average female body weight was higher than average male body-weight in June (mean=31.49, n=10 vs mean=29.58, n=10), July (mean=30.37, n=18 vs mean=28.96, n=17) and August (mean=30.22, n=5 vs mean=28.15, n=2). In June the difference was almost significant (t=2.07, P<0.053, df=18) and in July it was significant (t=2.52, P<0.017, df=33). The monthly winter body weight comparison between males and females is precluded due to very small sample sizes. However, one should expect the weight variations between winter and summer to be less pronounced for females since they were heavier in summer (NEWTON 1966). In fact, when the weights were divided into summer (May-September) and winter (December-April) only males showed a significant difference between seasons (males: t=2.7, P<0.01, df=38; females: t=0.7, NS, df=44). Although seasonal changes in body weight appeared to be small there was considerable diurnal variation: birds caught in winter before 12:00 h were, on average, 1.3 g lighter than birds caught after 14:00 h. Though sample sizes were small, this difference was significant (t=2.75, P<0.02, df=16).

Fat scores higher than two were recorded only twice (Fig. 6). When fat scores were divided into =0 and ≥ 1, winter-birds (December-April) had significantly more fat (P<0.001) than summer-birds (May-October; χ^2=13.78, df=1 with Yates correction; Fig. 6). The correlation between monthly mean fat scores and weights was slight (rs= 0.17, n=10) but when calculated without May and October (in which only two and one birds were captured, respectively) it improved strongly (rs=0.64, P<0.05, n=8). Thus, as

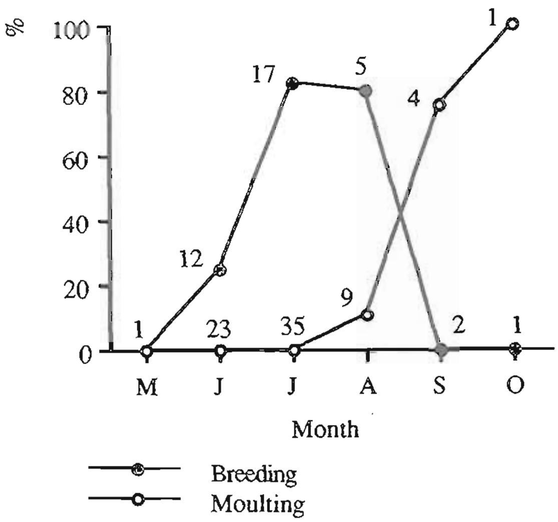

Fig. 4. Monthly comparison between the percentage of breeding and moulting adult birds. Breeding is presented as the percentage of females with brood patch and moulting as the percentage of adults undergoing primary moult. Sample size is indicated beside the points.

expected, increased fat deposits help to explain why birds in winter were heavier.

Mortality and recruitment. A total of 37 and 31 birds were caught in 1991 and 1992, respectively. Of these, only 23 (62%) and 17 (55%) were seen subsequently during the year of capture. The other 14 were presumed mainly transient visitors or unestablished first-year birds (as judged by their greater coverts). Of the 23 birds that were recorded again at least once in 1991, 11 and 4 were known to be alive, respectively in 1992 and 1993, which gives a maximum annual mortality rate of 58% (52% in 1991/92 and 64% in 1992/93). The mortality figure for birds caught in 1992 is 59%. These figures are almost certainly overestimates since it is likely that some settled individuals in the study area escaped being seen. For example, if only two and one more birds were seen, respectively in 1992 and 1993 the mortality rate figure would be 48%. In order to compensate for small sample sizes, also the birds that were not recorded again during their year of capture were considered. Only four were seen in

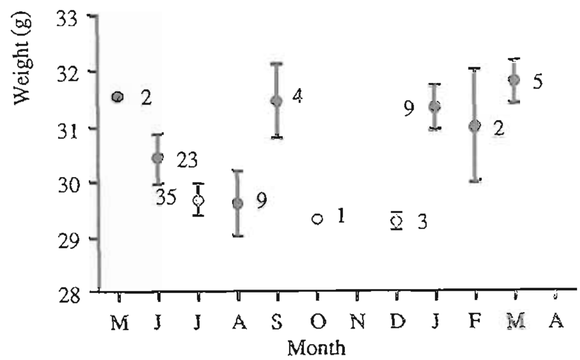

Fig. 5. Seasonal pattern of body-weight, shown by monthly means ± S.E. of birds mist-netted. Sample sizes are indicated beside the points. Data from 1991, 1992 and 1993 were combined.

subsequent years. If these had been seen at a similar rate to the settled individuals, the figures would be seven for 1991 and six for 1992. When calculations are based on the grand totals, the

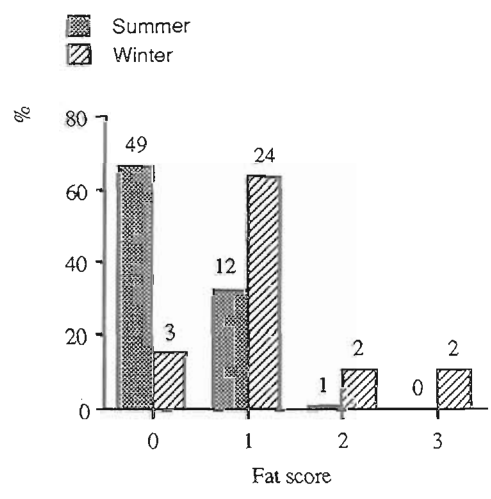

Fig. 6. Comparison between fat scores in summer (May-September) and winter (December-April). Numbers above bars indicate sample size. Data from 1991, 1992 and 1993 were combined.

mortality rate is 51% for 1991 and 58% for 1992. Thus, although accurate mortality rates cannot be calculated, a figure of about 50% was obtained (this fits with the 1:1 ratio of adults: juveniles after breeding; Fig. 3).

In a stable population, the number of juveniles surviving to enter the breeding population can be expected to be similar to adult mortality. Recruitment can be evaluated using the ratio: first years/adult birds, captured before the breeding season. Unfortunately, an accurate figure of recruitment was impossible to determine because some birds were difficult to age (see Methods). In June and July of 1992, 22 birds were captured. Of these, ten to twelve seemed first years which gives a recruitment figure between 45% and 59%. The comparison between this figure and the mortality figure for 1991/92 indicates that the Azores bullfinch population might be stable. However, the sample sizes are too small to draw any firm conclusions.

The proportion of birds ringed as adults in 1991 along the major road that traverses the study area (n=17), which were seen in the winter of 1992, increased from 17.6% in January and 11.8% in February to 41.2% in March and 35.3% in April. Moreover, in 1992, of 11 birds ringed in January/February, five (45.5%) were not seenafter April. Of these, four were first year birds. These results could not be explained by differential emigration of first-year birds, because there was nowhere for them to move to, so it should have been due to mortality. This area had the highest density of *Ilex perado* , which provides the main food in April (RAMOS in press a). A single *I. perado* tree was visited by at least 6 marked birds (of which two were definitely first-years). In addition, aggression between feeding Azores bullfinches was very infrequent (see also WILKINSON 1982) and caused only momentary interruptions of foraging. Field and laboratory observations of feeding birds and radio-tracking to plot home ranges, together suggested that first-year British bullfinches were neither excluded from ash trees (*Fraxinus excelsior*) nor suffered direct interference while feeding (GREIG-SMITH 1985). Because first-years had less ash seeds in their gut contents and were less efficient in dealing with ash seeds than adults, GREIG-SMITH (1985) attributed their poor winter survival mainly to relative incompetence in foraging.

Group size. Direct records of the Azores bullfinch group sizes showed that the median group size was always one or two and that there was little monthly change (Fig. 7). This shows that most individuals foraged independently or in pairs. In May and June the proportion of birds seen in pairs was significantly higher than the proportion of birds seen singly (χ^2=7.5 and 10.5, P<0.01, df=1 with Yates' correction), whereas in July and August, the majority of the birds were seen singly, but only in August was this significant (χ^2=5.3, P<0.05, df=1 with Yates correction). This suggests that in May and June birds were pairing up, and in August most females were incubating. There was a very slight tendency for larger groups (> 4 birds) to be encountered in May/June and November. The largest group of birds (n=8) was seen in May at about 340 m of altitude, when seeds were very rare at high altitudes. In August and September most groups larger than two consisted solely of juveniles. This possibly applies to November as well.

DISCUSSION

Despite showing strong preferences for native vegetation, (BIBBY & CHARLTON 1991, RAMOS 1993) the two nests of the Azores bullfinch that were located, were in *C. japonica*. At present there is no evidence to suggest that the Azores bullfinch should be specialized in terms of nest site selection. Both native and exotic forests provide an enormous amount of cover and predators were not common in the study area. Nonetheless, a few cats were present at low altitudes and head, wings and leg remains of an individual were found at a *P. capitatum* patch; the bird was presumably killed by a cat. NEWTON (1964a) and BIJLSMA (1982) studied the breeding

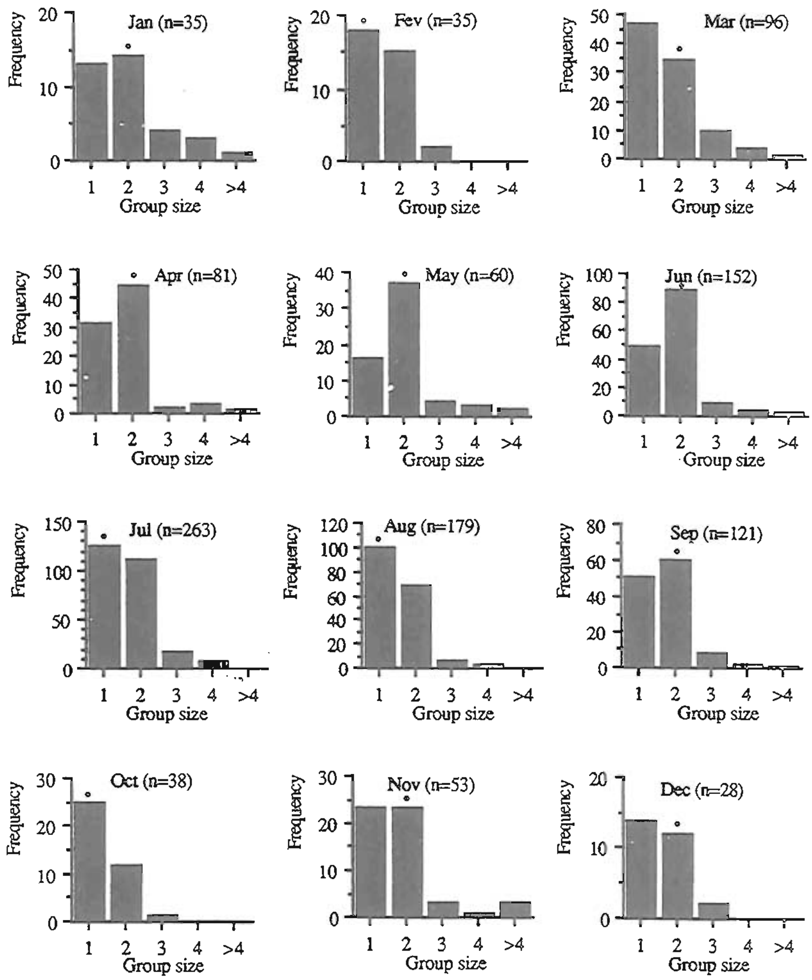

Fig. 7. Monthly distribution of Priolo group sizes observed within the study area between April 1991 and May 1993. Dots indicate monthly median group sizes.

of bullfinches in England and Holland, respectively, and do not report specialization in the choice of nest sites.

The decrease in the number of singletons and increased frequency of pairs in late spring and early summer can readily be explained by birds pairing up prior to the breeding season (WILKINSON 1982). Breeding was highly seasonal and occurred when food abundance was high. The breeding season was considerably later (mid June/August: May/August) and shorter than that of European (but not Northern) bullfinches (2 to 2, 5 months: 3 to 3, 5 months). Breeding in early summer may be advantageous because young fledge and disperse when fleshy fruits, a highly preferred food (RAMOS in press a) are abundant (LACK 1966). In September and October, all birds observed above Furnas, approximately 7 - 10 km from the main core of native vegetation, were juveniles feeding on fleshy fruits (*Leicesteria formosa)*. Also, the availability of protein may have an important role in enabling females to come into breeding condition (PERRINS 1970) and to feed young (NEWTON 1967). Nymphs of *Hemiptera* emerging on leaves of *Laurus azorica* are taken from May to July (RAMOS in press a) and represent a readily available source of protein.

Significantly higher female than male weights at this time may reflect a marked period of ovary action and egg formation (NEWTON 1966b).

Breeding and moulting were strongly seasonal but variations in weights and fat scores between summer and winter were slight. Winter birds were, on average, just 1.8 g heavier. This value is quite small when compared with the 4 to 5 g difference between summer and winter for the slightly smaller bullfinches in England (NEWTON 1966b, GREIG-SMITH & WILSON 1984). The slight seasonal changes in body-weight and fat scores of the Azores bullfinch more closely resemble those of tropical birds (WARD 1969a, 1969b, FODGEN 1972). These subtle changes are difficult to follow meaningfully by plotting mean weights of small samples (WARD 1969a). Similar diurnal changes in body weight to those of the Azores bullfinch have been documented for tropical birds (WARD 1969a). These variations could be caused by changes in fat, water, protein or the amount of food in the gut (WARD 1969a). British bullfinches caught in the evening were, on average, just over 1 g heavier than those caught in the early morning (NEWTON 1969).

Both Azores bullfinches (this study) and British bullfinches (NEWTON 1969) are heavier in the winter due to accumulation of fat. Winter nights in Britain are much longer and colder than those in the Azores, which may largely explain the higher winter fat scores of British bullfinches. The ability to accumulate sufficient fat each day, as an overnight energy source, critically affects survival (NEWTON 1969). Similarly, in less seasonal environments, most of the fat that birds deposit during the day is needed for overnight metabolism (WARD 1969a, 1969b).

Higher mortality rates in 1992/93 than in 1991/92 are presumably a result of a later availability of large flower buds of *I. perado* and *P. capitatum* seeds in 1993, which are very important food supplies in March and May/June, respectively (RAMOS in press a). Also, alternative foods (fern fronds) presented higher consumption indices in 1993 (RAMOS in press b).

Some evidence was found for higher juvenile than adult mortality in late winter. This is common in many species e.g. the Great tit, *Parus major*, (KREBS & PERRINS 1978). British national ringing recoveries also suggest highest bullfinch mortality in late winter (FLEGG 1980) although NEWTON (1964b) recorded heavy mortality from October to December in Wytham woods, Oxford. BIBBY (1974) estimated that about 50% of British bullfinches die each year, which is similar to the values obtained in this study.

Overall, the Azores bullfinch presents a strong seasonal pattern similar to that of western European bullfinches. There appeared to be slight variations upon this pattern, e.g. the slight variations in weight and fat, which could be an environmental correlate of a temperate oceanic island. Comparisons with the annual cycle of passerines of other North Atlantic islands may reveal further interesting points but, at present, no data are available. The phenology of most native plants of the montane forest was highly seasonal (a few individuals of certain species had two flowering periods in some areas), meaning that there would be no scope for a different annual cycle pattern.

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