

## Introduction

Bird migration is one of the most fascinating of all natural events. Yet, migration implies great risks and places huge energetic demands on birds (Sillet & Holmes, 2002; Newton, 2008). As well, in spring birds have to race to reach their breeding grounds as soon as possible in order to establish territories and find a mate (Alerstam, 1990), all of which makes their return journeys demanding in many senses. Furthermore, after wintering in sub-Saharan Africa, long-distance Palearctic migrants face a particularly difficult task since they have to cross two large geographical barriers in quick succession, the Sahara desert and the Mediterranean Sea.

The Sahara is the largest desert in the world and stretches in a 2,000-km wide north-south strip from the Atlantic coast to the Arabian Peninsula. Despite being mostly devoid of vegetation, this vast area is crossed by over two billion birds twice a year (Moreau, 1972; Hahn et al., 2009), some on direct/non-stop flights and others on intermittent flights during which time they may or may not stop to feed (Biebach et al., 2000; Schmaljohann et al., 2007a). Moreover, in spring the difficulty of crossing the Sahara is further compounded by the headwinds that blow at this time of year (Moreau, 1972). Nevertheless, due to winter rains, once in North Africa birds may benefit from better stopover conditions in spring than in autumn (Moreau, 1972; Alerstam, 1990), although shortly afterwards migrants will be faced with the challenge of crossing the Mediterranean Sea. Distances between the northern and southern shores range from c. 20 km across the Straits of Gibraltar to 600–1,000 km across most other parts of this sea. At first glance, the Mediterranean may seem less of an overwhelming geographical barrier than the Sahara, but for the vast majority of migrants landing in the sea means certain death.

Crossing large barriers such as the Sahara desert and the Mediterranean sea entails endurance flights which require large amounts of energy, potential challenges for orientation and drift-compensation (Spina, 2011). Furthermore, in these circumstances adverse weather can also lead to the mass mortality of migrants (Newton, 2008). However, given that birds spend about 90% of their time during migration at stopover sites, in many cases trying to replenish their fuel reserves (Hedenström & Alerstam, 1997; Lindström, 2003), the distribution

and quality of stopover areas are probably the most important factors shaping bird migration strategies. During spring, it is well known that most migrants fatten up in the Sahel just south of the Sahara or, to a lesser extent, in wintering or staging areas situated even further to the south (Zwarts et al., 2009; Ottoson et al., 2005). These pre-migratory fattening-up sites are crucial for spring migrants, although the fuel reserves that birds manage to amass there may not be sufficient for crossing the Sahara desert and reaching Europe. Birds may have to refuel in N Africa (Ash, 1969; Rguibi-Idrissi et al., 2003; Maggini & Bairlein, 2011), above all because, once in this region, most birds still have to cross the Mediterranean. Unfortunately, the role of North Africa as a staging-post for spring migrants is still poorly known and, similarly, in general many questions regarding spring migration across the Mediterranean sea remain unsolved.

In 1988 the Italian Bird Ringing Centre launched the *Piccole Isole* project (small islands project, PPI) aimed at understanding the different strategies employed by birds crossing the Mediterranean during their return journeys to Europe. Traditionally, autumn migration had always been well-studied in Europe and by the 1980s very little attention was paid to birds' northward journeys, particularly in the Mediterranean basin (Spina et al., 1993). The *Piccole Isole* project started as a national scheme involving ringing sites on four Tyrrhenian islands (Montecristo, Giannutri, Ventotene and Capri). However, soon afterwards, it increased its geographical scope with the inclusion of ringing sites in the western and eastern Mediterranean and an increase in the number of sites in Italy itself and in nearby areas such as Malta, Corsica and Sardinia. Initially, ringing sites mostly operated during the so-called 'standard period' (April 16–May 15), but subsequently some sites extended this period to 90 days to cover nearly the whole spring migration season (March–May). Nowadays, the project embraces almost 50 ringing sites, on both islands and the mainland, above all in coastal areas. It has spread to seven countries and mobilizes hundreds of ringers every year, thereby ensuring its status as one of the largest ringing projects in the world in terms of geographical coverage, years of operation (24 to date) and the quantity and quality of data obtained (more than a million birds ringed).

Bird ringing has played a crucial part in our understanding of bird migration and bird movements in general (Alerstam, 1990; Berthold, 1996). However, the key to the *Piccole Isole* project was the creation of a network of ringing stations that operate at the same time with the same methodological protocols across a large geographical area, thereby offering a unique opportunity for unravelling complex migratory patterns (Berthold et al., 1991; Spina, 2011). Thanks to this approach, the *Piccole Isole* project has greatly improved our knowledge of bird migration in the Mediterranean, particularly regarding the description of migratory routes, the differential migration of sex- and age-classes, the use of fuel reserves, the effects of weather and the stopover behaviour of birds staging on islands (*cf.* Spina, 2011). However, more importantly still, this network of ringing stations has proved its ability to provide a sound scientific basis for regional conservation policies, so vital in an area under such great pressure from hunting and tourism (Hepburn, 1985; Fenech 1992; Hoballah, 1996).

Since the first *Piccole Isole* sites started to operate in the western Mediterranean in 1992 the project has expanded so that nowadays the data obtained here and in the central Mediterranean form the bulk of the project. Moreover, the addition of a number of ringing stations from Morocco to the excellent coverage of the western Mediterranean (largely due to the number of sites operating constantly in the Balearic Islands and Els Columbrets, as well as in Catalonia in continental NE Spain) has given further value to the whole dataset. This has enabled us for the first time to study bird migration simultaneously right across the Mediterranean basin, not only in the areas from where migrants originate (NW Africa), but also in areas where birds stop while sea-crossing (insular sites) or while following less energetically demanding continental routes (coastal NE Spain). The purpose of this monograph is the presentation of the main results of this study in a synthesis of the first 16 years of operation of the *Piccole isole* project in the western Mediterranean and NW Africa.