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Green Roofs as a Habitat for Birds: A Review

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Abstract: Green roofs are a technology with a long tradition however, today are considered one of the most innovative developments for urban greening and constitute an opportunity for creating additional habitat for birds in the cities. Green roofs provide water and food mainly throughout insects, berries and seeds for feeding birds. Also provide space and cover that protect birds and their nests from predators. However, not all green roofs have the same ecological valueor equally favour the breeding of birds. It depends on the type of green roof, design, selected vegetation and maintenance. This encourages bird presence including of endangered species that permits urban people to obtain benefits such as aesthetic and psychological, ecological and some utilitarian ones. Conversely at the same time birds can damage plants that vegetate on green roofs especially in its establishment phase when the vegetated structure is more fragile or more rarely can act as disease reservoirs or cause accidents, e.g., in the airport environments. Despite the worldwide increasing wide spread of green roofs in the last decades until now little attention has been paid to bird populations in relation to this kind of urban greening and few specific studies have been undertaken. This study carries out a broad review on green roofs as a habitat for birds in the urban environments and proposes a standardised methodology aimed at studying bird population on green roofs.

Key words: Birds, habitat, biodiversity, green roof, animal sciences, urban greening, landscape

INTRODUCTION

A green roof is a green space created on top of a traditional roofing system by adding layers of growing medium and plants over a waterproofing membrane (Peck and Kuhn, 2002; Wikipedia, 2009). Green roofs are not a recent invention but an old technological development, heritage of the vernacular architecture in many regions of the planet. Their use is known for centuries, no doubt thanks to the excellent insulating quality that the combination of growing plants on a layer of some type of substrate gives to the roof of the buildings (Fernandez-Canero and Emilsson, 2008). Examples of its use in countries can be find with extreme climates as both in the cold Iceland and in the extremely warm Tanzania (Peck and Kuhn, 2002; Emilsson, 2005). During the Middle Ages green roofs were established in some Benedictine monasteries (Getter and Rowe, 2006).

Thanks to the modernist movement green roofs resurfaced in the early twentieth century. As the architect Le Corbusier expounded (Peck and Kuhn, 2002) invention and widespread use of horizontal roofs represented for the town's people a new horizon of possibilities to enjoy a new space outside the home, regardless of their economic status (Werthmann, 2007). Also the famous architect Frank Lloyd Wright, father of the green architecture used green roofs in his projects as a tool to help integrate the buildings into the landscape (Peck and Kuhn, 2002).

After the Second World War, many European countries like Switzerland, Germany and Austria, embarked on a campaign to rebuild their cities using green roofs in many new buildings. Those modern green roofs already were beginning to resemble the current structures.

Nevertheless in the last decades of the 20th century green roofs have been gaining increasing importance, thanks, no doubt to the growing concern about the urban environment and to the acknowledgement of the many benefits that they provide. In this context, emphasizes the role of leadership achieved by Germany as the pioneer country that has developed most of the technology currently in use worldwide (Werthmann, 2007).

Currently, the standards for green roof technology are well defined at international level and it derived primarily from the guidelines published in Germany for over 25 years (Philippi, 2005). The different green roofs systems are usually grouped into two categories, extensive and intensive green roofs.

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Extensive green roofs are characterized by being constituted with a thin layer of substrate whose thickness can vary between 3 and 25 cm (FLL, 2002). They need a low maintenance. The plants used are often slow-growing succulents like the members of the *Sedum* genus and others similar species from the Crassulacea family. The species should be chosen carefully to ensure their long-term survival especially considering that in this type of green roofs the only source of water is rainfall.

Intensive green roofs are characterized by increased thickness in the layer of substrate of 15 cm or more (FLL, 2002). This high maintenance vegetation system enables the establishment of a wide variety of plants including small trees. The cost of installing and maintaining this type of roofing is much higher than the extensive system. Intensive green roofs are similar to any other traditional garden and typically include irrigation system whose design will vary depending on the characteristics of the vegetation.

Germany is also an example of what can be achieved with proper planning and public promotion of green roofs. In 2001 it was estimated that around 14% of all German roofs (13.5 million m^2) had been greened (Snodgrass and Snodgrass, 2006). Worldwide an ever increasing number of countries are incorporating green roofs into their official plans and policies.

The research on green roofs began in the middle of last century; since them the list of benefits (Table 1) that entails its use has grown considerably. Some of these benefits have more notoriety when a lot of cities are addressing new ways for urban planning and development to improve the environmental conditions with objectives that include the search for sustainability and the mitigation of climate change.

There is not much information about birds using green roofs. However, in the last years have been published some interesting researches about the fauna in the green roofs. One of the most important studies was by Brenneisen (2001). He studied the birds, beetles and spiders associated with green roofs in Switzerland (Grant *et al*., 2003). Another interesting research is from Dunnett and Kingsbury (2004). These researchers do stress upon the importance of design in the level of biodiversity generated by green roofs.

Successful development of bird populations is increasingly constrained in the urban environment. Taking into account that green roofs provide additional habitatis of interest to study how urban greening can improve biodiversity in the cities. Therefore, the aim of this study is to carry out a broad review of the status of the knowledge related to green roofs as habitat for birds. It also wishes to propose a methodology for studying bird populations on green roofs.

HABITAT COMPONENTS OF THE GREEN ROOFS FOR BIRDS

It is a challenge to populate green roofs not only with plants but also with insects, birds and other animals. Particularly, remains unclear which birds will be able to successfully adapt to rooftop habitats because while some green roofs are inhabited by birds it is not yet clear which particular species are likely to thrive in these extreme environments and at the same time which will be beneficial to these ecosystems (Luckett, 2009). As Shaw (1985) stated, most birdlife management is habitat management. Thus, any management objective of increasing the carrying capacity of the green roofs for birds can be met largely by maintaining proper habitat conditions. The four basic components of habitat which are food, cover, waterand space (Shaw, 1985) are analysed below in relation to the presence and carrying capacity of birds in the green roofs.

Food: Availability of food is the most important component of habitat (Shaw, 1985). Green roofs are one of the most important ways to restore habitat for invertebrates (Cantor, 2008) and are usually colonized by numerous insects including spiders, beetles, ants, bugs, fliesand bees. In turns these sites attract predators like birds, bats, mammalsand reptiles. In this way it contributes to increase the availability of food for birds (Diekelman, 2009).

Table 1: Potential benefits of green roof infrastructure to the private and public sectors (Peck and Kuhn, 2002; TRCA, 2007)

Building owner benefits	Public benefits
Energy savings	Urban heat island effect mitigation
Satisfaction of a portion of stormwater policy requirements	Storm water retention
Roof membrane protection and life extension	Improved stormwater runoff quality
Sound insulation	Reduced emissions of greenhouse gases
Fire resistance	Air cleaning
Improved public relations	Creation of habitat
Provide added amenity space for the occupants (Accessible green roofs)	Biodiversity enhancement
Food production (agriculture)	

Some researches show that the main reason for birds visiting the green roofs was to look for food. Green roofs in the suburbs, placed closer to agricultural land were less frequently visited and used by birds than in the city. Apparently, the need of green spaces and food in the densely built-up areas resulted in more frequent use of the new habitats in the roofs (Dunnett and Kingsbury, 2004).

One of the most significant studies of the biodiversity value of green roofs has been developed in Basel, Switzerland. Seventeen green roofs were monitored including turf roofs, sedum roofs and specially designed roofs which landscape surfaces. The researches monitored invertebrates as indicators of vegetation structureand they also studies bird activity on the roofs. Bird species that relied on the roof's plants or animal species came frequently but those whose food supply was not present even if those birds were quite common in the city did not alight on the green roofs (Cantor, 2008).

Also the seeds and fruits of the plants of the roof can attract birds. For examplein a green roof located on top of a private house called Shaw's Cottages in London (UK) it was observed that the apple trees overhang the roof and fallen apples on the flat sections attract blackbirds (*Turdus merula*) and other birds (Grant *et al*., 2003).

Cover: Cover is any variation in the habitat that provides protection from weather or predatorsor that offers a better vantage point (Shaw, 1985). A common use of cover of particular importance for birdsis escape from predators. Nesting and roosting cover can also be critical for many species of birds to establish on green roofs. In this sense, some researches suggest that urbanization can decrease nest predation (Gering and Blair, 1999) something that made gardens and therefore, green roofs, suitable habitat for birds.

Clearly, a habitat function of green roofs is the provision of nesting sites for nesting birds (Brenneisen, 2006). Cover may also furnish important protection against severe weather, providing shade from the heat, relief from wind and precipitationor protection against radiant heat loss to a cold night sky. Many bird species use certain types for resting during periods of inactivity, something that has been described as loafing cover.

A wide range of bird species has nested successfully on urban roofs whether conventional or greened (Fig. 1). These are bird species usually favoured by the cliff habitatsor open grassy or stony habitats in the wild (Dunnett and Kingsbury, 2004) as is the case of some ground-nesting birds (Baumann, 2006). Roofs and other building surfaces do not need to be

Fig. 1: Green roof located in Scotland where it can be seen a nest built with gravel by an oystercatcher (*Haematopus* sp.) (Haslam, 2007). Creative Commons Licensed by John Haslam

intentionally planted to favour plant growth or nesting birds (Dunnett and Kingsbury, 2004). However, some researcher such as Cantor (2008), compare the properties of conventional roofs and green roofs and indicate that the latter are better habitats for insect and birds mainly due to the cover offered by plants. Particularly, dense small tree and shrub plantings, native or not can provide cover for nesting songbirds (Grant, 2006).

Green roof typology also influences availability of cover for birds. Because most extensive green roofs are inaccessible to the public, they can provide undisturbed habitat for birds (Getter and Rowe, 2006).

Although, it is obvious that the provision of habitats by green roofs is a poor substitute for the loss of natural habitats by creating green roof space there are increased opportunities to create additional refuge for bird life (Hung *et al*., 2006). In fact, even in densely populated urban areas, green roofs can attract birds which were found to have come back to the cities and towns after construction of green roofs on previously disturbed areas (Velazquez, 2005). For this reasonand as analysed below, some projects of brown and green roofs are specifically developed to create protective habitats on the roofs for bird species of interest (Cantor, 2008).

Water: Most bird species replenish body water by drinking surface water (Shaw, 1985). This accessible water is only available on green roofs especially in these intensive when are built with ponds, fountains and similar structures (Osmundson, 1999). Depending on the weather conditions of the area and green roof features, if nature does not provide enough rainfall to support the green roof plants then it is necessary to provide water through supplemental irrigation (Luckett, 2009). This remaining water from the irrigation system on the green roof is another important source for birds. When surface water is

not available, some birds can sustain themselves by drinking dew or by ingesting the water contained in succulent plants (Shaw, 1985) that are usually used in green roofs, e.g. sedum (Baumann, 2006; Brenneisen, 2006) eaten by oriole finches (*Linurgus olivaceus*) (Beesley, 1972).

If an increase in the bird population on green roofs is desired, waterers can also be installed as carried out in many conventional gardens (Gaston *et al*., 2005). Recommendations for creating habitat for some bird species on green roofs might include their being designed with water-retaining substrates (Baumann, 2006). Water can also affect birdlife on green roofs indirectly through changes in the habitat, mainly because plant growth and productivity can be markedly modulated by irrigation and rain. This is of particular importance due to the fact that plants provide birds with cover and food. Another related issue is that the quality of water collected on green roofs could affect birds' health and survival, although each particular green roof must be studied because in many cases water could be contaminated with phosphorus (Moran *et al*., 2004) or heavy metals (Berndtsson *et al*., 2006). Despite water importance, there is little data on this topic (Baumann, 2006) and no specific studies have been conducted on how water on green roofs affects or can be specifically managed with regard to bird populations. In fact, there is no agreement on whether water sources on green roofs are always necessary because even when there was not any water source, some birds have been successfully in breeding, e.g. northern lapwing (*Vanellus vanellus*) (Baumann, 2006). Clearly, its importance largely depends on the ecology of the species in question.

Space: Individual birds require varying amounts of space in which to find adequate water, food, coverand to locate mates. Populations of birds require even more space (Shaw, 1985) and the question naturally arises as to how much space is enough on green roofs to maintain viable and permanent populations and communities of birds (Taylor, 2008). In each case, the amount of space or suitable habitat depends upon the size of the population. This population size depends in turn, upon the size of the species, its dietand the productivity and diversity of the green roof habitat in relation to the habitat requirements of the species (Shaw, 1985). Clearly, many cases there are in which green roofs of a sufficient large size provide habitat for birds (Hake, 2007).

Each green roof is of a limited and relatively reduced area, thus acting as a fragmented habitat, mainly in the urban areas where many times structures adjacent to the green roof are inaccessible or not suitable habitats for some bird species. Moreover, other limiting factor for birds to colonise green roofs is access to the roofs (Taylor, 2008).

In fact, many species documented on green roofs largely depend on the height of the building (Hake, 2007). For this reason, living walks can also be used to link green roofs to the ground to create a green corridor that provides habitat for birds, insects and small lizards and help them to colonise the green roofs (Taylor, 2008).

Another important function of the green roofs in the urban environments is the formation of patch work stepping zone ecosystems which serve to reverse fragmentation of ecosystems that follows urbanization by offering temporary habitats to birds during their long migrations (Nowak, 2004). In this sense, working is needed to plot the migratory pattern of birds through the cities in order to target developments on the migratory path as green roofs refuges (Taylor, 2008).

The birds using a green roof tend to be highly mobile, not only because they have to be able to reach the roof but because the varying and intense temperature and moisture levels force them to move from one location to another (Peck *et al*., 1999).

In this sensein addition to the sheer space available on green roofs is also of importance the structural diversity and spatial distribution of plants and elements of the green roof. This is due to the fact that the biggest components that define suitable bird habitat are usable space and interspersion of habitat types.

Habitat area requirements and home range of many bird species in the wild are well-known. However, it remains to be investigated how much space is sufficient when these species populate green roofs. Therefore, the area of habitat needed by individual species for colonization becomes the central issue (Brenneisen, 2006).

BIRD'S USE OF GREEN ROOFS

Recently many studies have documented bird communities on a variety of green roof typesin several countries around the world (Oberndorfer *et al*., 2007).

Green roofs are used to some extent by nesting birds and native avian communities (Baumann, 2006; Oberndorfer *et al*., 2007) belonging to numerous species. Few bird species, however are able to successfully breed on green roofsand few studies have been undertaken on their potential for providing nesting locations, particularly for ground-nesting species (Baumann, 2006). Table 2 shows a recompilation of the main bird species whose breeding on green roofs has been confirmed.

Table 2: Main bird species that have been reported to breed on green roofs

Species	Location	Source
Blackbird (*Turdus merula*)	Sweden	Ohlsson (2001, 2002)
Black redstart (*Phoenicurus ochruros*)	England (UK)	Gedge and Kadas (2005), Pledge (2005), Brenneisen (2006)
Blue tit (*Parus caeruleus*)	Sweden	Ohlsson (2001, 2002)
Canada goose (*Branta canadensis*)	Canada	Bailly and Sbwoodside (2007)
Carrion crow (*Corvus corone*)	Sweden	Ohlsson (2001, 2002)
Chaffinch (*Fringilla coelebs*)	Sweden	Ohlsson (2002)
City dove (*Columba livia*)	Sweden	Ohlsson (2001, 2002)
Common gull (*Larus canus*)	Sweden	Ohlsson (2002)
Common tern (*Sterna hirundo*)	Switzerland	Brenneisen (2000)
Crested lark (*Galerida cristata*)	Switzerland	Brenneisen (2000)
Falcon (*Falco* sp.)	Belgium	Peck *et al.* (1999)
Great tit (*Parus major*)	Sweden	Ohlsson (2001, 2002)
Greenfinch (*Carduelis chloris*)	Switzerland	Brenneisen (2000)
	Sweden	Ohlsson (2001, 2002)
House sparrow (*Passer domesticus*)	England (UK)	Brenneisen (2004)
	Switzerland	Burgess (2004)
	Sweden	Ohlsson (2001, 2002)
Killdeer (*Charadrius vociferus*)	United States	Snodgrass and Snodgrass (2006), Swearingin *et al.* (2008)
Lapwing (*Vanellus vanellus*)	Germany	Brenneisen (2001)
	Switzerland	Brenneisen (2000, 2001), Baumann (2006)
Little ringed plover (*Charadrius dubius*)	Germany	Brenneisen (2001)
	Switzerland	Brenneisen (2000, 2001), Baumann (2006)
	England (UK)	Burgess (2004)
Mallard (*Anas platyrhynchos*)	England (UK)	Johnston and Newton (2004)
Magpie (*Pica pica*)	Sweden	Ohlsson (2001, 2002)
Meadow pipit (*Anthus pratensis*)	Switzerland	Brenneisen (2000)
Oystercatcher (*Haematopus ostralegus*)	Scotland (UK)	Duncan *et al.* (2001), Haslam (2007)
	Germany	Gedge and Frith (2004)
Ringed plover (*Charadrius hiaticula*)	England (UK)	Burgess (2004)
Skylark (*Alauda arvensis*)	Germany	Brenneisen (2001)
	Switzerland	Brenneisen (2001)
	England (UK)	Gedge and Kadas (2005)
Spotted flycatcher (*Muscipapa striata*)	Sweden	Ohlsson (2002)
Tree sparrow (*Passer montanus*)	Sweden	Ohlsson (2001, 2002)
Wheatear (*Oenanthe oenanthe*)	Switzerland	Brenneisen (2000)
White wagtail (*Motacilla alba*)	Sweden	Ohlsson (2001, 2002)
Willow warbler (*Phylloscopus trochilus*)	Sweden	Ohlsson (2001, 2002)
Wood pigeon (Columba palumbus)	Sweden	Ohlsson (2001, 2002)

Documented cases of use: In general terms, many investigations have demonstrated that generic green roofs provide habitat for more common bird species while roofs specifically designed to mimic habitats within the urban area will benefit uncommonand frequently endangered, species (Gedge *et al*., 2008).

A well documented case of how birds use a green roof is located in Lancashire (UK): the grass roof on the visitor centre at the Wildfowl and Wetland Trust reserve at Martin Mere. Mallards regularly breed on this particular green roof. Mallards (*Anas platyrhynchos*), skylarks (*Alauda arvensis*) and various finches and thrushes have all used the green roof. Other species, however have not nested, probably due to the disturbance caused by the occupants in the rooms below (Johnston and Newton, 2004).

Another example is the green roof of the Ford Motor Company's River Rouge Assembly Plant in Dearborn, Michigan (USA) where two species have been found using it: olive-sided fly catcher (*Contopus cooperi*) and killdeer (*Charadrius vociferus*) (Coffman and Davis, 2005). Similarly, several bird speciesincluding a falcon (*Falco* sp.), regularly alight and even nest on the Ecover factory green roof in Belgium (Peck *et al*., 1999).

Large-scale green roofs have been implemented at O'Hare International Airport at Chicago (USA) and have attracted birdlife. Most of the birds using these green roofs were killdeer, European starlings (*Sturnus vulgaris*) and mourning doves (*Zenaida macroura*). Killdeer nested on green roof whereas the other species were perched or loafing (Swearingin *et al*., 2008).

Hummingbirds, blue jays (*Cyanocitta cristata*), crows (*Corvus* sp.), swallows, pigeons (*Columba* sp.), sparrows (*Passer* sp.) and signs of hawks or owls have been observed on green roofs of the city of Portland (Oregon, USA) (Liptan and Strecker, 2003). Brenneisen (2000) reported 25 bird species on several green roofs in Switzerland. Up to 26 bird species have been monitored at the Augustenborg Botanical Roof Garden in Malmo (Sweden) that is the world's first botanical roof garden and that is located atop the Scandinavian Green Roof Institute. Fifteen of these species successfully nest on the green roofs (Ohlsson, 2002).

Green roofs designed to create habitats for birds: In addition to the previous examples of bird use of green roofs, there are several cases in which this kind of urban greening has been specifically implemented in order for providing habitat for birds. Some projects of brown and green roofs are developed to create protective habitats on the roofs for bird species of interest (Cantor, 2008).

The most emblematic case is that of the black redstart (*Phoenicurus ochruros*) that is one of the species for whichin England it is developing a specifically designed green roofs called eco roofs which provide habitat in densely built-up areas for endangered bird species (Snodgrass and Snodgrass, 2006). The black restart is rare in the United Kingdom. There are only between 50 and 100 breeding pairs that are fully protected, although his habitat, restricted to industrial and post-industrial sites in several British citiesis not (Dunnett and Kingsbury, 2004; Grant, 2006). A Species Action Plan identified green roofs as the potential solution to replacement habitat in the breeding localities of this species. Green roofs were designed to mimic the conditions found on the derelict sites favouring the black redstart. The built and planned green roofs designed to benefit black redstart are estimated in 15,000 m^2 (Grant, 2006).

A second well-know example of green roof specifically implemented for attracting birds is one of the City Hall Plots in Toronto (Canada): The Bird and Butterfly Meadow, designed to attract birds and butterflies and to illustrate people on the potential to create new habitat with green roofs (Nowak, 2004). This rooftop garden was specifically designed to attract a wide variety of bird and butterfly species and was a unique opportunity to create new habitat in an urban centre. In order for attracting birds, the plant species used in these plots were Western Ontario natives from Toronto. They include eastern columbine (*Aquilegia canadensis*), bottlebrush grass (*Elymus hystrix*), grey headed coneflower (*Ratibida pinnata*), New Jersey tea (*Ceanothus americanus*) and winecup (*Callirhoe involucrata*) (The Green Roof Infrastructure Monitor, 2001).

The project of green roofs at University Hospital of Basel (Switzerland) has demonstrated the possibility of creating new habitats for migratory species and species that suffered the loss of their habitat (Pledge, 2005).

Baumann, a researcher from Zurich University of Applied Sciences in Wädenswill (Switzerland) had studied a variety of five flat-roofed green roof projects in different regions of Switzerland to identify appropriate habitats for endangered bird species. Three ground-nesting bird species of Switzerland, the skylark, the northern lapwing and the little ringed plover (*Charadrius dubius*), have been affected by urban development but have been observed on green roofs. Even though each of these species has slightly different habitat requirements in terms of food supply, nesting and breeding, both of these habitats could be recreated on green roofs (Cantor, 2008). As part of a project at Zurich University of Applied Sciences in Wädenswill, several green roof locations with possible breeding pairs of northern lapwing and little ringed plover are being studied. The investigations are focusing on how breeding takes its course in the roofs whether chicks can surviveand when necessary, how changes in the design of flat roofs can improve breeding success (Baumann, 2006; Brenneisen, 2006).

Over again in Switzerland, a gravel roof where several nests of northern lapwing were usually located was greened in 2007 in order to provide more habitats for the birds, who responded by increasing in the number of the nests (Cantor, 2008).

More examples of birds use and breeding on green roofs can be found in the literature, particularly with regard to ground-nesting birds (Brenneisen, 2001). Few long-term investigations on how a brood develops on flat roofs or whether flat roofs can actually sustain these bird species has been completed. However, on the light of the studies already undertaken it can be stated that consistent, extensive greening clearly leads to significant improvements for birds (Brenneisen, 2001).

It can be concluded that a wide variety of bird species can be attracted to nest on green roofs. Interventions that can enhance bird use and breeding on green roofs consist in providing cover, water and food sources. Food can be provided either directly in the form of berries or indirectly by means of encouraging insects and other invertebrates. Moreover, additional food sources can be supplied using bird tables and feeders (Johnston and Newton, 2004) on the green roof.

Measures to promote bird nesting on green roofs: As birds need nesting placesand taking into account that in many green roofs nest sites will be insufficient or non-existent, artificial nest sites must be provided (Johnston and Newton, 2004).

A wide range of artificial structures has been used to provide nest sites for birds (Fig. 2). Main nest types are: open-fronted boxes, chimney type nest boxes, hole-entrance boxesand hole-entrance boxes with cup shape (Johnston and Newton, 2004). Each type must be chosen according to the nesting requirements and

Fig. 2: Augustenborg´s Botanical Roof Garden. Roof with several bird boxes

behaviour of the bird species to be favoured. Nest boxes must be sheltered from prevailing wind, rain and strong sunlight and preferably placed in a position facing any direction between north and south east to avoid hot sun (Johnston and Newton, 2004). Nest boxes can be installed on poles among the plants and on walls (Millett, 2004). Ground-nesting birds, whose breeding on green roofs has been reported (Baumann, 2006) can be favoured if the opportunity to nest amongst the vegetation (Gedge *et al*., 2008) is provided.

Some bird species, e.g., the house wren (*Troglodytes aedon*) would make a good bioindicator species for the green roofs if it nests because this confirms that this particular habitat draws and holds (Millett, 2004).

Other measures may also favour the bird breeding on the roofs: planting species with fruits and seeds of interest for the birds, putting drinking trough or other water elements and encouraging the presence of insects in turn attracts birds.

VALUES OF THE BIRD POPULATIONS LIVING ON THE GREEN ROOFS

Wildlife values can be classified, according to Shaw (1985) in positive (aesthetic, recreational, ecological, educational and scientific, utilitarianand commercial) and negative (accidents, crop and livestock damage and disease reservoir) ones.

Aesthetic and recreational: Birds on green roofs help to enhance aesthetic and psychological benefits for people in urban areas provided by the green roofs (Oberndorfer *et al*., 2007), thus contributing to maintain a pleasant living environment. Birdlife on green roofs offers aesthetic benefits and provides a view enjoyed by people whose houses and offices face the green roof (Millett, 2004; Cleveland, 2008). Particularly, birds chirping in trees and other plants can be easily observed, thereby increasing amenity. For example, green roof on the University Hospital of Basel (Switzerland) has been designed as a test site for urban bird observation and habitat creation. Instead of the usual grey city rooftops, patients enjoy a view more closely resembling a sandy river bank inhabited by several species of migratory birds (Pledge, 2005).

Ecological: Remains clear that green roof are not intended to replace natural areas at ground level (Velazquez, 2005), although one of the main objectives in the installation of green roofs is to increase the biodiversity in city centres (Cantor, 2008) because they can provide some habitat for wildlife (Velazquez, 2005). Encourage the presence and the breeding of birds on green roofs contribute evidently to achieve this objective. In fact, one of the benefits offered by green roofs is its contribution to urban biodiversity because they are one of the most important ways to restore habitat for invertebrates (Cantor, 2008) birds and other animals. In turns these sites attract predators like birds, bats, mammalsand reptiles. In this way, it contributes to increase the overall biodiversity of the urban area (Diekelman, 2009).

Educational and scientific: Although, several green roofs have been implemented with the aim of carrying educational and scientific activities, none of these have included specific birdlife research.

Utilitarian and commercial: Although until now have not been reported, it is possible to undertake utilitarian and economic activities involving birds on green roofs (e.g., pigeon lofts). A related example can be found in Asphof Rothenflush (Switzerland) where there is an organic farm with a unique chicken coop with a green roof modelled after Norwegian-style sod buildings. The green roof has had a beneficial effect on reducing the temperatures and improving ventilation of the hen house. In addition, the green roof provides an additional space for the chicken coop (Cantor, 2008).

A clear utilitarian value of the birds living on green roofs is derived from their beneficial activities as natural method for controlling insect pests because birds forage for insects (Hake, 2007). This is positive both to prevent disturbance to humans and to minimize damage to the plants that vegetate green roofs.

Accidents: Green roofs on buildings and facilities in the airports might attract birdlife. Birds are often sucked into jet aircraft engines, something that causes aircraft accidents resulting in loss of resources and occasionally in human deaths (Swearingin *et al*., 2008). A research shows thatin the United States, >75% of recorded bird strikes causing damage to civil aircraft are waterfowl (32%), gulls (28%) and raptors (28%) (Cantor, 2008). In

spite of that, opinions concerning the implementation of green roofs at the airports are not unanimous (Velazquez, 2005; Cantor, 2008; Swearingin *et al*., 2008). Some experts are worrying about the impact of large populations of birds for example, sea gulls as has occurred in some urban areas of London (Cantor, 2008). Some are concerned that several plant species are very attractive to birds because they offer food and coverand it could increase the risk of birds-aircraft collisions.

The airports occupy usually a large quantity of space with huge area of pavement for parking, runways and storage, consequently destroying ecosystems and creating enormous urban heat islands of waterproof surfaces. The resulting loss of natural green spaces and its inbuilt natural processes like greatly impacts storm water management, creates noise, destruction of habitat and biodiversity, air and water contaminationand on a large extent, contributes to global warming (Velazquez, 2005). They have many flat-roofed buildings and due to that these facilities are the natural alternative for green roofs that, having many ecological benefits could help to mitigate each of these environmental problems.

In Europe, major airports have successfully constructed green roofs in terminals, concourses, parking buildings maintenance buildings and others structures. In these airports there has been no increase in problematic bird populations that might interfere with aircraft operations (Velazquez, 2005; Cantor, 2008; Swearingin *et al*., 2008). This success is due to a careful design of the green roofs with a cautious initial selection of the plant species, monitoring of the resultsand adequate maintenance (Cantor, 2008).

The design of green roofs at the airports must discourage animal populations from settling in these areas. For examples, plants should be selected that do not produce flowers, berries, fruitsor seeds that attract animals. Plant height must be carefully regulated. The Schiphol International Airport from Amsterdam is blended into its unique natural surroundings and has three buildings with extensive green roofs and two buildings with intensive green roofs. In this airport, the managers have responded to the environmental challenges in different ways even with specially trained teams of dogs which are used to chase the birds away from the airport installations (Cantor, 2008).

Crop damage: Birds are not always desired visitors on a green roof. They can adversely affect green roofs, both in its initial phase of planting and when the green roof is consolidated, throughout its entire lifecycle.

Installing plants for appropriate growth on roof tops involves various methods: seeds, cuttings, plugs, pre-grown matsor plants in containers (Luckett, 2009). During the planting of a green roof, seeds and small plants are very exposed to several problems among which is the adverse participation of the birds. If it is chosen the green roof installation by plug plants as the plugs contain insects and other animals, it could attract birds, like crows, searching for food (Emilsson, 2005). They pull out the freshly planted plugs which abandoned out of the growth media for too long will dry out and die. This may be a challenge and an opportunity for the nurseries, they should produce and plant material which does not attract birds or which resists the birds pecking.

As well birds may cause problems during the establishment phase when a direct application of seed is chosen for planting on the green roof (Dunnett and Kingsbury, 2004). There are products used in the planting of seeds that bind the growth media together and which may both help to retain moisture for germination as well as to keep the wind and birds from displacing seed. In all these cases, there are a range of methods used for protect plants from birds, like bird nettingor like fake plastic owls and rubber snakeswhich frighten away unwanted birds (Luckett, 2009).

Birds are constantly searching for insect food and it could affect negatively to the fragile community moving the natural succession to an earlier stage (Grant *et al*., 2003) but even mature green roofs may have problems with activities of the birds. If moss becomes the dominant ground cover in an extensive vegetated roof, it could be problems with feed-seeking birds (Emilsson, 2008). High phosphorous concentrations in waters runoff from vegetated roofs might be related to inputting from bird droppings, although it seems more likely to input from fertilizers added to the substrate (Emilsson, 2005).

Another major unintended effect of birds on green roofs is the inadvertently introduction of plants and animals which sometimes could be detrimental to the vegetative structure. Weeds are usually introduced in green roofs by birds (Grant *et al*., 2003; Dunnett and Kingsbury, 2004; Pledge, 2005; Snodgrass and Snodgrass, 2006) and they could be introduced for example on the feet of birds (Dunnett and Kingsbury, 2004). Plants with berries from the Rosaceae and other families can be dispersed far and wide by birds (Dunnett and Kingsbury, 2004).

Grant *et al*. (2003) quote a research of Payne who in 2000 published a study of 639 roofs in East Anglia and stated that eight of the 30 most commonly wild plants species encountered in the roofs were dispersed by both wind and birds and three by birds alone.

Disease reservoirs: A zoonosis is any infectious disease that can be transmitted from non-human animals, both wild and domestic to humans or vice versa. Many serious diseases, e.g., avian influenza, fall under this category

(Wikipedia, 2010) and birds are important agents that can carry infectious organisms that may be zoonotic (Danial *et al*., 2008) also in urban areas (Friend *et al*., 2001). Green roofs attract birds and increase their populations in the city, acting as an enhanced interface between birds and humans in the urban landscape. To some extent, this could offers increased chances for disease transfer to humans, therefore increasing the potential risk of zoonosis. This possible negative effect of the green roofs has not been studied or reported so far. It is likely, however that does not involve serious negative impact on disease transmission to humans.

METHODS FOR STUDYING BIRD POPULATIONS ON GREEN ROOFS

When examining green roofs for recording the presence, use, activities and behaviour, breeding and nesting of bird species, some recommendations are proposed in order to standardise methods and to make easily comparable results throughout researches. The below recommen dations are proposed after reviewing the main studies that specifically carry out bird surveys and investigate bird populations on green roofs (Burgess, 2004; Baumann, 2006; Bates *et al*., 2007):

- The geographic location of the green roof under investigation must be specified and a description of the surrounding area (urban or rural environment) must also be provided
- Height (metres above street level), dimensions, exposure and main climatic variables of the green roof must also be specified
- The typology of the green roof (extensive, semi-extensive, semi-intensiveor intensive), along with a description of its structure (mainly, the substrate) and main elements, must be included
- The plant community supported by the green roof must be described as precisely as possible by performing a floristic inventory with plant identification at least to the species level
- The presence of water on the green roof must be acknowledged with specification of its sources
- If on the green roof there is any particular structure that can interacts with the birds, it must be specified
- A good vantage point must be chosen, located on neighbouring buildings, trees or similar structures which enables bird watching with comparative ease
- The observer must be hidden (inside a hide) or, alternatively must be placed far from the birds so that these are not significantly disturbedin order for allows them to display their natural behaviour. The observer can use binoculars
- In-person watching can be efficiently substituted by video recording because it allows a more accurate monitoring of the activities and behaviour displayed by the birds
- The time of year during which observations are made must be indicated. Moreover, periodicity (weekly, daily, etc.) and duration (hours or minutes) of the sampling observations must be specified. Due to the variation in the behaviour of the birds along their circadian rhythms, successive observations must be carried out at the same time of day
- Birds surveyed must be identified to the species level.
- Most important data to be recorded from birds of each Species are number of individuals (specimens) or number of bird visits, number of breeding pairs, presence and number of nests, number of eggs in the clutches, brooding activity, hatching success, number of hatchlings and post-hatching chick survival. Moreover, predation incidence can also be recorded
- Behaviour and activities displayed by the birds must be recorded and quantified. Main bird behaviours to be recorded are a function of the objectives of each investigation. Main behaviours that birds can display on green roofs are shown in Table 3

Table 3: Main behaviours and activities that can display birds on green roofs

Behaviour/Activity	Comments and additional details to be registered
Roosting	It can be recorded the element on which bird is perching
Grooming	
Foraging for food	It must be recorded the nature and species of food: insects, seeds, berries, leaves, seedlings, etc.
Drinking	It can be recorded the source of water
Singing	
Collecting nest material	It can be recorded the kind of material collected
Making the nest on the green roof	It can be recorded the place where the nest is constructed
Displaying courtship behaviour	
Mating	
Brooding	
Feeding chicks	It can be recorded if the food for chicks is collected by parents on the green roof
Using the green roof as stepping zone	It results of interest in the case of migratory birds
Pulling out plugs of soil and plants	It results of interest if this activity can be considered as damaging

CONCLUSION

Currently, the ecological value of green roofs is becoming very important. A greater variety in the design and construction of a green roof can contribute to increase the level of biodiversity in plants and animals (Dunnett and Kingsbury, 2004). The ecological value of the green roofs could be maximised by having a diversity of areas in the green surface, with heights and slopes, stony and rocky areas, unvegetated areas, a variety of vegetation types, poorly drained areasand even areas with water features like small ponds (Dunnett and Kingsbury, 2004).

All over the world, a new generation of green roofs is being planned with the aim of conserving the habitat of protected animals and plants species. The standard extensive sedum mat based green roof has quite limited ecological value in comparison to other types. It constitutes very little biomass which is particularly important for young precocial birdswhich have to find water and food by themselves because they are not fed by adults. Furthermore, this type of green roofs offers little cover against crows and other similar birds of prey; for this reason there will be a need for more biomass and different structures in order for them to survive (Dunnett and Kingsbury, 2004; Baumann, 2006; Cantor, 2008).

The use of native species and provision of quiet areas, nest and roost boxes and voids can help to attract wildlife to even intensively managed green roofs, like roof gardens (Grant *et al*., 2003).

It is necessary to develop new researches in order to establish the design guideline to ensure the success to create alternative habitats for birds on flats green roofs. Research as published by Brenneisen (2000), Dunnett and Kingsbury (2004) and Baumann (2006) may help to establish the best design alternative.

Scientists need to know which birds speciesin addition to previously mentioned ones will nest on such green roofs what types of substrate (natural soil, sand, gravel or stone) will attract them (due to their colours, textures) what types of vegetation will attract enough of the insects on which the young birds feedand what ecological conditions are optimum for maintaining viable populations of different bird species (Cantor, 2008).

It is also necessary to establish a common methodology in the study of the presence, useand activities of bird species on green roofs, to thus be able to analyze and compare results among different studies. To further this, it have proposed in this study a series of recommendations which could be used as a reference in future research.

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