



Short communication

**Trends in numbers of
petrels attracted to
artificial lights suggest
population declines in
Tenerife, Canary Islands**

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The secretive breeding behaviour of petrels makes monitoring their breeding populations challenging. To assess population trends of Cory's Shearwater *Calonectris diomedea*, Bulwer's Petrel *Bulweria bulwerii* and Macaronesian Shearwater *Puffinus baroli* in Tenerife from 1990 to 2010, we used data from rescue campaigns that aim to reduce the mortality of fledgling petrels attracted to artificial lights as proxies for trends in breeding population size. Despite increases in human population size and light pollution, the number of rescued fledglings of Cory's Shearwater and Bulwer's Petrel increased and remained stable, respectively, whereas numbers of rescued Macaronesian Shearwaters sharply declined. In the absence of more accurate population estimates, these results suggest a worrying decline in the Macaronesian Shearwater's breeding population.

Keywords: Canary Islands, light pollution, population size, rescue campaigns, seabirds.

The Procellariiformes (including petrels and shearwaters, hereafter petrels) comprise one of the most endangered bird taxa, as many species have undergone substantial declines in recent times (Butchart *et al.* 2004). The main causes of their population declines are introduced predators, interactions with fisheries and nesting habitat loss

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(Carlile *et al.* 2003, Bourgeois & Vidal 2007, Le Corre 2008). Some conservation actions are being developed for charismatic and emblematic species (e.g. Carlile *et al.* 2003). However, for smaller species, population declines often go unnoticed and only a few recovery programmes have started so far (e.g. Bourgeois & Vidal 2007). Monitoring and estimating the breeding population size of petrels is challenging because of their secretive breeding behaviour; the majority are nocturnal, nest in underground burrows that are difficult to count and often occupy inaccessible, remote nesting sites (Bretagnolle *et al.* 2000, Gregory *et al.* 2004). Therefore, in the absence of accurate census data, other indices or proxies for population size might be used to assess population trends (Gregory *et al.* 2004).

On archipelagos worldwide, thousands of fledglings of different petrel species are attracted to artificial lights during their first flights from nest-burrows to the sea, a phenomenon called 'fallout' (Reed *et al.* 1985, Telfer *et al.* 1987, Le Corre *et al.* 2002, Rodríguez & Rodríguez 2009, Miles *et al.* 2010, Rodrigues *et al.* 2011). Grounded birds are vulnerable to starvation, predation, dehydration and collision with vehicles. Rescue campaigns have been carried out in many places (Le Corre *et al.* 2002), and most of the rescued birds (> 90%) are later released into the wild (Telfer *et al.* 1987, Ainley *et al.* 2001, Le Corre *et al.* 2002, Rodríguez & Rodríguez 2009, Miles *et al.* 2010, Fontaine *et al.* 2011).

The Canary Islands are an important breeding area for petrels in the northeastern subtropical Atlantic (Arcos *et al.* 2009). At least seven petrel species (including shearwaters and storm-petrels) breed regularly in the archipelago (Lorenzo 2007). Tenerife Island is the largest, highest and the second most inhabited (2034 km², up to 3718 m asl, over 900 000 inhabitants) of the Canary Islands (ISTAC 2011) and is home to six breeding petrel species (Lorenzo 2007). There are no long-term monitoring programmes on the Canary Islands to detect population trends of petrels (Lorenzo 2007). Following the work of Ainley *et al.* (2001) on the endangered Newell's Shearwater *Puffinus newelli* on Kauai (Hawaiian archipelago), we used data from rescue campaigns to evaluate the population trends of the three most common petrel species involved in fallout on Tenerife: Cory's Shearwater *Calonectris diomedea*, Bulwer's Petrel *Bulweria bulwerii* and Macaronesian Shearwater *Puffinus baroli* (formerly Little Shearwater *Puffinus assimilis*) (Rodríguez & Rodríguez 2009). At present, these three species are protected under the National and Regional Catalogue of Threatened Species (Spanish and Canarian Governments) and they are listed as nationally vulnerable (Cory's Shearwater) and endangered (Bulwer's Petrel and Macaronesian Shearwater) because their populations are thought to be in decline (Madroño *et al.* 2004). Cory's Shearwater is the most abundant Canarian seabird and is widespread on the islands, breed-

ing in cliffs, slopes and ravines, often several kilometres inland. Bulwer's Petrel and Macaronesian Shearwater breed in marine rocks and sea cliffs, although the finding of some Bulwer's Petrels at high altitude and several kilometres inland suggests that this species could breed in high interior mountains. Cory's Shearwater and Bulwer's Petrel breed on all the Canary islands. No accurate estimates of the breeding population for Tenerife are available, but in the period 1997–2003, ca. 2000–3000, 400 and 70 breeding pairs have been estimated for Cory's Shearwater, Bulwer's Petrel and Macaronesian Shearwater, respectively (Lorenzo 2007, Rodríguez & Rodríguez 2009 and references therein).

Here, we report the number of rescued fledglings of these three petrel species during 21 years on Tenerife, Canary Islands, use these to assess population trends and propose appropriate conservation measures.

MATERIAL AND METHODS

We collected data on the numbers of fledglings recovered on Tenerife Island by the rescue campaigns during 1990–2010 for the three petrel species, following Rodríguez and Rodríguez (2009). The rescue programme is an island-wide public conservation programme that has recovered disorientated petrels attracted to artificial lights on their first flights from the nest-burrow out to the sea since 1990 (Anonymous 1995). This programme has been implemented by the La Tahonilla Wildlife Rehabilitation Centre and funded by the local government (Cabildo Insular de Tenerife). The number of rescued fledglings of each species was recorded every year for each municipality separately.

The number of rescued birds might depend on several factors (Ainley *et al.* 2001). First, the annual rescue effort probably varied because it is a volunteer programme and depends on the efficacy of the awareness campaign conducted each year before the fledgling season, as well as the number of previous campaigns carried out (Le Corre *et al.* 2002, Salamolard *et al.* 2007). As it was not possible to know how many people were involved in the rescue campaign and their level of awareness each year, we used human population size, taken from ISTAC (2011), as an informal assessment of the size of the rescue campaign. Secondly, the amount of light pollution could vary through the study period. To evaluate the evolution of light pollution in Tenerife Island, three stable average artificial light layers from 1992, 2000 and 2008 (911.25×911.25 m resolution; pixel values ranking from 0 to 63 relative units) were obtained from the National Geophysical Data Center (USA) (<http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html>), following a methodology similar to that of Rodrigues *et al.* (2011). The annual mean value of stable artificial lights was extracted using ARCGIS (version 9.2; ESRI, Redlands, CA, USA) for the three

layers and the observed increase was calculated. In addition to measured light, the gross electricity production was also evaluated (ISTAC 2011). Thirdly, the lunar phase has an impact on the number of retrieved fledglings (Ainley *et al.* 2001), so we identified years where the peak fledgling period coincided with a full moon. Finally, the number of retrieved fledglings is likely to reflect the overall size of the breeding population and breeding success. Thus the number of fledglings produced cannot exceed the number of breeding pairs (Day *et al.* 2003) (petrels lay a single egg per breeding season; Warham 1990).

RESULTS

The three petrel species showed different trends in recoveries throughout the study period (Fig. 1). The number of rescued Cory's Shearwater increased, Bulwer's Petrel recoveries remained stable, but recoveries declined in Macaronesian Shearwater. The Canary human population increased steadily from 623 823 in 1991 to 906 854 in 2010. Similarly, the gross electricity production increased from 1431 Gigawatt hours in 1991 to a peak of 3550 Gigawatt hours in 2008 and slightly decreased to 3357 Gigawatt hours in the last 2 years (2009 and 2010). Human population size and gross electricity production were highly correlated ($r = 0.98$, $P < 0.001$, $n = 20$). As a consequence of the growth in human population and electricity production, light pollution intensity (and consequently area affected) increased by 22.6% from 1992 to 2000 and by 13.1% from 2000 to 2008 (Fig. 2).

DISCUSSION

Although changes in the number of rescued birds over the last two decades could provide a proxy for population trends, they can be biased by several factors (i.e. variation in annual effort of the rescue campaign, light pollution intensity and moon phase). As a consequence of increasing awareness, the number of rescued birds is likely to have increased during the first few rescue campaigns (Le Corre *et al.* 2002). Indeed, on Tenerife in the third rescue campaign (1992) more than twice as many birds were rescued than in the first two seasons (1990–91; Fig. 1). Thus, we can assume that at least initially the awareness level has increased during our study period. In addition, human population, gross electricity consumption and urbanized area have notably increased in Tenerife, which could have increased both rescue effort and light pollution. From 1992 onwards, the use of shielded lights increased and mercury and halogen lights began to be substituted with low sodium vapour lights as imposed by the Sky Law (Ley del Cielo 31/1988, Real Decreto 243/1992), which aims to protect the research activity of the Astrophysical Institute of the Canary Islands by

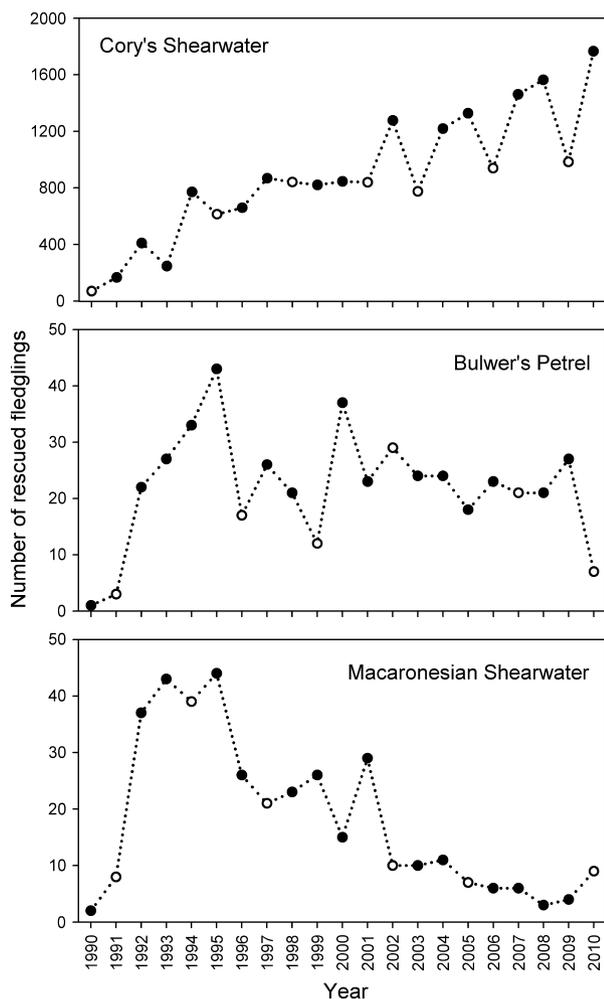


Figure 1. Number of rescued fledglings of three petrel species collected by the rescue campaigns on Tenerife (Canary Islands). Open circles indicate years where the peak fledging period coincided with a full moon (± 4 days) (see Rodríguez & Rodríguez 2009).

reducing light pollution. However, according to our analysis this law was not sufficient to reduce the overall extent of the area affected by light pollution and its intensity. Breeding success can vary from year to year, although these annual variations should not skew long-term fledgling fallout trends, unless low breeding success has been sustained over a long period of time. This then would result in a smaller number of young birds being recruited as breeders in the following years and in the long term would result in a population decline. Lastly, numbers of rescued fledglings can be lower when the peak fledging period coincides with a full moon (Ainley *et al.* 2001), but in our data it does not appear to affect long-term trends of the fallout (see Fig. 1).

If breeding population size is stable, one would expect that the numbers of fledglings rescued would correlate positively with the annual effort of the rescue campaigns and the increment of light pollution. Under current conditions on Tenerife, with increasing rescue effort and light pollution, even a declining population could show a positive trend in the number of rescued fledglings. A decline in the number of rescued fledglings, however, suggests a worrying situation because this indicates a decline in the breeding population and/or a decline in breeding success sustained over several consecutive years.

The three petrel species showed different trends in the numbers of rescued fledglings during the study period. In the case of Cory's Shearwater, we cannot confidently predict a real population trend. Population size might be increasing given that at least a proportion of the thousands of rescued fledglings during the last rescue campaigns would have been recruited as breeders, but no accurate information on recruitment of released birds is available. Anecdotal data, based on unoccupied burrows during the last few years and high numbers of adult birds predated by feral cats (A. Rodríguez & B. Rodríguez pers. obs.), as well as the assumptions of other authors (Madrño *et al.* 2004, Lorenzo 2007), contradict the apparent population increase from this study. This is also supported by the viability models recently published for this species in the Azores archipelago, which requires unrealistic demographic parameters to permit population stability (Fontaine *et al.* 2011). Furthermore, lights from new urbanized areas that appeared on Tenerife during the study period may attract individuals from colonies not previously affected (Figs 2 and 3), which could contribute to the observed increase of rescued birds. This pattern of light attraction spreading to newly developed urban areas was also seen on Kauai (Ainley *et al.* 2001). We also believe that the level of public awareness is not completely saturated. Therefore, if the breeding population is actually declining while citizenship awareness is increasing, we expect to find the number of rescued Cory's Shearwater fledglings to peak within the next few years, as reported for the declining population of Newell's Shearwater (Ainley *et al.* 2001, Day *et al.* 2003, Duffy 2010).

For Bulwer's Petrel and Macaronesian Shearwater, the situation appears less favourable. For Bulwer's Petrel, the pattern of recoveries was stable during the years 1992–2009. The most important breeding colonies for this species are located on shoreline marine rocks, places where fledglings easily reach the sea and light pollution has increased only mildly in comparison with other areas (e.g. touristic cities; Figs 2 and 3). However, the stable number of rescued birds could still indicate that the population is declining, as has been suggested (Madrño *et al.* 2004, Lorenzo 2007).

For Macaronesian Shearwaters, the situation appears critical, as the pattern of recoveries suggests a sharp

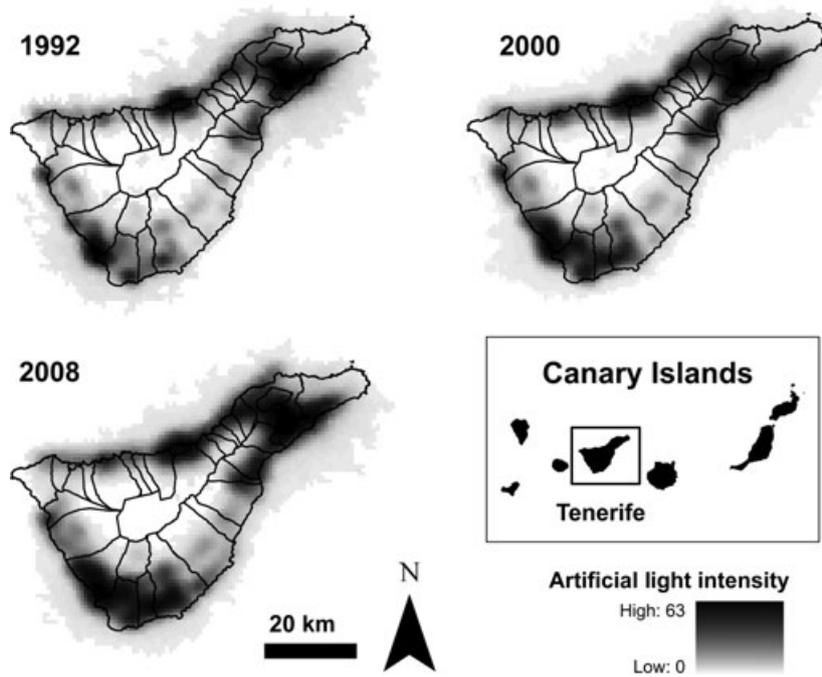


Figure 2. Levels of artificial light intensity during the night on Tenerife Island in 1992, 2000 and 2008. Darker shading indicates more illuminated areas. Lines indicate municipal limits and coastline. Artificial light intensity was taken from satellite images by the National Geophysical Data Centre (see text).

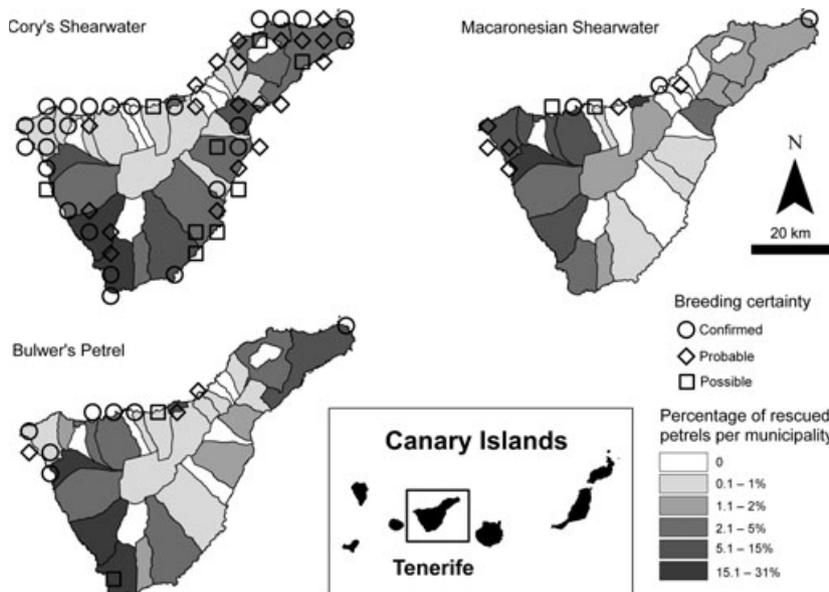


Figure 3. Geographical distribution of breeding colonies and the number of fledgling petrels attracted to artificial light on Tenerife Island during 1998–2010. Certainty of breeding at possible colony locations in each 5 × 5-km square is given as confirmed, probable and possible (modified from Lorenzo 2007).

population decline, like many petrel species in this and other archipelagos (Day *et al.* 2003, Le Corre *et al.* 2003, Bourgeois & Vidal 2007, Rodríguez *et al.* 2008). The change to more efficient lighting systems since the Sky Law came into force could be a non-mutually exclusive explanation for the negative trend in the number of rescued birds, as Macaronesian Shearwater might not be attracted to the modified light sources (see Reed *et al.* 1985, Salamolard *et al.* 2007). Passerines, for example, are affected differently by different qualities of lights (Poot *et al.* 2008). However, this seems unlikely to be the complete explanation and a population decline has also been suggested by limited field observations (Madroño *et al.* 2004, Lorenzo 2007, pers. obs.). For the Newell's Shearwater population on Kauai, additional data from radar counts and population viability models confirmed the population decline initially suspected from the decreasing numbers of rescued birds (Ainley *et al.* 2001, Day *et al.* 2003).

Trends in numbers of rescued birds are affected by several sources of error (see above), but given the lack of accurate census data on these petrel populations, as well as the secretive breeding behaviour and the inaccessibility of their breeding sites, this is currently the only available information, at least for Bulwer's Petrel and Macaronesian Shearwater. However, to carry out more formal analyses in future studies, we would need to (1) implement a massive ringing effort of nestlings every year to assess accurately the percentage of fledglings affected by light pollution; (2) determine burrow occupancy rate and correlate this with the number of rescued fledglings; (3) survey citizens' awareness; and (4) begin other programmes to estimate population trends such as radar surveys (Day *et al.* 2003). Because prevention is often easier than cure, for Macaronesian Shearwater we recommend the immediate design, publication and execution of a conservation plan as required by Spanish and Canarian law. This conservation plan should be based on three key points: (1) control of cats and rats at colonies; (2) enhancement of the rescue campaign during the fledging months to improve citizens' awareness and improve rehabilitation procedures to reduce the mortality of rescued birds by providing food and liquid, and test waterproof properties of plumage; and (3) execution of a detailed survey programme on the distribution, population size and breeding parameters to evaluate its demographic dynamics.

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