CHANGES IN THE POPULATION SIZE OF YELLOW-LEGGED GULL *LARUS MICHAHELLIS* AT ESSAOUIRA AND MOGADOR ISLAND, WEST-CENTRAL MOROCCO

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ABSTRACT

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This study concerns changes in the size and population structure of a Yellow-legged Gull *Larus michahellis* colony, last assessed in 1985 in the city of Essaouira and on Mogador Island, Morocco. Using point-transect sampling, the average density measured in 2019 was 53.5 ± 2.8 birds/ha (5350 ± 280 birds/km^2), which translates to a population size of almost 30000 birds. The highest density occurred on Mogador Island, with 217.2 ± 28.3 birds/ha, a much higher density than previously recorded. The Yellow-legged Gull breeding population in the Essaouira–Mogador Island area has grown 3.58% per year since 1985, with an annual average reproductive rate of 1.04 chicks/pair. An increased availability of food via open landfill sites seems to be the major cause for this population boom. More detailed studies, however, are needed to better understand the effect of food abundance on population growth for this colony.

Key words: Distance sampling, human-gulls conflict, Mogador Island, Morocco, population size, urban landscape

INTRODUCTION

Populations of gulls *Larus* spp. have increased sharply throughout coastal areas of the Mediterranean basin since the middle of the 20th century. These increases have been attributed to gulls' opportunistic behaviour and omnivorous diet, which allow them to take advantage of anthropogenic food resources, such as landfills and industrial fishing. They also benefit from growing legal protection, in the form of biological reserves and ecological designations on islands and islets where they breed (Vidal *et al.* 1998, Bonnet *et al.* 1999, Oro *et al.* 2005, Skórka *et al.* 2005, Arizaga *et al.* 2014). Among Laridae, the Yellow-legged Gull *Larus michahellis* (hereafter YLG) is the most common and widespread large gull of the Mediterranean basin and the Atlantic coast of northwestern Africa (Beaubrun 1994, Yésou & Beaubrun 1995, Thibault *et al.* 1996), occurring in southern Europe, northern Africa, and on the eastern Atlantic islands (i.e., the Canary Islands (Bermejo & Mouriño 2003, Olsen & Larsson 2003), Madeira (Nogales *et al.* 2001), and the Azores archipelago (Neves *et al.* 2006)). The species' European population increased sharply during the 20th century, with the breeding population reaching a half million pairs by 2015 (BirdLife International 2019). In Morocco, this common species breeds along both the Mediterranean and Atlantic coasts (Beaubrun 1988, Thévenot *et al.* 2003). The largest and most important colony is at Mogador Island (west-central Morocco) with 2000–2500 breeding pairs, which is *ca*. 48% of the Moroccan breeding population (Beaubrun 1988)).

The Mogador Archipelago (also known as Îles Purpuraires) has been a permanent biological reserve since 1980 and a RAMSAR site since 2005. The site also has abundant local anthropogenic food resources, particularly in Essaouira's open landfills and marine dumpsites, where the regular coastal fishing fleet discards waste from more than 10000 tonnes of fish landed per year (ONP 2020). Accounting for their protected status and good food availability, we predicted positive changes in YLG population dynamics since the last census in the mid-1980s and subsequent changes in the spatial distribution of YLGs in this urban environment. Indeed, many YLG pairs nest on the rooftops of industrial and administrative buildings, and sometimes even on the rooftops of residential housing. This population had not been surveyed during the last 30 years, and we undertook a follow-up survey to assess the current status of the population.

The monitoring of gull colonies is typically based on counts of active nests, often using strip transects (Walsh *et al.* 1995, Bibby *et al.* 2000, Cadiou & Yésou 2006). As an alternative to strip counts, distance sampling is a widely used method for estimating bird density (Bibby *et al.* 1998, Buckland *et al.* 2001, Gregory *et al.* 2004, Buckland *et al.* 2008, Conroy & Carroll 2009). Distance sampling involves counting individuals and measuring their distance from the observer, on the assumptions that every bird is detected at a zero distance and that the probability of detection decreases as distance from the observer increases. Distance sampling has two forms: line-transect sampling and point-transect sampling. Line-transect sampling consists of counting and measuring the distance to the detected individual when walking along a line. However, line-transect sampling is usually not suitable for urban areas, as it is difficult to randomly allocate sampling units due to frequent obstacles such as buildings or streets. Point-transect sampling consists of measuring distances within a given radius from every detected bird to a fixed observer during a specified period. Therefore, point-transect sampling is more appropriate for urban areas (Buckland *et al.* 2001).

Our study aimed to determine the population size and structure of the YLG colony in Essaouira and on Mogador Island using the point-transect sampling method. We then evaluated changes in the size, growth rate, and annual rate of reproduction of the breeding population over the last 30 years and compared our results to those of Beaubrun (1988).

MATERIAL AND METHODS

Study area

Essaouira (31°31′N, 009°45′W) is a small city of 90 km^2 of which ~6 km^2 is occupied by humans (77 966 persons; RGPH 2014). It is located on Morocco's central Atlantic coast (Fig. 1). Offshore by 1.2 km is the archipelago of Mogador, which is composed of eight calcareous islands and islets. The most accessible of these is Mogador Island, where we conducted our study. It is a single landmass at low tide, but at high tide, a small portion is submerged; the two resulting islands are D'zira Ikbira (Big Island), which is 22.7 ha (0.227 km^2) and reaches an altitude of 29 m, and Firaoun (Pharaoh Island), which covers an area of 2.1 ha (0.021 km^2), reaches a maximum altitude of 26 m, and has a crater in the middle. Neither island is inhabited by people and both are fully protected by conservation laws.

Essaouira's climate is arid to semi-arid and is strongly influenced by the Atlantic Ocean, with a dry season lasting seven months. Temperatures are influenced by the cool Canary Current and are thus relatively mild. The average annual maximum temperature is 22.3 °C, which occurs in August and September, and the average annual minimum is 9.5 °C in January. The mean annual precipitation of 295 mm is highly variable.

The biological reserve of the Mogador Archipelago, which shelters an important nesting avifauna, has been fully protected since 1980 and was designated as a RAMSAR site in 2005. These measures protect an important colony of almost 1 000 pairs of Eleonora's Falcons *Falco eleonorae* (Qninba *et al.* 2015) and other notable nesting species, particularly the Great Cormorant *Phalacrocorax carbo maroccanus* (de Naurois 1961).

Survey method

The study was conducted during the 2019 (March to August) breeding season. We used a 0.1 km^2 grid of 56 quadrats, covering the entire urban area of Essaouira and Mogador Island. Fifty of these quadrats were randomly selected for sampling. In each, we randomly located one point transect.

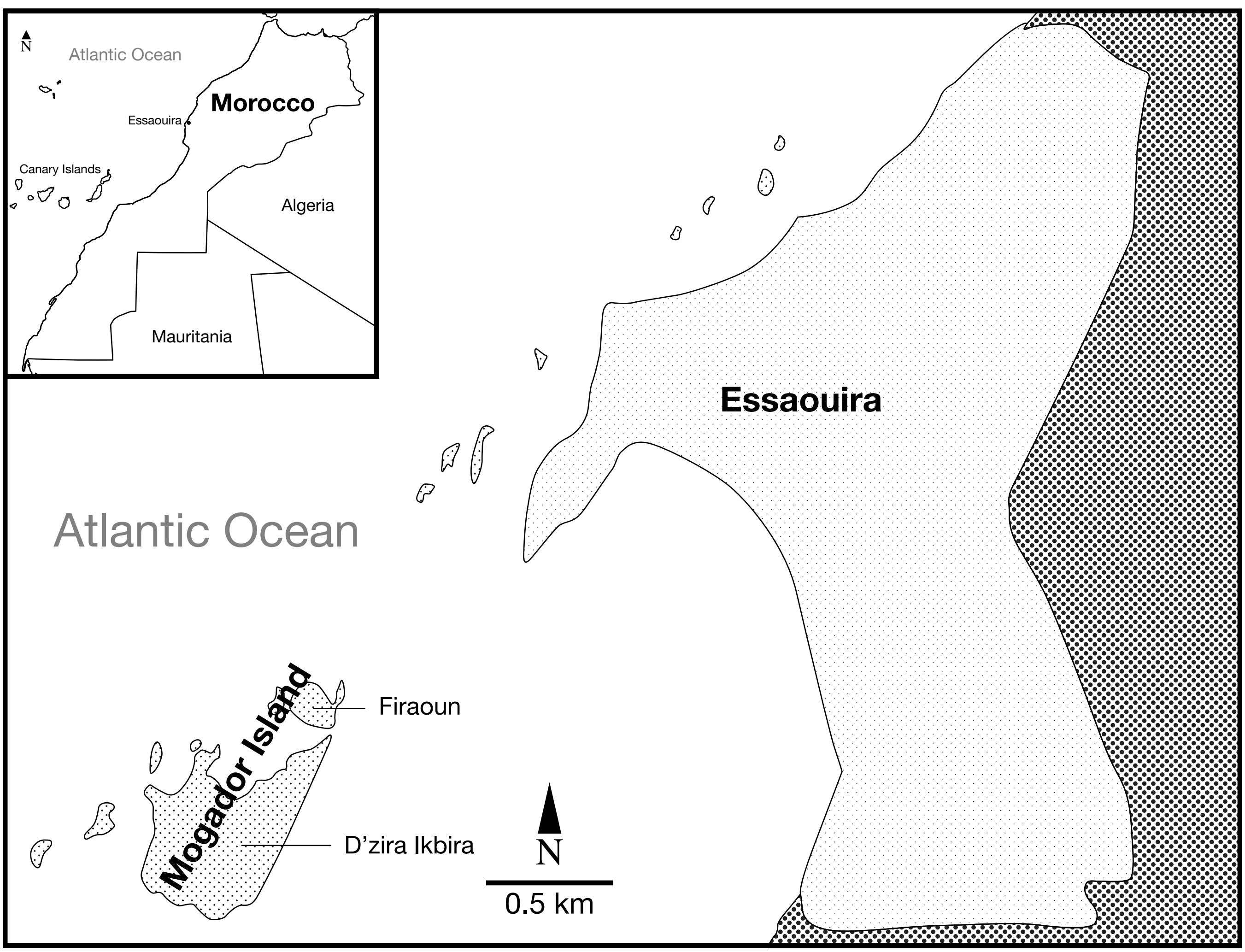

Fig. 1. Map showing Essaouira (urban area) and Mogador Island (natural area) on the west-central coast of Morocco.

Sampling was performed by the same two-person team during the entire sampling period. The first observer's mission was to detect gulls without using binoculars, to assess detection probability. The second observer's mission was to determine the age classes of birds detected by the first observer. We sampled each plot for five minutes using fixed-radius (200 m) point transects (Buckland *et al.* 2001) between 06h30 and 11h00. All point transects were replicated over three sampling sessions for each grid cell. Point transects were not repeated on the same or consecutive days, and each plot was visited twice per month. YLGs that were disturbed during the observers' arrival were recorded at their initial location. We recorded the number of individuals and groups of individuals ("clusters") detected, as well as the cluster size and distance from the observer upon detection. We measured each detection distance in meters using a Bushnell Tour V2 Laser Rangefinder®. We recorded only birds observed during the five-minute sampling period at each site; birds flying through the quadrat during this time (i.e., coming from outside the quadrat) were neither recorded nor included in the analysis.

The YLG population structure was determined using four age classes based on plumage (Garner 1997): juvenile/first year, second year, third year, and adults (four or more years). Observations were made with binoculars by the second observer. The individual birds encountered in the point transects were assumed to be representative of the population's demographic structure.

Data analysis

Data were analysed using the software Distance, version 7.3 (Thomas *et al.* 2010), which models detection probability as a function of detection distance, accounting for the decrease in the probability of detecting the target species with increasing distance from the point transect's origin. We tested 12 models and selected the best based on the shape of the curve describing the probability of detecting gulls relative to the recorded distances and the Akaike Information Criterion (AIC) value. This value provides a method to select the best model to fit the data at hand: for a given data set, the AIC value is computed for each of a set of models, and the model with the smallest AIC has the best fit. The best models show a reduction in detection probability with increased distance between the observer and the bird, along with low AIC values (Buckland *et al.* 1993, 2001). The obtained densities are given, along with their coefficients of variation (CV, in %). The total population size was estimated by extrapolating the mean density to the total study area.

Because YLG populations in Morocco, and especially in Essaouira, are not regularly counted, the current regional status of the species remains unknown. The only baseline census was conducted by Beaubrun (1988). We, therefore, performed a theoretical calculation to assess the change in this species' population based on growth rate ($Gr = E_f/E_i$ as a %) and on annual reproductive rate (ARr), using the formula proposed by Migot & Linard (1984):

$$ARr = \sqrt[n]{\frac{E_f}{E_i}}$$

where n = number of years between the two counts, E_f = final count, and E_i = initial count. Our ARr was calculated based on Beaubrun's counts of YLGs at Mogador Island between 1978 and 1985 (Beaubrun 1988) and on our theoretical estimate of the breeding population calculated from the proportion of adults during the present study, assuming all adults (age ≥ 4 years) participate in breeding.

To account for spatial variations, we computed density separately for each zone: 1) overall area (island + city), 2) natural area (island), and 3) urban area (city; Table 1). Spatial comparisons of density were made with paired sample *t*-tests. All statistical tests were

TABLE 1
Analysis of point-transect surveys of the Yellow-legged Gull *Larus michahellis* population in the Essaouira–Mogador Island area of Morocco during the breeding season of 2019

Surveyed zone (surface area)	Sampling session	Model[a]	AIC	Effective detection radius (m)	Density (birds/ha)	Coefficient of variation (%)	Population size
Overall (Essaouira/Mogador Island, 560 ha)	1	U/C	3358.74	53.08	56.78	11.40	31799
	2	HN/SP	3157.83	51.83	52.16	9.40	29211
	3	HN/C	3231.61	53.97	51.64	11.40	28920
Mean ± standard deviation				52.96 ± 1.08	53.53 ± 2.83	10.73 ± 1.15	29977 ± 1585
Natural area (Mogador Island, 40 ha)	1	HN/C	484.22	45.65	193.54	18.10	7741
	2	NE/HP	397.47	44.63	209.56	22.00	8382
	3	U/C	479.97	33.81	248.59	17.60	9944
Mean ± standard deviation				41.36 ± 6.56	217.23 ± 28.32	19.23 ± 2.41	8689 ± 1133
Urban area (Essaouira, 520 ha)	1	HR/SP	2868.93	53.63	29.46	13.90	15317
	2	HN/C	2740.90	55.47	32.90	21.40	17108
	3	HN/C	2728.90	62.42	29.98	10.50	15590
Mean ± standard deviation				57.17 ± 4.64	30.78 ± 1.86	15.27 ± 5.58	16005 ± 965

[a] Cosine (C), half normal (HN), hermite polynomial (HP), hazard rate (HR), negative exponential (NE), simple polynomial (SP), uniform (U). (Buckland *et al.* 2004)

carried out using SPSS, version 21 (Chicago, USA). Differences were considered statistically significant at $P < 0.05$.

RESULTS

There were enough detections (> 60; Buckland 2006) to model detectability for YLGs in the Essaouira–Mogador Island area (n = 346 detections for sampling session #1; n = 25 for session #2; n = 331 for session #3; see Table 1). An example of a fitted detection function is given in Figure 2. Accordingly, the YLG population in the Essaouira–Mogador Island area is composed of approximately 29 977 ± 1 585 birds. More than 50% (i.e., 16 005 ± 965 individuals) occupied the urban area. The highest density was noted on Mogador Island, at 217.2 ± 28.3 gulls/ha (21 720 ± 2 830 gulls/km^2). According to paired sample t-test, there was a significant difference between YLG densities in natural (i.e., Mogador Island) and urban habitats (30.78 ± 1.86 gulls/ha; $t_4 = 11.38$, $P < 0.05$).

In total, we conducted 50 point transects that were replicated over three sessions, and we recorded 3 420 birds (Table 2) of which 50.8% were adults (n = 15 225), 20.7% were in their third year, 14.7% were in their second year, and 13.8% were juveniles. The YLG population of Mogador Island is composed almost exclusively of breeding adults (> 90%). Meanwhile, the composition observed in the urban environment showed a lower dominance of adults (39.4%), with the other three age groups well represented (25.3%, 18.4%, and 16.9% of third-, second-, and juvenile/first-year gulls, respectively).

The number of breeding YLGs has increased in the study area over the last 34 years (Table 3), growing from 4 260 individuals in 1985 (Beaubrun 1988) to 15 255 in 2019. The average ARr for this period is 1.04, despite a slight decrease in numbers in 1985 (ARr < 1).

DISCUSSION

Given that distance sampling is the best method to estimate population densities, especially when dealing with birds colonizing both urban and natural habitats (Barbraud *et al.* 2014, Johnston López *et al.* 2015), we used point-transect sampling to evaluate the YLG population size in the Essaouira–Mogador Island area. We chose this technique because urban areas pose numerous challenges for those using detectability and distance sampling to estimate avian abundance (i.e., Pacifici *et al.* 2008, Koper *et al.* 2016).

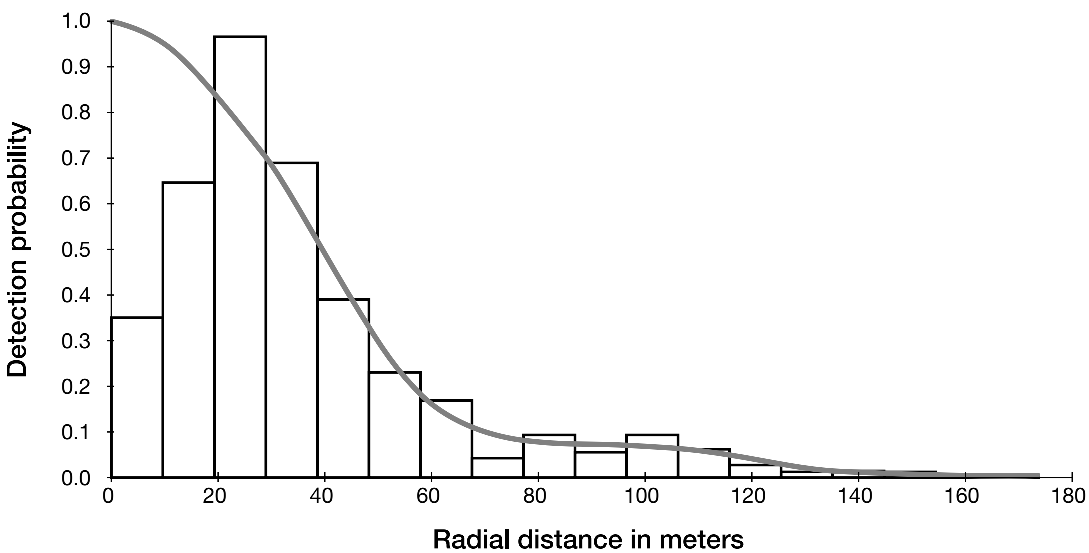

Fig. 2. Distance histogram and fitted detection function for the Yellow-legged Gull *Larus michahellis* population in the Essaouira–Mogador Island area, surveyed during the breeding season of 2019.

TABLE 2
Demographics of the Yellow-legged Gull *Larus michahellis* population in the Essaouira–Mogador Island area, surveyed during the 2019 breeding season

Age class	Overall		Urban area		Natural area	
	n	%	*n*	%	*n*	%
Juvenile/First year	472	13.80	448	16.85	24	3.15
Second year	503	14.71	490	18.43	13	1.71
Third year	708	20.70	672	25.28	36	4.72
Adults	1 737	50.79	1 048	39.43	689	90.42

TABLE 3
Population growth rate (Gr) and annual reproductive rate (ARr) for the Yellow-legged Gull *Larus michahellis* in the Essaouira–Mogador Island area between 1978 and 2019

Census	Breeding population (individuals)	Population growth rate (Gr)	Annual reproductive rate (ARr)
1978[a]	4 230	-	-
1980[a]	4 625	1.09	1.05
1985[a]	4 260	0.92	0.98
This study	15 225	3.58	1.04

[a] According to Beaubrun (1988)

Point-transect methods may not work well for species that are not noisy or visible enough to allow appropriate numbers of detections, and Buckland (2006) suggests a realistic minimum of 60–80 detections; we recorded 325–346. Because point-transect estimates tend to be more biased than line-transects if distances are over- or under-estimated (Buckland *et al.* 2001, Simons *et al.* 2005), we measured distances using a rangefinder to obtain accurate distance measurements for our density models. Even though urban species are well habituated to human presence and move little in response to observers (Fuller *et al.* 2009), we used the snapshot approach, as recommended by Buckland (2006). Thus, detected birds were recorded at their initial locations. We considered abundance estimates to be reliable, since the associated CVs were less than 20% of total estimated abundance. Under this criterion, we believe that we accurately estimated the YLG population size.

The average density of 53.5 gulls/ha represents almost 30 000 gulls colonizing a city populated by only 77 000 human inhabitants (RGPH 2014). This indicates that human-bird conflicts might be common in Essaouira. Gull conflicts with humans reported in the literature include the transmission of pathogens and parasites through water and upland habitat pollution (Fouchier *et al.* 2005, Nugent *et al.* 2008, Bonnedahl *et al.* 2009, Velarde *et al.* 2010, Hammouda *et al.* 2011), noise and building damage (Vermeer *et al.* 1988, Soldatini *et al.* 2008), and aircraft hazards at airports (Dolbeer & Bucknall 1997).

Comparing data from the present study with the results of Beaubrun (1988) showed a 250% increase in the number of breeding YLGs between 1985 and 2019. This increase in population—3.58%/year overall—is in accord with the expansion of the species throughout its range (Fasola *et al.* 1993, Thibault *et al.* 1996, Vidal *et al.* 1998, Skórka *et al.* 2005, Telailia *et al.* 2015). More YLGs have also been reported on several islands off the Moroccan coast and in the mid-Atlantic (Guyot & Thibault 1988, Beaubrun 1994, Morais *et al.* 1995, Vidal *et al.* 2001, Vidal *et al.* 2004, Neves *et al.* 2006).

Based on previous studies, the growth of the YLG population is likely due to a combination of three main factors: availability of anthropogenic food through uncovered garbage and open-air peri-urban landfills; growth of industrial fishing; and protection of several areas where the species breeds, especially certain islands and islets (Oro *et al.* 1995, Duhem *et al.* 2008, Castège *et al.* 2016). Indeed, the abundance of food is the product of a sharp increase in the human population in the Essaouira region (the average rate of human population growth in Morocco since 1994 is 1.32%), the production of trawling discards from the city's fishing port, and an increase in the number of open-air dumps (the municipal landfill is 12 km away). The most important factor that could explain the phenomenal population growth of gulls in Essaouira, however, is the protection of Mogador Island, which provides a refuge for YLG nesting. The inaccessibility of the island for humans and other predators is very important in breeding success (Vidal *et al.* 2001).

It is important to note that the increase in the number of YLGs recorded at the study site was followed by an increase in the area used for nesting due to urban colonization. Beaubrun (1988, 1994) made no mention of nesting in urban areas in 1985. This could be explained by the fact that only a few areas were used for nesting on Mogador Island in 1985, but the whole island was colonized by breeding pairs in 2019; the predominance of adults was added proof.

In summary, our results showed an explosion in the YLG population in the Essaouira and Mogador Island area, which seems to be one of the most important YLG breeding areas along the southwestern Atlantic coast of Morocco. The data also revealed an extensive and increasing tendency of the species to breed in urban areas. The number of roof-nesting gulls is increasing (SB pers. obs.) but hard to determine because of the difficulties in surveying some residential buildings where rooftops are completely unreachable. The abundance of alternative food from human activities and fish discards, which occur during spring and summer mainly in the Essaouira harbor (ONP 2020), may explain the boom. Although we do not have data yet, we strongly suspect that YLG success could negatively impact the breeding success (e.g., via predation on the eggs and young) of Eleonora's Falcons, whose most important Moroccan breeding population is in the Mogador Archipelago. Therefore, developing a program to monitor YLG population size and breeding parameters as well as improving the management of anthropogenic food waste, e.g., by sealing refuse containers and properly disposing of fishery wastes (Oro & Martínez-Abraín 2007), should help local authorities control the size of the YLG population.

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