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Colonization of the Yellow-legged gull in the southeastern Bay of Biscay and efficacy of deterring systems on landfill site

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A B S T R A C T

On the French Basque Coast (southwest of France), the Yellow-legged gull *Larus michahellis* has undergone a widespread demographic and geographical increase in the last decade, originally by population breeding in northern Iberia. The demographic increase seems to be due to a combination of several factors: the establishment of a landfill close to the coast and the availability of nesting sites.

Birds foraging on landfill sites affect day-to-day site operation. In recent years, thousands of gulls were present daily on the landfill site and have used waste as another feeding opportunity. Management methods were used to limit access of birds to the landfill site and to control the population to a natural dynamic. Distress calls and pyrotechnic means were used on the landfill site for 11 months. Abundance, behavior, efficacy of the deterring systems and distribution along the whole coast were studied.

Initial results showed a significant decrease in the abundance of gulls on the landfill site. A change in their behavior was also noted with a reduction in resting and feeding birds. This, combined with the uninterrupted, random, deterring system at the landfill site showed an efficient measure to control gulls population. Monitoring along the coast did not show any significant impact on common resting sites.

Despite these promising results, we cannot exclude a new opportunistic response from the gulls. In addition, the proximity of Spanish colonies requires cross-border management for effective control of the population. Long-term monitoring is needed both at the landfill site to measure possible habituation and at the nesting sites to assess breeding success after one year of deterring actions.

1. Introduction

Gulls are often found to be superabundant due to their adaptable, opportunistic and gregarious nature which makes them highly adapted to living in man-modified habitats (Blokpoel and Spaans, 1991). In France, the Yellow-legged gull *Larus michahellis* has also undergone a population explosion over the past 30 years, notably on the northern shores of the Mediterranean Sea (Yésou and Beaubrun, 1995; Thibault et al., 1996). This gull, whose breeding range extends from the Azores to the Aral sea, is the most common and wide-spread larid of the Mediterranean basin and includes at least 120,000 nesting pairs in the western Mediterranean (Pérennou et al., 1996). On the Atlantic coast, the geographical distribution of gulls during breeding and non-breeding season has also been extended. The global population of Yellow-legged gulls was estimated to be 235,000 pairs in the late 1990s (Heath et al., 2000) including 42,000 in France and less than 200 pairs on the Atlantic coast until 2000 (Vidal et al., 2004).

The demographic increase is due to a combination of three main factors (Oro et al., 1995; Oro, 1999; Duhem et al., 2008): the establishment of a number of peri-urban open-air landfills; the development of industrial fisheries; and the protection of several areas where the species breed, in particular certain islets. Landfills provide an abundant food supply, particularly during the non-breeding period, but they generate impacts at both individual and population levels, with consequences translated to ecosystem functioning (Oro et al., 2013).

Some control programmes have already been implemented around the world. Various methods are used: destroying eggs (Engeman et al., 2012); culling adults (Bosch et al., 2000); use of distress calls, pyrotechnics, blank ammunition, hawks, wailers and helium-filled bird-scaring kites (Baxter, 2000; Cook et al., 2008;

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Soldatini et al., 2008; Thiériot et al., 2012).

The Basque coast and northwest Iberian coast (Cantabrian; Bay of Biscay) have also been heavily colonized by the Yellow-legged gull since the second half of the 20th century, with nearly 100,000 pairs breeding in Iberia (Arizaga et al., 2009). Currently, two sub-species are recognized as breeding in Iberia (Pons et al., 2004): *L. m. michahellis*, present around the Mediterranean basin, and *L. m. lusitanius*, on the Atlantic coast from the southeastern Bay of Biscay to central Portugal. Previous studies have shown movements of Mediterranean Yellow-legged gulls to the Bay of Biscay, related to their foraging behavior during the non-breeding season, whereas *L. m. lusitanicus* appears to be resident (Munilla, 1997; Martínez-Abrain et al., 2002; Arizaga et al., 2009; Galarza et al., 2012).

The French Basque Yellow-legged gulls colonies (Bay of Biscay; south-west of France) have been established since 1996 and underwent a sharp population increase between 1996 and 2013 (Castège et al., 2013). This population explosion, also observed along the Spanish Basque coast where large new colonies appeared during the same period, is partly linked to the high availability of food in three landfills: Urteta and San Marcos in Spain (Arizaga et al., 2009) and Zaluaga Bi in France (CSDU - Centre de Stockage des Déchets Ultimes - Ultimate Waste Storage Center). The San Marcos landfill closed in 2008, so gulls began to use the Urteta landfill where falconry is implemented since 2010 (Arizaga et al., 2013a). Some studies had already proven that geographic variation in diet is correlated with the distance of colonies to important feeding locations, such as harbors, fishing areas, refuse tips or crops (Moreno et al., 2009; Ramos et al., 2009).

Birds foraging on landfill sites affect day-to-day site operation. *Via* predation, the Yellow-legged gull has also played a role in the attrition of a small population of European Storm petrels *Hydrobates pelagicus*, already decreasing in relation with the climate change (Hémery et al., 1995; Castège and Hémery, 2009; Castège et al., 2009). This kind of threat is often due to particular individuals which specialize in killing European Storm petrels (Sanz-Aguilar et al., 2009).

For 11 months, deterring systems were used at the CSDU landfill site to reduce the nuisance and damage caused by the increasing population of gulls. The present work describes the colonization of the Yellow-legged gull in the southeastern Bay of Biscay and presents the results of the deterring actions, their efficacy and potential effect on the Yellow-legged gull population in the area.

2. Materials and methods

2.1. Study area and survey

The study area is located along the French Basque coast (southwest of France) in the southern half of the Bay of Biscay. Three different surveys were conducted: (1) colonization by breeding gulls since 2001, (2) spatial distribution of gulls on the French Basque coast during breeding and wintering periods since 2006 and (3) response to deterring systems on the landfill site since 2013. Data on ringed birds are opportunistic as we recorded their presence regardless monitoring or period. Sometimes age classes could not be distinguished because gulls were too numerous on the landfill. Therefore, these data are not used in this study.

2.1.1. Breeding gulls monitoring

Two colonies are established in this area, at a distance of 20 km: Biarritz and Hendaye (Fig. 1). First observation of breeding pairs has been referenced in Hendaye in 1996 (Milon and Castège, 2015) but, then, data were not available until 2001. Between 2001 and 2013, all nests (breeding pairs) were counted in Biarritz and Hendaye, in April and July, by which time almost all clutches have been completed, directly on colonies or by using a telescope from the coast. The breeding population is expressed in numbers of nests.

2.1.2. Whole population monitoring

The second survey was conducted during the breeding and wintering periods at six stations (Fig. 1): Biarritz, Saint-Jean-de-Luz, the Cliff, Hendaye, Txingudi bay and the CSDU, the only landfill site where constant, highly predictable and significant food sources are available (St Péé sur Nivelle, ca. 6 km inland). Research effort was equal in all stations in terms of time and people sampling.

Data were collected since 2006 on randomly selected days and time periods, from sunrise to the end of the day. Several samples were recorded each month, according to observers' availability. Exceptionally and beyond our control, there was no monitoring in winter 2006 on the landfill site. The abundance of Yellow-legged gulls in the study area was weighted by the sampling effort and expressed as mean numbers of individuals per count. Daily and annual mean abundances were used to carry out descriptive analyses.

2.2. Deterring systems at the landfill

The CSDU was created and has been in operation since 2003. It has a storage capacity of one million tons and aims to eliminate 50,000 tons of waste per year from the surrounding communities. It is located almost 6 km inland and has attracted gulls since its creation. Wastes were dumped and compacted in an area covering approximately 2500 m^2. Birds used this area from the first hour of daylight to the end of the day. Additional observations of Yellow-legged gull behavior were made (resting, feeding, in site flight and out site flight).

For 11 months (from April 2013 to March 2014), deterring actions were used on the CSDU site to limit the access of birds to the landfill and to control the population dynamics. The deterring actions combined pyrotechnics and distress calls (natural or man-made calls) from the trash compactor or a static point. There was a break every day between 1 p.m. and 2 p.m. First sights of habituation were observed in October 2013. Therefore management was adapted through uninterrupted deterring actions. In addition, pyrotechnic shots outside the landfill were performed to deter huge groups of gulls resting on nearby fields.

Gulls experienced two different deterring treatments during the study period: “simple deterring systems”, implemented in April 2013 until September 2013 and “uninterrupted deterring systems”, from October 2013 to March 2014. A break of two months in the visual counts was made (January and February 2014). A control period, from March 2013 to April 2013 (6 weeks) was applied before the implementation of the deterring systems.

2.3. Statistical analysis

Efficacy of the deterring systems was assessed by the *E* index (established by Soldatini et al., 2008) using the following formula:

$$E = [(N - nFD) - (nFD - nR)]/N$$

With:

- initial number of birds (N): the total number of birds counted prior to the treatment;
- number of departures (nFD): total number of birds that took off in response to the signal;

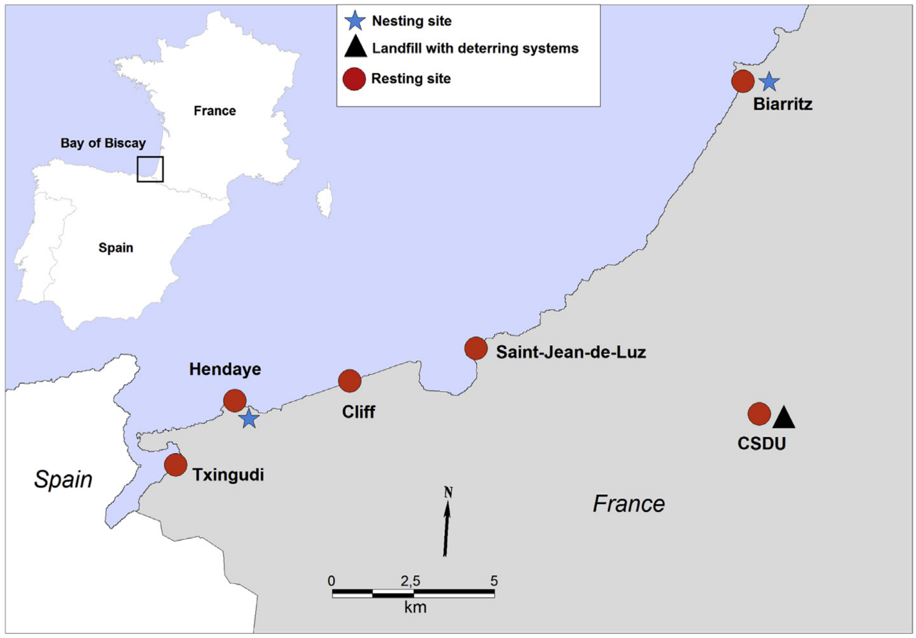

Fig. 1. Location of the sampling points including colonies (blue star), resting sites (red circle) and landfill (black triangle). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

- number of returned birds (nR): number of birds back in the area after the trial; birds were counted when the flock of landed birds was almost stable and the birds started looking for food

The interpretation of E index can be summarized as follows:

$E \geq 1$ no reaction (in the case of $E > 1$: more gulls arrived in the study area than were present at the start of the stimulus);

$0 \leq E < 1$ weak reaction (the whole flock or a small part of it takes off and comes back again. Total numbers are unchanged);

$E < 0$ strong reaction (the whole flock flies away and no birds, or only some, come back).

Analyses were performed with a daily mean index. Possible changes in E index and behavioral patterns of gulls during deterring actions were analyzed with a Chi2 test. The non-parametric Kruskal–Wallis H test (one-way ANOVA on ranks) and Wilcoxon Mann–Whitney U test (post-hoc test) were used to compare median abundance before and after deterring actions at the landfill site or over the whole survey area. To take into account seasonality in Yellow-legged gulls ecology (Castège and Hémery, 2009), we compared the abundance of 6 weeks between March 2013 and April 2013 (before the deterring systems were installed) with the same 6 weeks between March 2014 and April 2014 (during the deterring period).

To assess the significant breaks and changes in level of abundance studied over time, a segmentation procedure (Hubert et al., 1989) was used. It is an iterative procedure with successive cutting of the sample based on the statistical tests of comparison of means. This procedure was used to test fluctuations in the mean level of the abundance data set. The calculations were carried out using Khronostat software, available at: http://www.hydrosciences.org/spip.php?article239.

The graphs and statistical analyses of the data were undertaken using Excel v7, and R software. Sampling fluctuations around the mean abundance were described by their standard error ($SE=SD/\sqrt{n}$ with SD: standard deviation and n: sample size).

3. Results

3.1. Colonization by breeding Yellow-legged gulls

The local population of breeding Yellow-legged gulls rose sharply (6450%) between 1996 and 2013 (Fig. 2). The first proof of successful nesting of this species in the area began in Hendaye in 1996 and in Biarritz in 2002. The number of breeding pairs increased at both sites to reach a total of 135 in 2013. The reproductive population was more abundant in Hendaye. The colonization pattern in Biarritz began slowly before reaching a peak in 2006 (number of breeding pairs was threefold).

The origin of the gulls can be tracked through the ringing process. Among the ringed gulls observed, 337 were identified (Fig. 3). Immature birds represented 64.1% of the ringed gulls (Table 1). In our case, gulls were from the Spanish Basque coast, mainly (89%) from the colonies in San Sebastian, located within 50 km. These ringed gulls were mostly recorded at the landfill site (82%).

3.2. Efficacy of the deterring actions at the landfill

The deterring actions have been conducted since April 2013 and up to the present, but analyses presented in this paper were stopped in March 2014. Hubert's segmentation procedure revealed two significant breaks in measures from landfill observations (Fig. 4). The first break coincided perfectly with the start of deterring operations. In the first weeks (1–6) gulls' abundances decreased from a daily mean of about 1261.3 (±404.8) to 148.9 (±52.4) and gulls were not trying to rest or feed on the site. They began to feed again after 7 weeks of deterring actions but only when the trash compactor was stopped. Around 20 weeks later, gulls began using the fields nearby to rest, instead of the landfill, and waited for the employee break to feed.

The "uninterrupted deterring actions" were applied 27 weeks after the beginning of the deterring systems. The number of gulls immediately dropped (25.6 ± 10 gulls per count) and birds no longer tried to feed at the landfill. Gulls avoided the site during 3

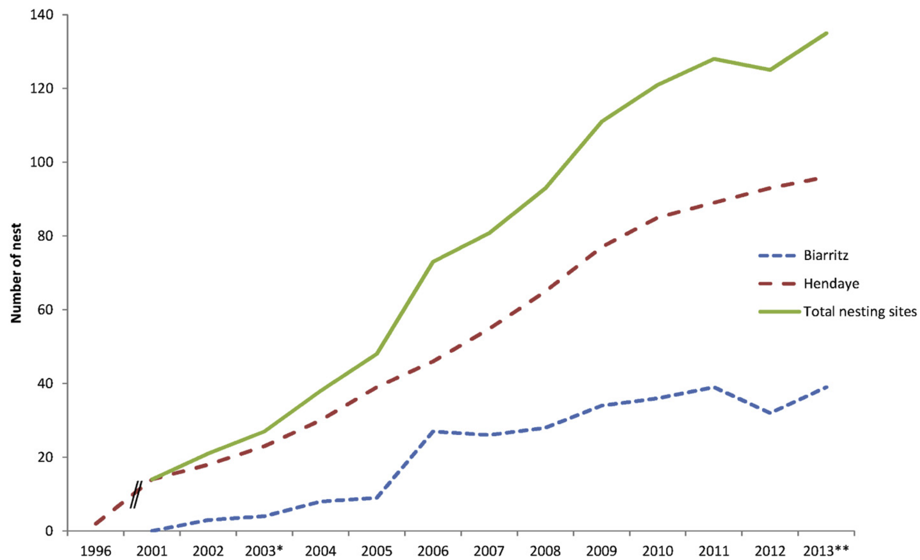

Fig. 2. Changes in Yellow-legged gull reproductive population (breeding pairs) at the two nesting sites of the French Basque coast from 1996 to 2013. The single * indicates the opening of the landfill and the double ** indicates when the deterring systems were installed. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

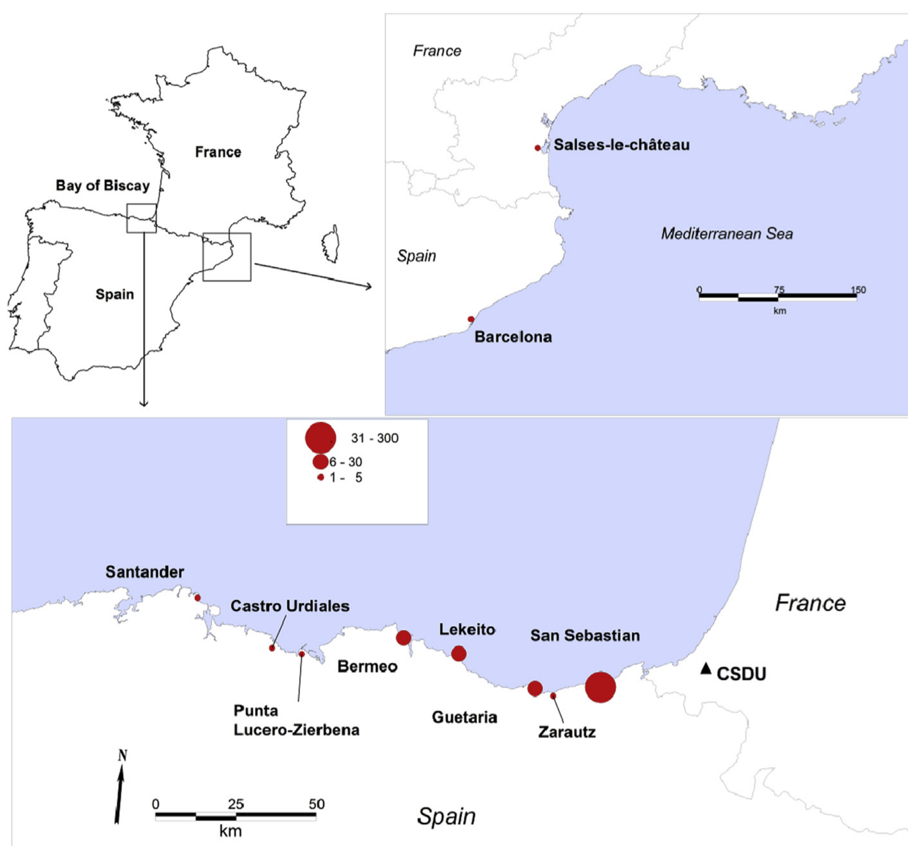

Fig. 3. Origin and total number of the ringed Yellow-legged gulls recorded on the French Basque coast from 2006 to 2013. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

weeks. Despite these visual results, no significant break was measured. A second break appeared more than a month and a half after the start of uninterrupted operations when the number of gulls increased again. This break coincided with the beginning of the wintering season and the return of migratory gulls.

The first weeks of control (*i.e.* March 2013) showed a higher abundance ($p \ll 0.01$) compared to the same period (*i.e.* March 2014) during "uninterrupted deterring actions". Fluctuations in abundance were quite irregular from the start of deterring actions but there were no significant changes in the median values

Table 1
Distribution of adults and immatures, origin, total number and percentage of the ringed Yellow-legged gulls recorded on the French Basque coast from 2006 to 2013 (the age of the gull from Punta Lucero-Zierbena is unknown).

Colony	No. Gulls	% Adults	% Immatures
San Sebastian	300	35.3%	64.7%
Guetaria	13	53.9%	46.1%
Lekeito	8	37.5%	62.5%
Bermeo	7	28.6%	71.4%
Castro Urdiales	2	0%	100%
Santander	2	0%	100%
Zarautz	2	50%	50%
Punta Lucero-Zierbena	1	/	/
Barcelona (Mediterranean Sea)	1	100%	0%
Salses le château (Mediterranean Sea)	1	0%	100%
Total	**337**	**35.6%**	**64.1%**

between the two management periods ("simple deterring actions" and "uninterrupted deterring actions") ($p = 0.42$).

The efficacy of the deterring systems regarding the *E* index did not show a trend over time (Fig. 5). Overall, the deterring actions gave quite good results. They varied between weak and strong reaction. A single measurement indicated "no reaction". Although statistically non-significant (Chi2 test, $p = 0.09$), the "uninterrupted deterring actions" showed stronger reactions (70%) than the "simple deterring actions" (40%).

The behavior of gulls changed in response to deterring actions (Chi2 test, $p << 0.01$). Resting was the dominant behavior before the survey (56.6%) ahead of feeding (33.4%). During the "uninterrupted deterring actions", gulls were clearly stressed out (64% were flying) and they rested off-site (18.1%). Only 6% of them were trying to feed (Table 2).

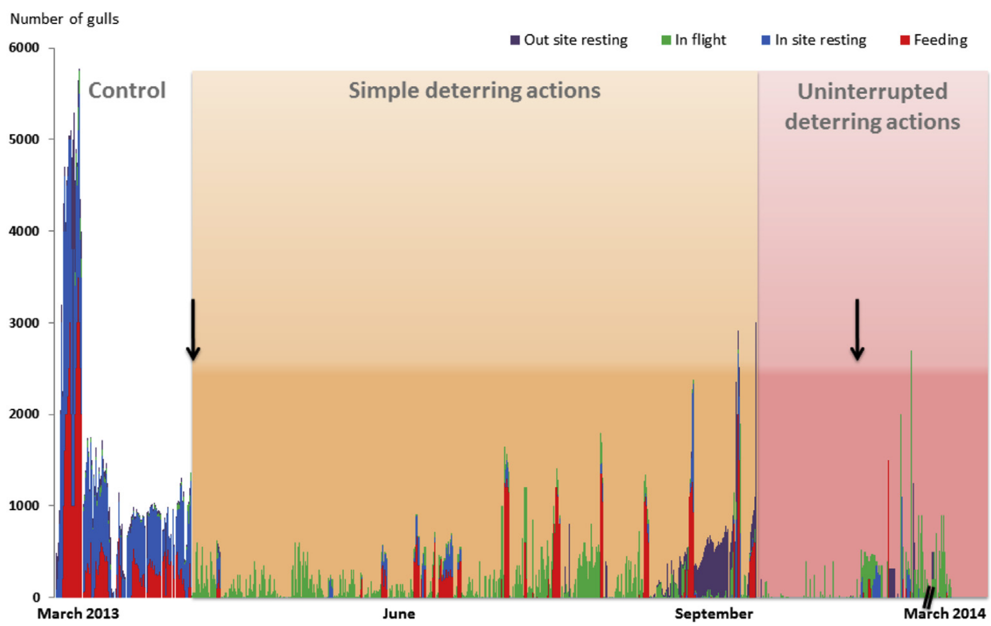

Fig. 4. Changes in the number of Yellow-legged gulls and behavioral response per count during the study on the CSDU ("Simple deterring actions" present a daily break compared to "uninterrupted deterring actions" implemented in October 2013). The black arrows represent the significant breaks revealed by Hubert's segmentation procedure. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

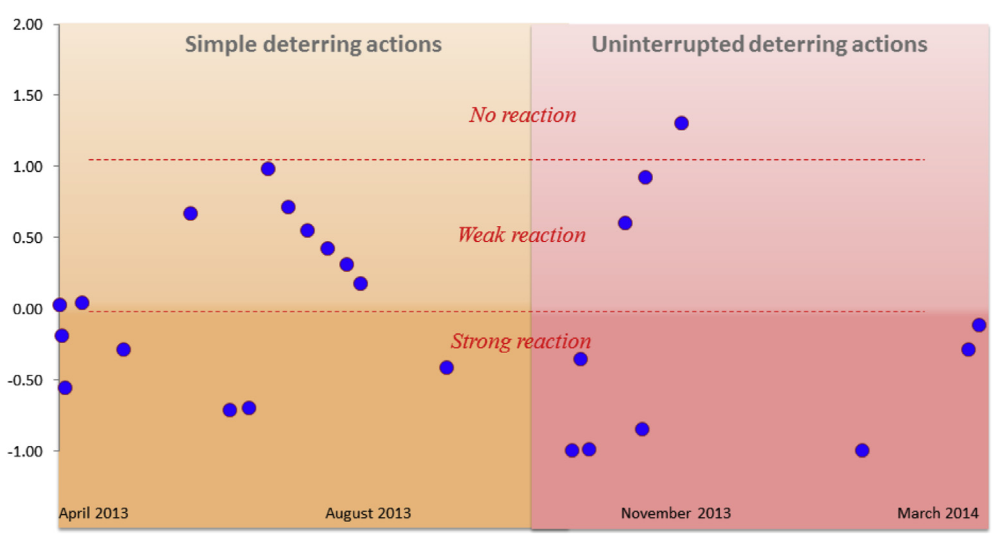

Fig. 5. Mean daily index (Soldatini et al., 2008) over the time summarizing the effects of deterring actions on Yellow-legged gull movement and approach to the CSDU site. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Distribution of mean abundance (mean numbers of individuals per count) ± standard error (SE) and percentage of Yellow-legged gulls based on their behavior at the CSDU site before the deterring actions (control) and during the deterring experiments ("Simple deterring actions" presented a daily break unlike "uninterrupted deterring actions" implemented in October 2013).

Behavior	Control period	SE	%	Simple deterring actions	SE	%	Uninterrupted deterring actions	SE	%
Feeding	525.3	69.5	33.4%	90.5	11.2	28.1%	13.7	8.2	6.5%
Resting	888.4	66.3	56.6%	42.2	6.4	13.1%	24.3	7.4	11.4%
Flying	27.5	4.7	1.8%	132.6	7.3	41.2%	136.5	22.1	64%
Outside resting	129.5	31.1	8.2%	56.6	7.5	17.6%	38.5	17.8	18.1%

3.3. *Impacts of the deterring systems on the French Basque coast*

Temporal variation in mean abundance of wintering Yellow-legged gulls at the landfill site increased from 2006 to 2011. A significant decrease ($p = 0.01$) was noted after the deterring systems establishment between winter 2012 (*i.e.* September 2012 to January 2013) and winter 2013 (*i.e.* September 2013 to January 2014) (Fig. 6b) unlike the breeding period (Fig. 6a) during which no statistical change was found. Abundance has not fluctuated at the other locations along the French Basque Coast (*i.e.* Biarritz, Saint Jean de Luz, Cliff, Hendaye, Txingudi) in response to the deterring actions, neither in wintering nor in breeding period.

4. Discussion

On the French Basque coast, the Yellow-legged gulls breeding population has undergone a sharp increase since 1996. This population comes from the colonies in Spain which have also grown rapidly for 20 years (Arizaga et al., 2009). Indeed, we controlled 335 ringed gulls from the Spanish Basque coast colonies (Fig. 3, Table 1). Since 1996, the installation of colonies indicated a northward expansion of these populations. This colonization by gulls from Spain was most probably facilitated by the abundant, stable feeding source available at the CSDU landfill site. The important role of landfills in increasing the number of gulls' colonies or the influence

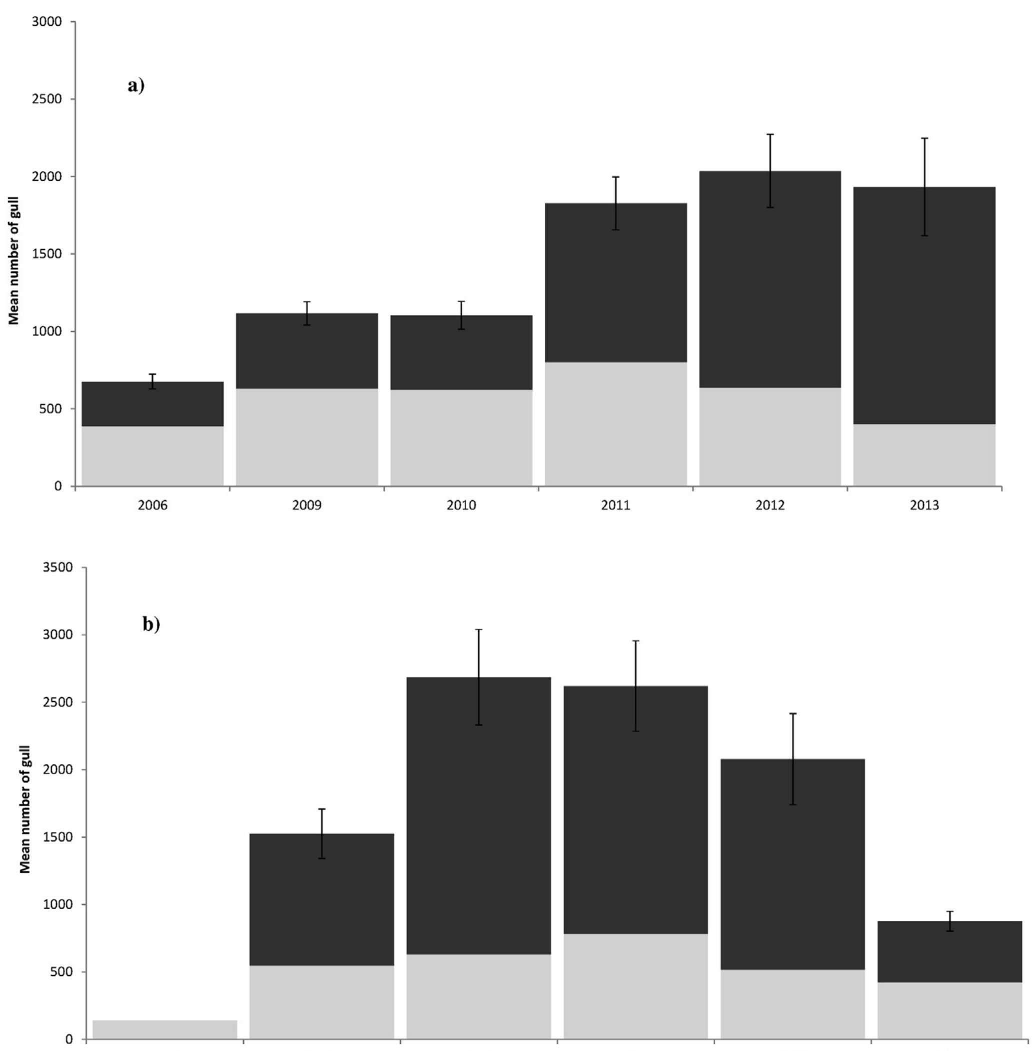

Fig. 6. Mean number (mean number of individuals per count, ± SE) of Yellow-legged gull during breeding (a) and following wintering (b) periods at the CSDU landfill site in black, and the coastal sites (Biarritz; Saint-Jean-de-Luz; Hendaye; Txingudi) in grey from 2006 to 2013. There was no monitoring in winter 2006 at the landfill site.

of the location of colonies has already been studied in Spain (Arizaga et al., 2013a, b) and on the Mediterranean coast (Bosch et al., 1994; Sol et al., 1995; Rock, 2005; Soldatini et al., 2005; Duhem et al., 2008; Ramos et al., 2009).

Our study has measured the impacts of deterring systems on the gull's abundances on two scales: at the landfill and on the whole French Basque coast. At the landfill site, a significant decrease was noted after the deterring actions between the same weeks of the breeding season (March 2013 (control) and March 2014). This result indicated the success of the deterring systems on gulls which used to forage or rest at the landfill. At a greater scale, abundance of gulls during the breeding period did not change along the whole coast between 2012 and 2013. However, it significantly decreased at the landfill site between winter 2013 and the winter following the establishment of deterring systems (2013). Our results suggested that the decrease in abundance at the landfill was not transferred to other coastal sites (Biarritz, Saint-Jean-de-Luz, the Cliff, Hendaye, Txingudi bay).

Overall, these results showed that the loss of attraction of the landfill for wintering gulls was probably due to the deterring actions. Indeed, as a gregarious species (Blokpoel and Spaans, 1991) the decrease in abundances of gulls at the landfill site could discourage use by new migratory birds. Moreover, Arizaga et al. (2013a) showed that gulls have moved to more distant regions during the winter when access to main landfills was limited. We cannot exclude a new extension of the foraging distances of these wintering populations. This would also explain the decline of abundance in the winter period on the landfill (Fig. 4), while coastal sites are still occupied by more sedentary populations.

As demonstrated by several studies, the Yellow-legged gull is an opportunistic feeder and is highly adaptable in response to changes in landfill accessibility (Duhem et al., 2003; Arizaga et al., 2013a). Hence, we considered that gulls used an alternative foraging habitat, mainly the marine environment since the diet of some gull colonies from the area is reported to also depend on fish (Arizaga et al., 2011, 2013b). By the way, the Bay of Biscay already provided an important supply of food during the non-breeding season for Mediterranean Yellow-legged gulls (Galarza et al., 2012; Arizaga et al., 2010, 2013a). This hypothesis of an alternative foraging habitat might be supported with diet analyses.

Other studies concluded that deterring systems work for a limited period due to the effects of habituation (Woronecki, 1988; Belant and Ickes, 1997; Baxter, 2000; Baxter and Allan, 2006; Gagliardi et al., 2006; Ronconi and St. Clair, 2006; Cook et al., 2008; Soldatini et al., 2008; Thiériot et al., 2012). Considering simple and uninterrupted deterring actions, our results indicated an acceptable efficacy for almost one year (Fig. 5). In addition, methodological tests in previous studies were often carried out over a short period (*i.e.* a few weeks to a few months), while our experiment lasted over a year. The noted efficacy in our study can be explained by our combined method based on acoustic and pyrotechnic methods, minimizing the habituation of gulls, as predicted by Cook et al. (2008).

Results from the landfill site showed a significant decrease in the abundance but also a change in the behavior of gulls. The role of landfills in terms of social interaction, resting and feeding (Belant et al., 1993) was here reduced by the deterring actions. Gulls were more stressed out (in flight) and they had to change their resting and feeding habits. A slight habituation during the employee break was recorded around 7 weeks after the beginning of the “simple deterring action”. Since “uninterrupted deterring actions” have been carried out, this problem has disappeared and abundance in feeding and resting gulls remained far below the usual numbers of gulls during the wintering period (more than 5000 ind.). This new type of management led to a decrease in the abundance of gulls and to almost no longer feeding behavior.

Arizaga et al. (2013a) demonstrated that management of landfills on a local scale had direct implications on the movement patterns of local gulls. According to previous studies (Pons, 1992; Pons and Migot, 1995; Oro et al., 2013) we can expect future impacts on breeding parameters (clutch size, number of breeding pairs, hatching success, etc.) and population dynamics.

The proximity of Spanish colonies (<50 km for the biggest one) should lead to cross-border management. The Yellow-legged gulls that feed and nest along the French Basque coast came mainly from these Spanish colonies and had probably used the CSDU because of the closing of Spanish landfills. Our study highlighted the need to manage gull populations beyond the local scale in order to guarantee that the biological pattern and population dynamic of the species did not influenced by anthropogenic food. To our knowledge, Yellow-legged gulls can still access to three landfills in Spain (Jordi et al., 2014). Two European Union Action Plans are currently under development and seek to decrease the availability of food derived from human activities to gulls, such as landfills (Landfill Waste Council Directive) and fishery discards (Common Fisheries Policy Reform).

The Common Fisheries Policy Reform is currently planning a decrease in discarded fish that will probably impact the breeding performance of the Yellow-legged gull (Oro et al., 1995; Bicknell et al., 2013) in the coming years. Some gulls species are able to switch to alternative prey or move into novel habitat such as inland and urban environment in response to discard declines (Oro et al., 1997, 2013 and references therein). However, this switching of prey by a facultative scavenger presents a potentially serious threat to some seabird communities (*e.g.* Furness, 2003; Votier et al., 2004). The overall situation might eventually lead to a decrease of the gull population until stability around a new dynamic equilibrium occurs, as predicted by Oro et al. (2013).

These management decisions should be taken into account when forecasting changes in gull population dynamics. In this regard, presumed drastic reductions are expected in most Yellow-legged Gull colonies. Some Spanish Basque colonies have already been impacted by previous closing landfills (Arizaga et al., 2014) then we expect the same consequences to the French Basque coast colonies.

In conclusion, we recommend deterring actions on landfill sites with (1) biological monitoring to eventually adapt the actions (2) a combined and random technique to limit gull habituation and, (3) uninterrupted actions with no break during the day-to-day operations of the landfill. Overall, a true assessment of the impact of management on gull populations (demographic parameters, possible habituation, behavior changes, etc.) needs further monitoring on a long-term basis. Consequently, coordinated cross-border management must be considered in the future.

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