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Parasitic fauna of a yellow-legged gull colony in the island of Escombreras (South-eastern Mediterranean) in close proximity to a landfill site: potential effects on cohabiting species

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Abstract

We identified the ectoparasites and helminth fauna of yellow-legged gulls (*Larus michahellis michahellis*), breeding near to a solid waste landfill, and compared infection levels with those of other yellow-legged gull colonies. Moreover, we analysed correlations between parasites and sex and body condition of yellow-legged gulls, co-infections and the helminth community structure in order to propose the role of this species as reservoir of certain parasites. We also discuss the potential transmission of parasites between the yellow-legged gull and the endangered Audouin's gull, because interactions between these two species, such as kleptoparasitism and predation, occur frequently around colonies. The following species were recorded: *Ornithodorus capensis* (Arthropoda); *Cosmocephalus obvelatus*, *Paracuaria adunca*, *Eucoleus contortus*, *Tetrameres skrjabini* and *Contracaecum* sp. (Nematoda); *Tetrabothrius cylindraceus* (Cestoda); *Acanthotrema armata*, *Cardiocephaloides longicollis* and *Ornithobilharzia intermedia* (Digenea). *Tetrabothrius cylindraceus*, *A. armata* and *O. capensis* are new parasite records for this host. The dependence of yellow-legged-gulls on fishery discards is supported by the dominance of parasites transmitted through marine intermediate hosts with interest to fisheries in the study area. However, the shift in diet from natural resources to food derived from human activities seems not to affect the parasitic fauna of yellow-legged gull. Besides of direct physical contact between individuals in nesting and resting habitats, the high availability of fishery discards could increase the risk of Audouin's gulls to be infected by common parasites of yellow-legged gull.

Keywords

Fishery discards, helminths, *Larus audouinii*, *Larus michahellis*, parasite transmission, reservoir, rubbish dump, ticks

Introduction

Over the last decades much attention has been focused on the increase of yellow-legged gull (*Larus michahellis*) (Aves, Laridae) populations (Vidal *et al.* 1998), which has been associated to high food availability, mainly from fishery discards and open-air refuse dumps (Bosch *et al.* 1994; Duhem *et al.* 2003; Ramos *et al.* 2009). Landfill sites are highly correlated with the presence of intestinal parasites (Abeyeba and Akinbo 2002), which are potentially infectious for animals or a threat to public health (Hatch 1996). In fact, many cases of parasite infections associated with waste landfill have been recorded in mammals (Wilson *et al.* 1994), invertebrates (Bot *et al.* 2001) and birds (Kuklin 2013).

The subspecies *L. m. michahellis* (Olsen and Larsson 2004) occurs along the Mediterranean coast (Pons *et al.* 2004) and feeds mainly on refuse dumps and fishery discards (Furness *et al.* 1992; Ramos *et al.* 2009). Although the shift in diet from natural resources to food derived from human activities is likely to affect trophically transmitted parasites (Aponte

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*Corresponding author: shparejo@gmail.com *et al.* 2014), this has received limited attention. At landfills, due to the high concentration of gulls, helminth eggs shed in the faeces, as well as the directly-transmitted parasites (such as arthropods) can be dispersed indiscriminately (Abeyeba and Akinbo 2002). However, recent studies on the parasitic fauna of yellow-legged gulls are scarce (Bosch *et al.* 2000; Álvarez *et al.* 2006) and more knowledge of their parasites is needed, especially in colonies feeding in refuse dumps.

Among the negative effects of yellow-legged gulls' population growth on other bird species, habitat and foraging competition (Martínez-Abraín *et al.* 2003; Oro *et al.* 2004), nest predation (Rusticali *et al.* 1999; Hernández-Matías and Ruiz 2003) and predation on adults (Oro *et al.* 2005) are well documented. Nevertheless, the role of yellow-legged gull as reservoir and transmitter of parasites to cohabiting birds has not been assessed. In the Mediterranean Basin, the yellow-legged gull share some of the same habitats as the endemic Audouin's gull (*L. audouinii*) (Cramp and Simmons 1983), that is considered Near Threatened (BirdLife International 2014). This risk of parasite transmission may increase during the breeding season by predation of yellow-legged gulls on Audouin's gull nests (Castilla 1995) but, also, by competition for breeding habitat and food resources (Oro and Martinez-Vilalta 1994). Therefore, the impact of parasites on Audouin's gull may have important implications to its health and, therefore, its conservation status.

The main goal of this study was to identify the ectoparasites and helminth fauna of yellow-legged gulls breeding near to a major municipal landfill and compare infection levels with those of other yellow-legged gull colonies. Moreover, we examined correlations between parasites and sex and body condition of yellow-legged gulls, co-infections and the helminth community structure. This information allowed us to propose the role of this species as reservoir of parasites that could be important to threatened species. Furthermore, we discuss the potential transmission of parasites between the yellow-legged gull and the endangered Audouin's gull, since interactions between these two species occur frequently around colonies.

Materials and Methods

A total of 39 yellow-legged gulls were captured in April 2008 from a breeding colony on Escombreras (37°33´50″N; 00°58´10″W) (South-eastern Mediterranean, Murcia, Spain). Escombreras is one of the largest of a total of 18 islands that constitute the *Espacio Natural Protegido de las Islas e Islotes* of the Mediterranean coast. This island has a surface of 4 ha, a maximum altitude of 60 m and lacks of vegetation cover.

Captures took place coinciding with the onset of the breeding season, as a part of the annual strategy to prevent the rise of the yellow-legged gull populations carried out by the *Consejería de Agricultura*, *Agua y Medio Ambiente* (autonomous region of Murcia), by sacrificing adult birds to decrease their reproductive success.

Immediately after euthanasia, ectoparasites were collected and preserved in 70% ethanol. Subsequently, gulls were individually stored in plastic bags, transferred to the University of Murcia (Animal Health Laboratory) and preserved at –20°C until necropsy. In the laboratory, carcasses and plastic bags were again carefully inspected for ectoparasites. Specimens were mounted in Hoyer's medium (Krants 1978) and identified according to Vermeil and Marguet (1967) and Jones *et al.* (1972).

Before necropsy, measures of body mass and tarsus length were recorded. All gulls were adults (> 4 years) on the basis of their plumage coloration, according to Grant (1982). The body condition was expressed as the ratio of body mass divided by tarsus length (Ruiz *et al.*. 1995; Bosch *et al.* 1997; Bosch and Figuerola 1999). The gull sex was determined at necropsy, being 13 males and 26 females (sex ratio 1:2).

Trachea, air sacs and lungs were carefully examined. Sections of the alimentary tract (divided into oesophagus, crop, proventriculus, ventriculus, small and large intestine) were scraped and the content washed in a sieve (mesh size 300 mm diameter). Both content and mucosa were observed under the stereomicroscope for helminths. Nematodes were collected, fixed in 70% alcohol, and cleared with Amman's lactophenol for examination¸ and platyhelminths were fixed in 3% formaldehyde and stained with Semichon's acetic carmine (Pritchard and Kruse 1982). Subsequently, helminths were identified using morphometric characteristics according to Skrjabin *et al.* (1951), Baer (1954), Yamaguti (1971), Anderson *et al.* (1974), Schmidt (1986), Khalil *et al.* (1994) and Pearson *et al.* (2008).

Muscle tissue was analysed for the presence of *Trichinella* larvae by a pooled artificial digestion method (Gamble *et al.* 2000). Briefly, 10 g of pectoral muscles without fat from each gull were chopped to facilitate digestion; each pool was formed by five gull muscle samples (50 g) digested with freshly prepared 1.5% (w/v) pepsin (1: 10 000 activity) and 1.5% (w/v) chlorhydric acid in distilled water. Digestion was carried out at 40°C for one hour under gentle shaking. The digested material was washed by centrifugation at 500 g for five minutes and the sediment was resuspended in 10 ml of distilled water. When larvae were detected in a Favatti chamber, 10 g muscle sample from each gull analysed in a positive pool were tested individually using the same digestion method. Larvae were washed three times in distilled water and preserved in small conical plastic vials with absolute ethyl alcohol until their identification at the Community Reference Laboratory for Parasites (*Istituto Superiore di Sanità*, Rome, Italy). For this purpose, a PCR analysis was carried out according to Pozio and La Rosa (2003).

Prevalence (P), mean intensity (MI), and mean abundance (MA) were determined according to Bush *et al.* (1997). Specifically, P is the percentage infected of individuals, MI is the estimated number of parasites per infected individual, measured in specimens per infected animal (spia) and, finally, MA is the estimated number of parasites per total number of examined host, measured as specimens per analysed animal (spaa). All values are expressed as mean ± Standard Deviation (SD).

Following Hanski (1982) and Fedynich and Pence (1994), three categories of helminths were established according to their prevalences: "essential or key species" (those with $P > 70\%$), "secondary species" ($P = 20–70\%$) and, finally, "tertiary or satellite species" (when $P < 20\%$). Holmes and Price (1986) noted that essential and secondary species (together are known as "common species") constitute the basic structure of the helminth community in a host population. Hence, we included only common species in the statistical analysis.

We used the independent two-samples T-test to study whether prevalence and intensity values differed between host sexes. A contingency table was conducted to test whether parasite prevalence influences body condition. In addition, we conducted bivariate correlations to determine possible associations between pairs of parasite species. Finally, we carried out a multiple linear regression to study combinations among more than two species parasitizing together the same individuals.

Results

The diversity of parasites

All birds were infected by ectoparasites ($n = 358$; $P = 100\%$; MI = 9.2 spia ± 0.02 SD) identified as *Ornithodoros capensis* Neumann, 1901 (Acarina: Argasidae).

Thirty-five of the 39 gulls harboured helminths ($n = 389$; $P = 89.7\%$; MI = 11 spia ± 3.95; MA = 9.8 spaa ± 2.16). Most of the recovered parasites were platyhelminths ($n = 334$). Specifically, all cestodes ($n = 28$; $P = 64.1\%$; MI = 1.1 spia ± 2.6) were identified as *Tetrabothrius cylindraceus* Linton, 1927 (Tetrabothriidae), and three trematode species ($n = 306$; $P = 82.1\%$; MI = 19.2 spia ± 3.3) were found: *Acanthotrema armata* Lafuente, Roca and Carbonell, 2000 (Heterophyidae) ($n = 287$), *Cardiocephaloides longicollis* Rudolphi, 1819 (Strigeidae) ($n = 15$) and *Ornithobilharzia intermedia* Odhner, 1912 (Schistosomatidae) ($n = 4$). Within nematodes ($n = 52$; $P = 82.1\%$; MI = 8 spia ± 2.5), five species were identified: *Cosmocephalus obvelatus* Creplin, 1825 (Acuariidae) ($n = 29$), *Paracuaria adunca* Creplin, 1846 (Acuariidae) ($n = 10$), *Tetrameres skrjabini* Panova, 1926 (Tetrameridae) ($n = 5$), *Eucoleus contortus* Creplin, 1839 (Capillaridae) ($n = 5$) and *Contracaecum* sp. ($n = 1$). In addition, two Anisakidae nematodes were found but they could not be identified because of their deteriorated condition.

Most helminths (87%) were found in the small intestine (*T. cylindraceus*, *A. armata*, *C. longicollis*, *O. intermedia*) and 52 helminths were located in the oesophagus and proventriculus (*C. obvelatus*, *E. contortus*, *P. adunca*, *T. skrjabini*, *Contracaecum* sp.).

In two gulls ($P = 5.3\%$), *Trichinella*-like larvae were recovered from muscle tissue by the artificial digestion method (0.45 larvae/g of muscle; $n = 9$ larvae). The morphometric characteristics of these larvae coincide with *T. pseudospiralis*, but their size was smaller than the one described for *Trichinella* spp and negative results were obtained by the PCR analysis. Unfortunately, the larvae could not be identified using morphometric criteria.

The distribution of parasites in gull population

Among all endoparasites found in this study, *T. cylindraceus*, *A. armata* and *C. obvelatus* registered the highest prevalence. Moreover, *A. armata* and *C. obvelatus* also recorded the highest values of MI (Table I).

We found a positive correlation between host sex and both P and MI of three parasite species. The P and MI of *C. obvelatus* ($T = 2.13$, $p = 0.025$ and $T = 2.25$, $p = 0.016$, respectively) and *T. cylindraceus* ($T = 2.13$, $p = 0.018$ and $T = 2.41$, $p = 0.001$, respectively), and the MI of *A. armata* ($T = 2.16$, $p = 0.020$), were higher in female gulls. Moreover, the MA of *O. capensis* was also higher in females ($T = 2.11$, $p = 0.023$). No statistically significant association was found among P or MI and gull body condition, irrespective of the host sex.

Bivariate correlations were positive between *C. obvelatus* and *T. cylindraceus* ($r_p = 0.26$, $p = 0.050$) and *T. cylindraceus* and *A. armata* ($r_p = 0.29$, $p = 0.032$). Finally, the multiple linear regression revealed that MI of *C. obvelatus*, *T. cylindraceus* and *A. armata* were positively associated ($F = 14.32$, $p = 0.001$) in yellow-legged gulls.

Discussion

The diversity of parasites

This study found three parasite species that are new records for the yellow-legged gull: *O. capensis*, *T. cylindraceus* and *A. armata*. *Ornithodoros capensis* has been previously recorded from the laughing gull (*Larus atricilla*) (Keirans *et al.* 1992), the red-billed gull (*Chroicocephalus scopulinus*) (Austin 1984) and the black-tailed gull (*Larus crasssirostris*) (Kohls 1957), while *T. cylindraceus* and *A. armata* have been previously found in Audouin's gulls (Roca *et al.* 1999).

Two of the ten parasites found in this study (*O. capensis* and *E. contortus*) can be transmitted directly to other animals whereas eight have an indirect life cycle (*C. obvelatus*, *P. adunca*, *T. skrjabini*, *Contracaecum* sp., *T. cylindraceus*, *A. armata*, *C. longicollis* and *O. intermedia*). Adult females of the tick *O. capensis* lay small egg batches following each blood meal. The larva, the five nymphal stages and the adults all actively search for hosts from which to take blood-meals and, after feeding, they drop to the ground (Hoogstraal 1979). The eggs of the nematode *E. contortus* occupy the oesophagus of the host and are released in the faeces. If environmental conditions (temperature, sunlight, humidity) are

Table I. Prevalence, mean intensities (± Standard Deviation) and mean abundances for each parasite species found in the yellow-legged gull (*Larus michahellis michahellis*) from South West Mediterranean coast, Spain. *Common species

Species	Prevalence (%)			Mean intensity (± 3.95 SD)			Mean abundance		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
DIGENEA									
*A. armata**	30.70	69.50	51.28	10.5 ± 0.15	22.2 ± 0.99	16.33 ± 0.8	1.61	10.2	7.36
*C. longicollis**	30.70	15.38	20.51	2.25 ± 0.18	1.50 ± 8.14	1.88 ± 0.12	0.69	0.23	0.38
O. intermedia	15.38	7.890	10.26	1.00 ± 9.61	1.00 ± 6.95	1.00 ± 7.86	0.15	0.08	0.10
CESTODA									
*T. cylindraceus**	30.77	61.50	64.10	1.00 ± 2.02	1.15 ± 2.61	1.12 ± 2.58	0.38	0.88	0.72
NEMATODA									
*C. obvelatus**	15.38	46.15	35.90	1.00 ± 2.63	2.25 ± 0.14	2.07 ± 0.11	0.15	1.03	0.74
E. contortus	00.00	15.38	10.26	0.00 ± 0.00	1.25 ± 9.41	1.25 ± 7.86	0.00	0.19	0.13
*P. adunca**	30.70	11.50	17.95	1.25 ± 9.21	1.66 ± 9.01	1.43 ± 9.05	0.38	0.19	0.26
T. skrjabini	15.00	8.00	10.26	1.00 ± 9.61	1.50 ± 6.95	1.25 ± 7.86	0.15	0.12	0.13
Contracaecum spp.	00.00	03.80	2.560	0.00 ± 0.00	1.00 ± 5.12	1.00 ± 4.09	0.00	0.04	0.03
Anisakidae	00.00	07.69	5.130	0.00 ± 0.00	1.00 ± 7.08	1.00 ± 5.72	0.00	0.08	0.05
ARTHROPODA									
*O. capensis**	100.0	100.0	100.0	6.23 ± 0.00	10.65 ± 0.0	9.18 ± 0.00	6.23	10.6	9.18

favourable, the first-stage larva is formed inside the egg. A new host can be infected by ingestion of these eggs from contaminated soil or water (Anderson 1992). Therefore, the transmission of *O. capensis* and *E. contortus* may occur through physical contact between gulls in the feeding and resting habitats due to the gregarious behaviour of the yellow-legged gull (Vidal *et al.* 1998). But *E. contortus* can also use earthworms as paratenic hosts (Anderson 2000), and is therefore likely acquired in crops and terrestrial environments (Ramos *et al.* 2009).

In this study, most of the indirectly-transmitted parasites have a two-host life cycle, except the nematodes *P. adunca* and Anisakidae and the cestode *T. cylindraceus* that have a three-host life cycle. Only the species *Anisakis simplex* has been isolated before from yellow-legged gull in Galicia (Cordeiro-Paredes 2004; Sanmartín *et al.* 2005; Álvarez *et al.* 2006) and it involves various hosts at different levels of the marine food web; crustaceans (first intermediate host), fish and squids (second intermediate hosts) and mammals and birds (definitive hosts) (Ishikura *et al.* 1992).

Crustaceans and fish are the main intermediate hosts of all parasites found in this study. For instance, the amphipods *Crangonyx laurentanus*, *Gammarus fasciatus* and *Hyalella azteca* are intermediate hosts of *C. obvelatus* (Anderson 1992). Fish species act as paratenic hosts of *C. obvelatus* (Wong and Anderson 1982), *T. skrjabini* (Mollhagen 1976) and *Contracaecum* spp (Anderson 1992), and as second intermediate hosts of *P. adunca*, such as *Neogobius melanostomus* (Gobiidae) (Moravec 1994). For *T. cylindraceus*, fish and, cephalopods and teleosts, are the first and the second intermediate hosts, respectively (Temirova and Skrjabin 1978). The life cycle of *A. armata* is not known, but this trematode is considered Audouin's gull specialist (Roca *et al.* 1999) and, therefore, it probably uses fish (the main diet of Audouin's gull) as intermediate hosts. For *C. longicollis* several marine fish species have been documented as intermediate hosts, for example *Diplodus annularis*, *D. vulgaris*, *Boops boops*, *Pagellus mormyrus* (Sparidae) and *Belone belone* (Scombresocidae) (Prévot 1980). The life cycle of *O. intermedia* is also unknown but the *Ornithobilharzia* sp., whose life cycle is known, use marine species as intermediate hosts (Rind 1984). The infestation of yellow-legged gulls (final hosts) occurs by ingestion of these intermediate hosts with infected larvae of the parasites described.

The distribution of parasites in gull population

The most prevalent parasite species were *C. obvelatus*, *T. cylindraceus* and *A. armata*, which are acquired from marine species. In the present study, yellow-legged gulls likely consumed specific species of amphipods, cephalopods and fish infected with more specimens of these parasites than other prey-borne parasites (e.g. *Contracaecum* spp). The next most prevalent parasites *C. longicollis* and *P. adunca* are also typically found in fish.

Our study showed higher values of prevalence and mean intensity than those recorded in the Medes Islands (northwestern Mediterranean Sea) by Bosch *et al.* (2000) for *C. obvelatus* (P = 27.9%, MI = 1.6 spia), *P. adunca* (P = 4.9%) and *C. longicollis* (P = 11.5%), and in Galicia by Álvarez *et al.* (2006) for *P. adunca* (P = 16.8%) and *C. longicollis* (P = 1.9%) and by Sanmartín *et al.* (2005) for *T. skrjabini*

(P = 1.2–2.8%) and *O. intermedia* (P = 0.3%). Our prevalence values are probably higher than those of previous studies on the parasitic fauna of yellow-legged gulls due to the relatively recent increase in the consumption of fishery discards (Ramos *et al.* 2009). For instance, *D. annularis*, *D. vulgaris*, *B. boops* and *B. belone*, described as intermediate host for these parasites, are species of interest to fisheries in the study area (Verdiell 2010).

We observed a positive association between the most prevalent species, *C. obvelatus*, *T. cylindraceus* and *A. armata*, and female gulls. *Acanthotrema armata* registered the highest prevalence and mean intensity for female birds among all parasites found in our study; also we found a higher prevalence for this trematode when compared with the values recorded by Roca *et al.* (1999) in Audouin's gull (P = 31%, MI = 34.6 spia). Moreover, *E. contortus* and *Contracaecum* sp. were only found in females. All samples in our study were taken during the breeding period (27% of the sacrificed females were forming eggs) when females experience an immune system depression (Atkinson and Van Riper 1991) and therefore, they were probably more susceptible than males to parasite infections (Oppliger *et al.* 1996).

Our results agree with Bosch *et al.* (2000) in a significant relationship between female gulls and *E. contortus*, found in earthworms (Anderson 2000), probably because the tendency of females to spend more time foraging in agricultural fields than males (Aponte *et al.* 2014). However, crops are increasingly less arable in the Region of Murcia and the availability of earthworms is therefore reduced. Given the abundance of other food sources such as fishery discards and organic matter from landfills, a change in the trophic habits of gulls, moving to a diet low in worms, could explain why our values for *E. contortus* were lower than those observed by Bosch *et al.* (2000) (P = 66.4%, MI = 8.1 spia) and by Sanmartin *et al.* (2005) (P = 14.5%, MI = 5 spia).

Bosch (1996) described a worse body condition in yellow-legged gull females during the breeding period, however we did not find correlation between parasitic intensities and body condition of female gulls. The absence of this correlation can be due to the proximity of Escombreras colony to a major municipal landfill and fishery discards. Therefore, a high abundance of food availability may have counteracted the effect of parasitism of these yellow-legged gulls.

In our study there is a consistent association between the helminths detected, in contrast with Bosch *et al.* (2000) who did not find a clear pattern, probably because they found only one parasite species categorised as a common species. On the other hand, the co-infections revealed that intensities of *C. obvelatus*, *T. cylindraceus* and *A. armata* usually appear associated in the same bird. These positive associations between parasites in yellow-legged gull can result from facilitation processes, such as immunosuppression induced by one species and benefiting others (Poulin 2001), and are probably due to a diet consisting mainly of marine intermediate hosts (Bush and Holmes 1986).

Potential risks to the Audouin's gull

The yellow-legged gull exerts pressure over Audouin's gull through kleptoparasitism and competition for the same ecotope (Martínez-Abraín *et al.* 2003). Direct contact transmission of *O. capensis* and consumption of *E. contortus* eggs could occur when there is physical contact and trophic interactions between individuals of these two gull species. Anomalous development and nest desertion have been observed in tern (*Sterna* spp.) colonies harbouring *O. capensis* infected with arboviruses (Feare 1976). These viruses, transmitted by *O. capensis*, could easily circulate among individuals in the colonies (Austin 1984). Because yellow-legged gulls frequently visit the Audouin's nests during the breeding period such sanitary risk may be considered as a cause of breeding failure of the threatened Audouin's gull.

The Audouin's gull could also be susceptible to infection of the common parasites of yellow-legged gulls (e.g. *C. obvelata* and *P. adunca*) by feeding on fishery discards infected by larvae in waters adjacent to their colonies (Wong and Anderson 1982). Our results suggest that the yellow-legged gull acts as reservoir of *C. obvelatus* that, in their adult or larval stage, may affect other vertebrates. Larvae of this nematode initially invade the proventriculus and then, after moulting to the fourth larval stage, they settle throughout the oesophagus (Muzaffar and Jones 2004). Our results are consistent with those observed by previous authors (Bosch *et al.* 2000), since many fourth stage larvae of *C. obvelatus* were isolated from the oesophagus. It is likely that this parasite infestation might be occurring in an expansion phase in yellow-legged gull colony from Escombreras, as reflected by its prevalence value (> 20%). Moreover, *C. obvelatus* in combination with other endoparasites (e.g. the cestode *T. cylindraceus* previously isolated from Audouin's gulls) could have a negative impact in gulls, for instance reducing their breeding success (Bosch *et al.* 2000).

Besides of *O. capensis*, other two parasite species isolated in this study can have potential repercussions on gull health. For example, *Anisakis simplex* can be frequently transmitted to accidental hosts such as piscivorous birds and humans which, when infected, develop anisakidosis (Ishikura *et al.* 1992). On the other hand, *O. intermedia* may cause the human infection called "cercarial dermatitis" or "swimmer's itch" (Rind 1984), and both visceral and nasal schistosomes and paralysis can be developed in bird hosts (Kolářová *et al.* 2005).

The finding of *T. cylindraceus* and *A. armata*, previously described from the Audouin's gull in the Chafarinas Islands (Roca *et al.* 1999), as a new records for yellow-legged gull, and the positive associations of *C. obvelatus*, *T. cylindraceus* and *A. armata* suggest that an indirect consequence of the increased availability of fishery discards is the increased rate of exposure to dietary-transmitted parasites in both gull species (Delgado-V and French 2012). These parasites, once transmitted to other unusual host species (e.g. Audouin's gulls), can increase their virulence (Ebert 1998).

Implications for future studies and conservation management

Most parasites found in this study has been described before in yellow-legged gull, hence, the shift in diet from natural resources to food derived from human activities (Duhem *et al.* 2003) seems not to affect the parasitic fauna of this species. The dependence of yellow-legged-gulls on fishery discards (Ramos *et al.* 2009) is supported by the dominance of parasites transmitted through the consumption of marine intermediate hosts with interest to fisheries in the study area.

Although it is known that management of food from human origin seems the most effective way of controlling populations of large gulls (Bosch *et al.* 1994), the European Union environmental policies to reduce fishery discards (Gewin 2004) are still not adequately implemented. Besides of the physical contact between individuals in nesting and resting habitats, the high availability of fishery discards increase the risk of Audouin's gulls to be infected by common parasites of yellow-legged gull. Therefore, more epidemiological studies should be developed in mixed colonies of yellow-legged and Audouin's gulls to attempt conservation measures designed to protect threatened species.

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