Journal of Helminthology (2005) **79**, 361–371 DOI: 10.1079/JOH2005309

Helminth fauna of the yellow-legged gull *Larus cachinnans* in Galicia, north-west Spain

M.L. Sanmartín*, J.A. Cordeiro, M.F. Álvarez and J. Leiro

Laboratorio de Parasitología, Instituto de Investigación y Análisis Alimentarios, Universidad de Santiago de Compostela, C/ Constantino Candeira, s/n, 15782 Santiago de Compostela, Spain

Abstract

Thirty-six helminth species were found in 324 gulls examined during June 1994 to February 1996 from different localities of Galicia: 25 trematodes (*Brachylaima* sp., *Brachylecithum microtesticulatum*, *Cardiocephaloides longicollis*, *Cryptocotyle lingua*, *Cryptocotyle concavum*, *Diplostomum spathaceum*, *Echinostephilla virgula*, *Galactosomum phalacrocoracis*, *Gigantobilharzia acotylea*, *Gymnophallus deliciosus*, *Gynaecotyla longiintestinata*, *Himasthla elongata*, *Himasthla quissetensis*, *Knipowitschiatrema nicolai*, *Levinseniella* (*Levinseniella*) *propinqua*, *Maritrema gratiosum*, *Maritrema linguilla*, *Microphallus primas*, *Microphallus similis*, *Ornithobilharzia canaliculata*, *Parorchis acanthus*, *Phagicola minuta*, *Psilostomum brevicolle*, *Renicola* sp. and *Stephanoprora denticulata*), four cestodes (*Alcataenia micracantha*, *Microsomacanthus ductilis*, *Tetrabothrius* (*Oriana*) *erostris* and *Wardium cirrosa*), six nematodes (*Anisakis simplex*, *Contracaecum rudolphii*, *Cosmocephalus obvelatus*), *Eucoleus contortus*, *Paracuaria adunca* and *Tetrameres* (*Tetrameres*) *skrjabini*) and one acanthocephalan (*Arhythmorhynchus longicollis*). *Tetrabothrius erostris* was the most prevalent species (79.6%), followed by *C. obvelatus* (47.8%), *C. lingua* (37.4%), *G deliciosus* (30.9%), *G. longiintestinata* (22.8%), *P. adunca* (21.9%), *B. microtesticulatum* (17.6%), *E. contortus* (14.5%) and *M. similis* (9.3%). *Microphallus similis* was the dominant species, with a Berger-Parker index (BP) of 0.32, followed by *T. erostris* (BP = 0.10). All species presented an aggregated dispersion except *G. acotylea* and *G. phalacrocoracis*, which showed a random dispersion. Species that seem to have the greatest predilection for specific sites along the intestine are: *C. longicollis* and *A. micracantha* (first third), *Brachylaima* sp., *M. similis* and *G. longiintestinata* (last third) and *A. longicollis* (second half). Eight species are known to be pathogenic to commercially important fish or molluscan species and several are pathogenic to humans.

Introduction

The family Laridae comprises mainly marine coastal birds (gulls, terns, skuas, and skimmers), feeding on aquatic prey and/or carrion and many gull species are abundant with a very wide distribution and colonial breeding (Díaz *et al.*, 1996). Furthermore, gulls show much opportunism and adaptability, allowing them to prosper in man-made environments (Munilla, 1997). The omnivorous diet of gulls allows them to feed in both marine and terrestrial habitats (Glutz von Blotzheim & Bauer, 1982; Cramp & Simmons, 1983; Munilla, 1997). For this reason, gulls are susceptible to infection with a wide variety of parasites whose larval forms develop in freshwater and marine fish, molluscs and crustaceans. Gulls may also be accidentally infected with diverse parasites containing terrestrial stages in their life cycle. Previous studies have demonstrated much diversity in the helminth fauna of gull species, e.g. Threlfall (1966)

*Fax: + 34 981 547171
E-mail: mpduran@usc.es

Table 1. The prevalence and intensity of infection, together with aggregation and dominance indices of helminth species in 324 yellow-legged gulls from Galicia, Spain.

Species	No. birds parasitized	Prevalence (%)	I_T*	I_M* ± SD* (range)	Ab_M* ± SD*	ID*	BP
Trematodes							
Brachylaima sp.	15	4.6	144	9.6 ± 15.0 (1–58)	0.44 ± 3.72	31.1	0.008
Brachylecithum microtesticulatum	57	17.6	1893	33.2 ± 49.8 (1–291)	5.84 ± 24.31	101.2	0.101
Cardiocephaloides longicollis	13	4.0	47	3.6 ± 3.2 (1–10)	0.15 ± 0.94	6.1	0.002
Cryptocotyle concavum	1	0.3	55	55 (55)	0.17 ± 3.06	55.0	0.003
Cryptocotyle lingua	121	37.4	1836	15.2 ± 33.1 (1–200)	5.67 ± 21.46	81.3	0.099
Diplostomum spathaceum	4	1.2	182	45.5 ± 66.7 (1–142)	0.56 ± 8.16	118.5	0.010
Echinostephilla virgula	5	1.5	66	13.2 ± 19.3 (1–47)	0.20 ± 2.69	35.7	0.003
Galactosomum phalacrocoracis	3	0.9	3	1 (1)	$9{\cdot}10^{-3}$ ± 0.10	1.0	$2{\cdot}10^{-4}$
Gigantobilharzia acotylea	1	0.3	1	1 (1)	$3{\cdot}10^{-3}$ ± 0.056	1.0	$5{\cdot}10^{-5}$
Gymnophallus deliciosus	100	30.9	1309	13.1 ± 16.5 (1–116)	4.04 ± 10.96	29.8	0.070
Gynaecotyla longiintestinata	74	22.8	1753	23.7 ± 45.7 (1–291)	5.41 ± 23.90	105.5	0.094
Himasthla elongata	21	6.5	464	22.1 ± 30.8 (1–108)	1.43 ± 9.41	61.8	0.025
Himasthla quissetensis	3	0.9	20	6.7 ± 8.1 (2–16)	0.06 ± 0.90	13.2	0.001
Knipowitschiatrema nicolai	3	0.9	12	4 ± 3.5 (2–8)	0.04 ± 0.47	6.0	$6{\cdot}10^{-4}$
Levinseniella propinqua	1	0.3	27	27 (27)	0.08 ± 1.50	27.0	0.001
Maritrema gratiosum	11	3.4	206	18.7 ± 26.7 (1–93)	0.63 ± 5.80	52.9	0.011
Maritrema linguilla	6	1.8	60	10 ± 10.3 (1–28)	0.19 ± 1.86	18.7	0.003
Microphallus primas	1	0.3	506	506 (506)	1.56 ± 28.11	506.0	0.027
Microphallus similis	30	9.3	5909	197 ± 909 (1–5000)	18.24 ± 278.32	4247.4	0.32
Ornithobilharzia canaliculata	1	0.3	2	2 (2)	$6{\cdot}10^{-3}$ ± 0.11	2.0	$1{\cdot}10^{-4}$
Parorchis acanthus	8	2.5	14	1.8 ± 0.9 (1–3)	0.04 ± 0.30	2.1	$7{\cdot}10^{-4}$
Phagicola minuta	2	0.6	252	126 ± 175.4 (2–250)	0.78 ± 13.89	248.0	0.014
Psilostomum brevicolle	2	0.6	3	1.5 ± 0.7 (1–2)	$9{\cdot}10^{-3}$ ± 0.12	1.7	$1{\cdot}10^{-4}$
Renicola sp.	22	6.8	148	6.7 ± 9.5 (1–36)	0.46 ± 2.95	19.0	0.008
Stephanoprora denticulata	2	0.6	6	3 ± 2.8 (1–5)	0.02 ± 0.28	4.3	$3{\cdot}10^{-4}$
Cestodes							
Alcataenia micracantha	31	9.6	145	4.7 ± 5.8 (1–24)	0.45 ± 2.25	11.3	0.008
Microsomacanthus ductilis	3	0.9	54	18 ± 21 (1–42)	0.17 ± 2.41	34.9	0.003
Tetrabothrius erostris	258	79.6	1920	7.4 ± 12.4 (1–100)	5.92 ± 11.42	22.0	0.103
Wardium cirrosa	1	0.3	29	29 (29)	0.08 ± 1.61	29.0	0.002
Nematodes							
Anisakis simplex	22	6.8	54	2.4 ± 2.8 (1–14)	0.17 ± 0.95	5.4	0.003
Contracaecum rudolphii	3	0.9	5	1.7 ± 1.2 (1–3)	0.02 ± 0.18	2.2	$3{\cdot}10^{-4}$
Cosmocephalus obvelatus	155	47.8	553	3.6 ± 3.9 (1–26)	1.71 ± 3.26	6.2	0.030
Eucoleus contortus	47	14.5	233	5 ± 8 (1–40)	0.72 ± 3.49	16.9	0.013
Paracuaria adunca	71	21.9	220	3.1 ± 3.1 (1–19)	0.68 ± 1.92	5.4	0.012
Tetrameres skrjabini	9	2.8	139	15.4 ± 38.5 (1–118)	0.43 ± 6.6	100.6	0.007
Acanthocephalans							
Arhythmorhynchus longicollis	16	4.9	97	6.1 ± 6.3 (1–26)	0.30 ± 1.90	12	0.007

* I_t, total intensity; I_M, mean intensity; Ab_M, mean abundance; SD, standard deviation; ID, aggregation (dispersion index); BP, Berger-Parker dominance index.

lists 151 helminth species from the herring gull *Larus argentatus*, including 87 trematodes, 36 cestodes, four nematodes and four acanthocephalans. In addition, gulls act as definitive hosts for pathogenic helminths infecting various commercially important marine fish and mollus-can species.

Galicia is a region of northwest Spain with an important fish and mollusc aquaculture industry, including important natural fisheries, so that a knowledge of the helminth fauna of gulls and other hosts of helminths infecting gulls, is of direct commercial relevance. Furthermore, to date there have been few studies undertaken in Spain on the helminth fauna of gulls (Lafuente *et al.*, 1998, 1999; Roca *et al.*, 1999; Bosch *et al.*, 2000).

In the present paper, the prevalence and intensity of infection with helminths of 324 gulls from north-west Spain are investigated and their pathological effects at the intermediate host level discussed.

Materials and methods

A total of 324 *Larus cachinnans* was captured in different localities in the region of Galicia (north-west Spain), including the estuaries of Arousa, Pontevedra and Vigo, various islands close to the coast (now a part of the Atlantic Islands National Park, containing very large breeding colonies), as well as the municipal waste dumps of the cities of A Coruña (on the coast) and Santiago de Compostela (inland), where gulls feed in large numbers on organic waste. Gull capture was undertaken between June 1994 and February 1996 with appropriate permission from the regional and local authorities. In the breeding colonies, gulls were captured using traps placed on nests to obtain live adults as previously described by Mills & Ryder (1979). Chicks and immature birds were also captured. In waste dumps, traps of this type could not be used, so nets were used instead. In addition, the Wild Bird Recovery Centre in Cotorredondo provided various specimens that had been found dead or dying in different locations within the above-mentioned estuaries, and which had been deep frozen.

All live gulls were transported to the laboratory, where they were killed by an overdose of anaesthetic, then measured, weighed, aged and sexed, and most were frozen at $-20°C$ until dissection. After thawing, the viscera, eyes and air sacs were removed and examined for helminths. The alimentary tract was further divided into oesophagus, proventriculus + gizzard, intestine, intestinal caeca, rectum and cloaca. The intestine was divided into 20 equal sections, which were examined separately. All helminths recovered were washed in physiological saline; in the case of fresh material, helminths were relaxed and killed in Berland's fluid, fixed in 70° alcohol, and mounted for microscopic observation using standard procedures (see Cordeiro-Paredes, 2004). Samples of muscle tissue were also examined for *Trichinella* spp.

Prevalence, mean abundance and mean intensity of infections were calculated as described by Bush *et al.* (1997). The Berger-Parker (BP) index, calculated as described by Magurran (1988) was used to quantify species dominance whereas the index of dispersion (ID), calculated as described by Anderson & Gordon (1982), was used to quantify dispersion of parasite species. The significance of ID values was assessed using Ping's test (Ping, 1995).

Results and Discussion

Helminth richness and infection levels

The 36 helminth species identified in the present study (table 1), are within the range of species richness of 31–41 species reported previously for other gull species (Pemberton, 1963; Threlfall, 1967, 1968a; Bakke, 1972a, 1972b, 1973, 1985; Bakke & Barus, 1975, 1976), with one exception in the case of *L. cachinnans* in the Medas Islands in the Mediterranean off Spain, where Bosch *et al.* (2000) recovered only ten helminth species.

Of the 36 helminth species from *L. cachinnans* in Galicia, 25 were trematodes, four cestodes, six nematodes, and one an acanthocephalan. A total of 22 are first reports for Spain: the trematodes *Cryptocotyle concavum* (Creplin), *Galactosomum phalacrocoracis* Yamaguti and *Phagicola minuta* (Looss) (Heterophyidae), *Echinostephilla virgula* Lebour, *Himasthla elongata* (Mehlis), *Himasthla quissetensis* Miller & Northup, *Psilostomum brevicolle* (Creplin) and *Stephanoprora denticulata* (Rudolphi) (Echinostomatidae), *Parorchis acanthus* (Nicoll) (Philophthalmidae), *Gigantobilharzia acotylea* Odhner (Schistosomatidae), *Gymnophallus deliciosus* (Olsson) (Gymnophallidae), *Gynaecotyla longiintestinata* Leonov, *Levinseniella* (*Levinseniella*) *propinqua* Jaegerskioeld, *Maritrema gratiosum* Nicoll, *Maritrema linguilla* Jaegerskioeld and *Microphallus* (*Spelotrema*) *similis* (Jaegerskioeld) (Microphallidae); the cestodes *Alcataenia micracantha* (Krabbe) (Dilepididae), *Microsomacanthus ductilis* (Linton) and *Wardium cirrosa* (Krabbe) (Hymenolepididae); the nematodes *Contracaecum rudolphii* Hartwich (Anisakidae) and *Tetrameres* (*Tetrameres*) *skrjabini* Panova (Tetrameridae), and the acanthocephalan *Arhythmorhynchus longicollis* (Villot) (Polymorphidae). The remaining 15 species have been reported previously from Spain by various authors; see review by Cordero del Campillo *et al.* (1994), and also the studies of gull populations on Spanish Mediterranean islands by Lafuente *et al.* (1998, 1999), Roca *et al.* (1999) and Bosch *et al.* (2000). As far as is known, the present study reports for the first time *E. virgula* as a parasite of a *Larus* species and there are no previous reports of *Galactosomum phalacrocoracis* or *Phagicola minuta* in gulls.

Tetrameres skrjabini is infrequent in gulls and other Palearctic seabirds. To date, it has only been cited from Eastern Europe and the former USSR (see Barus *et al.*, 1978a,b). Barus *et al.* (1978b) found this species in *L. ridibundus*, though with rather lower prevalence than in the present study.

Anisakis simplex appeared in the oesophagus, in some cases producing ulcers. Of 22 gulls infected with this species in the present study, a total of 54 larvae were recovered, of which 36 were L3, 7 were in L3–L4 transition, and 11 were L4. There have been surprisingly few reports of *Anisakis* spp. in fish-eating birds, and no reports of L4. Bakke & Barus (1975) found *A. simplex* L3 in *L. canus* in Norway, with a markedly lower prevalence (2.23%) than in the present study.

Diplostomum spathaceum showed a lower prevalence in the present study (table 1) than in most previous studies, where prevalences have ranged from 0.15% (Threlfall, 1967, in *L. argentatus*) to 59% (Ehrhardt *et al.*, 1966, in *L. atricilla*). In contrast, *Cryptocotyle lingua* showed a higher prevalence (table 1) than in most previous studies, only lower than Pemberton (1963) in *L. argentatus* (50%) and *L. fuscus* (100%), and Bakke (1972a) in *L. canus* (63.9%). The mean intensity of infection by *C. lingua*, though high, was likewise lower than in these studies.

Knipowitschiatrema nicolai has been reported from gulls in several studies, in some cases with high prevalence and intensity (Timon-David, 1955; Pemberton, 1963; Prevot, 1974). In Spain, this species has been cited in *L. audouini* by Lafuente *et al.* (1998) and Roca *et al.* (1999), with a prevalence of 60.3% and a maximum intensity of 110 individuals. *Microphallus primas* has been reported from gulls (*L. ridibundus*) by Lorch *et al.* (1982), with a prevalence of almost 44%, which is much higher than in the present study.

Psilostomum brevicolle (table 1) is infrequent in gulls (Bakke 1972a,b; Pemberton, 1963; present results). In oystercatchers (*Haematopus ostralegus*), however, Borgsteede *et al.* (1988) and Goater *et al.* (1995) obtained values of 42.2% and 95% respectively, suggesting that its presence in gulls is accidental. By contrast, *Tetrabothrius erostris* was more frequent in the present study than in most previous studies (Pemberton, 1963; Williams & Harris, 1965; Ehrhardt *et al.*, 1967; Threlfall, 1968a; Keppner, 1973; Bakke, 1985; Bosch *et al.*, 2000).

Only 11 birds were entirely helminth-free. Species richness at the infracommunity level was in most cases 2, 3 or 4, and occasionally up to 10 different helminth species. The dominant species was *Microphallus similis*, with a Berger-Parker dominance index of 0.32 (table 1), followed by the cestode *Tetrabothrius* (*Oriana*) *erostris* (Lönnberg), which is likewise the most prevalent species (table 1).

The component species of the helminth fauna of *L. cachinnans* in Galicia (i.e. prevalence > 10%; Bush *et al.*, 1990) were only eight: *Tetrabothrius erostris*, *Cosmocephalus obvelatus* (Creplin), *Cryptocotyle lingua*, *Gymnophallus deliciosus*, *Gynaecotyla longiintestinata*, *Paracuaria adunca* (Creplin), *Brachylecithum microtesticulatum* and *Eucoleus contortus* (Creplin). The species that was dominant in terms of abundance, *M. similis*, almost entered into this category (prevalence = 9.3%).

Hanski (1982) classed parasites as 'nucleus' and 'satellite' species: nucleus species being those with a high prevalence (i.e. regionally common) and a high abundance (i.e. locally abundant), and satellite species being those with a low prevalence and a low abundance. Hanski suggests that if stochastic variation in extinction rates and/or local colonization is sufficiently high, species will tend to fall clearly into one or other of these groups, with very few intermediate species. As seen in the present study, in the helminth community of *Larus cachinnans* in Galicia only one species, *Tetrobothrius erostris*, showed a prevalence over 70% and all the other species but five belong to the satellite species group, most of them with prevalences under 7%. The most abundant species (*Microphallus similis*) did not show a high prevalence (table 1), so that if we apply Hanski's model to this parasite community, we are obliged to accept that the dominant species in this community should be placed into the satellite species group because of its prevalence.

All species found presented an aggregated dispersion (ID significantly greater than 1; see table 1) except *Gigantobilharzia acotylea* and *Galactosomum phalacrocoracis*, which showed a random dispersion (ID not significantly different from 1). The most aggregated species was *Microphallus similis* (ID = 4247, due to the presence of 5000 specimens within a single host individual), followed by *Microphallus* (*Spelophallus*) *primas* (Jaegerskioeld) and *Phagicola minuta*. These three species are all very small, which may make it possible for them to reach very high intensities without killing the host.

Localization in the host

Figure 1 summarizes data on the distribution of intestinal helminths along the intestinal tract and includes those helminths with prevalences of at least 1.2% (i.e. more than three hosts), although in the text species with lower prevalences are discussed.

Cardiocephaloides longicollis, *Alcataenia micracantha* and *Microsomacanthus ductilis* were predominantly distributed in the anterior sections of the intestine (sections 2–7, 1–6, and 1–12 respectively) (fig. 1). This is similar to the findings of Prévot & Bartoli (1980) for *C. longicollis*, and Threlfall (1967, 1968a) and Bakke (1985) for *A. micracantha* and *M. ductilis*.

Brachylaima sp., *M. similis*, *G. longiintestinata*, *A. longicollis*, *M. primas*, *G. phalacrocoracis*, *Knipowitschiatrema nicolai* Issaitschikow, *L. propinqua* and *W. cirrosa* were predominantly distributed in the posterior sections of the intestine, although *M. similis* and *G. longiintestinata* also occasionally appeared in most of the sections (fig. 1). This may be related to the high intensities of infection by these species, particularly *M. similis*. The present findings for *Brachylaima* sp. agree with those of Threlfall (1967, 1968b) and Bakke (1972a), who found species of this genus in the mid and posterior intestine. In the case of *M. similis*, the present results are similar to those obtained by Bakke (1972a).

Maritrema gratiosum, which was found throughout the intestine, mainly in hosts with high levels of infection, was more frequently present in the anterior and posterior regions (sections 1–10 and 15–20). *Microphallus linguilla* (fig. 1) was also present throughout the intestine but, in contrast to *M. gratiosum*, was most frequent in the mid regions (sections 6–14). However, the prevalence and mean intensity of infection with *M. linguilla* were rather low (table 1), so that these findings cannot be considered conclusive.

Although *H. elongata* was located in sections 9 and/or 10 in 12 (57%) of 21 gulls in which it was found, it also occurred in other regions of the intestine (fig. 1). Loos-Frank (1967) found this species in the duodenum, although Threlfall (1967, 1968b), as in the present case, found *H. elongata* mostly in the mid-region of the intestine. *Himasthla quissetensis*, on the other hand, was found in the mid and posterior regions. Prévot (1974) found this species in the posterior and not in the mid region of the intestine. In two of the three gulls in which *H. quissetensis* appeared, *H. elongata* was also present.

https://doi.org/10.1079/JOH2005309 Published online by Cambridge University Press

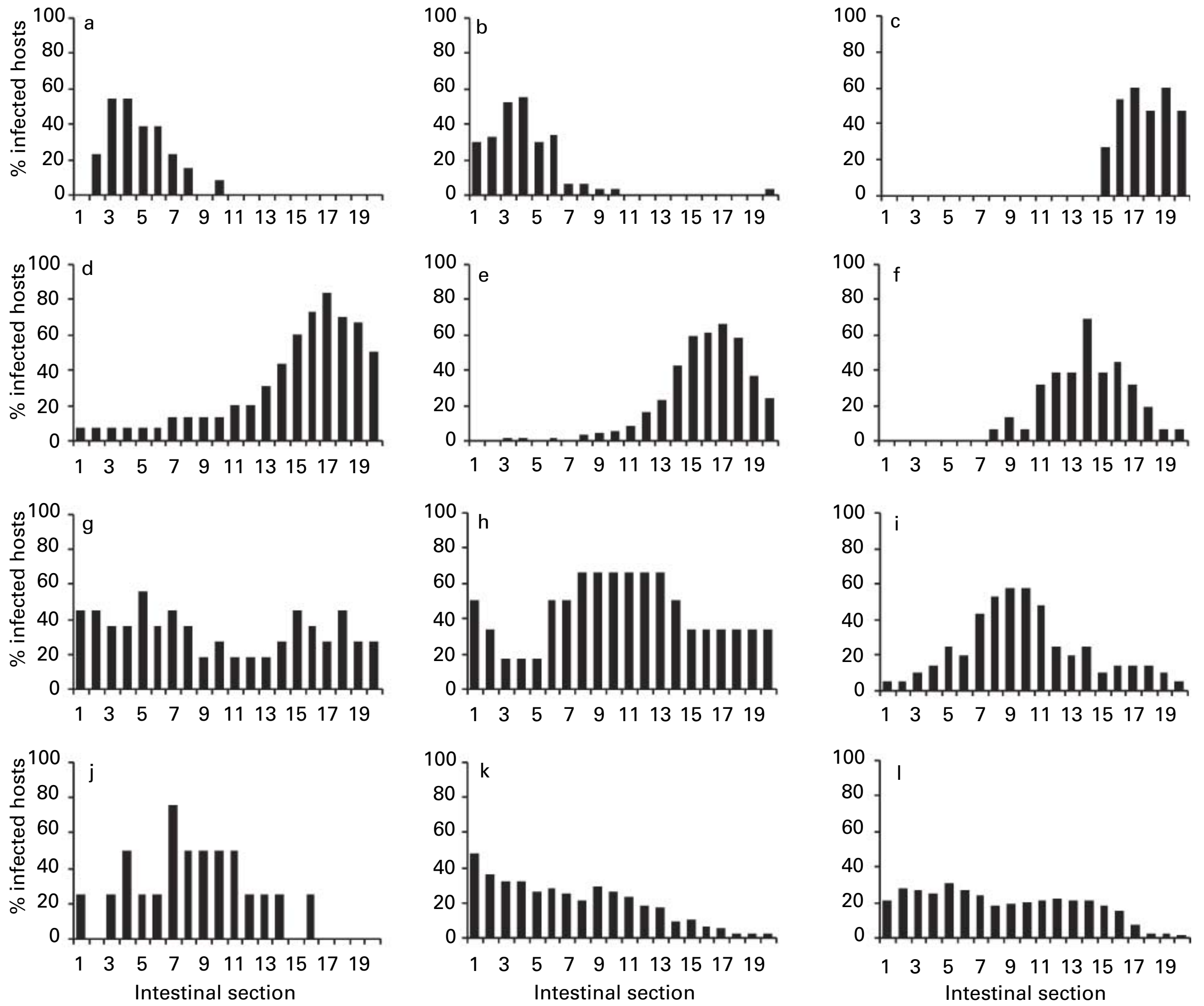

Fig. 1. Frequency distribution of helminth species along the intestine of yellow-legged gulls with prevalence (%) values ≥ 1.2%. a, *Cardiocephaloides longicollis*; b, *Alcataenia micracantha*; c, *Brachylaima* sp.; d, *Microphallus similis*; e, *Gynaecotyla longiintestinata*; f, *Arhythmorhynchus longicollis*; g, *Maritrema gratiosum*; h, *Maritrema linguilla*; i, *Himasthla elongata*; j, *Diplostomum spathaceum*; k, *Cryptocotyle lingua*; l, *Tetrabothrius erostris*.

Phagicola minuta, which was only found in two gulls, was likewise located predominantly in the mid-region of the intestine, but occasionally in other regions, probably reflecting the high infection intensities in these two birds (table 1).

Psilostomum brevicolle was located in the mid region of the intestine (sections 8-13), in agreement with the findings of Bakke (1972a,b) in *L. canus*, but Pemberton (1963) found this species in the posterior part of the intestine of *L. ridibundus*.

Diplostomum spathaceum was located in sections 1 to 16 (fig. 1), though predominantly in the medial third (sections 7–11). Niewiadomska (1984) and Threlfall (1968b) only found this species in the posterior part of the intestine, whereas Sitko (1968) and Bakke (1972a) also found *D. spathaceum* in the anterior third.

Stephanoprora denticulata, *Echinostephilla virgula* and *Cryptocotyle concavum* occurred in the mid and posterior regions of the intestine. *Stephanoprora denticulata* showed a very low prevalence and mean intensity, so that these findings cannot be considered conclusive. *Cryptocotyle concavum* was found in sections 10–17 in a single host individual.

Cryptocotyle lingua and *Tetrabothrius erostris* were found along the entire length of the intestine (fig. 1), though more frequently in the anterior third, as previously confirmed by Threlfall (1967) and Bakke (1972a) in various gull species.

The remaining helminths were extra-intestinal and were found in previously reported locations. *Anisakis simplex*, *Contracaecum rudolphi*, *Cosmocephalus obvelatus* and *Eucoleus contortus* were found in the oesophagus and the latter species, *Paracuaria adunca* and *Tetrameres skrjabini* in the proventriculus; *Parorchis acanthus* in the rectum and cloaca; *Gigantobilharzia acotylea* and *Ornithobilharzia canaliculata* were found in the mesenteric veins; *Gymnophallus deliciosus* in the gall bladder; *Brachylecithum microtesticulatus* in the pancreatic ducts and *Renicola* sp. in the kidneys.

The two most prevalent species, *Tetrabothrius erostris* and *Cosmocephalus obvelatus*, are thus parasites of the small intestine (fig. 1) and oesophagus respectively.

Taking into account only the two most prevalent species in these two organs, the combination of species occurring with highest prevalence is *T. erostris* alone or with infrequent species (combination T in fig. 2). However, the summed prevalences of *T. erostris* plus one or more of the frequent species (*Alcataenia micracantha*, *Cryptocotyle lingua*, *Gynaecotyla longiintestinata* and *Microphallus similis*) gave a total greater than combination T.

Negative interactions between the more prevalent species present in the small intestine were not detected. Of all the combinations comprising two or more species with high prevalences, the most frequent was *T. erostris* plus *C. lingua* (combination TC in fig. 2), followed by *T. erostris* plus *G. longiintestinata* (combination TG in fig. 2). In fact, *C. lingua* and *G. longiintestinata* showed higher prevalences in their respective combinations with *T. erostris* than alone or accompanied by less frequent species. This may suggest a positive interaction between these three species. Furthermore, *T. erostris* and *C. lingua* have very similar distributions in the intestine (fig. 1). Another possibility might be that these three species are found so commonly together because they use a single intermediate host. However, this does not appear to be the case as *C. lingua* uses fish as the intermediate host (Buchmann, 1986; Wood & Matthews, 1987; Poynton, 1993; Zander, 1993, 2003; Zander *et al.*, 1993, 2000), while *G. longiintestinata* uses crabs (*Carcinus mediterraneus*) (Prévot, 1974). The intermediate hosts of *T. erostris* are unknown. *Microphallus similis* was only present in combination with one or more other high-prevalence species (fig. 2).

In the case of oesophageal parasites, those showing the highest prevalence were *Cosmocephalus obvelata* and *Eucoleus contortus*. The former species was present with much higher frequency alone or accompanied by a low-prevalence species (combination C in fig. 3) than accompanied by *E. contortus*. By contrast, *E. contortus* was present with a slightly higher prevalence accompanied by *C. obvelata* than alone or in combination with a low-prevalence species (combination E in fig. 3).

Pathogenicity

Of 36 helminth species found, eight have been previously reported to have pathogenic effects on one or more intermediate hosts of commercial importance. Species of the genus *Diplostomum* are pathogenic to fish as cercariae cause lesions in the skin and other tissues during penetration and migration (Moczon, 1994). They also cause obstructions in blood vessels, particularly in the gills (Heckmann, 1993), causing asphyxia and hypoxia. Finally, cercariae reach the lens or vitreous humour in the eye, resulting in cataracts, corneal ulcers,

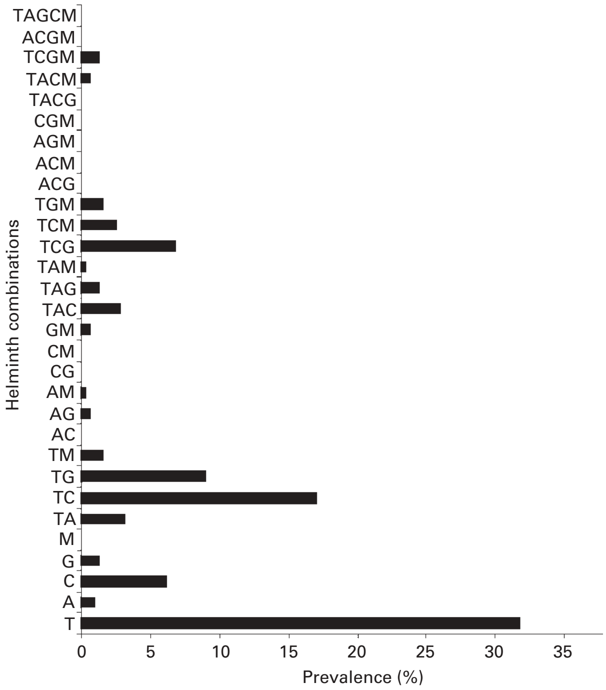

Fig. 2. The most frequent helminth combinations (prevalence > 9%) in the small intestine of *Larus cachinnans* in Galicia, Spain. T, *Tetrabotrius erostris*; A, *Alcataenia micracantha*; C, *Cryptocotyle lingua*; G, *Gynaecotyla longiintestinata*; M, *Microphallus similis*; TA, *T. erostris* + *A. micracantha*; TC, *T. erostris* + *C. lingua*; TG, *T. erostris* + *G. longiintestinata*; TM, *T. erostris* + *M. similis*; AC, *A. micracantha* + *C. lingua*; AG, *A. micracantha* + *G. longiintestinata*; AM, *A. micracantha* + *M. similis*; CG, *C. lingua* + *G. longiintestinata*; CM, *C. lingua* + *M. similis*; GM, *G. longiintestinata* + *M. similis*; TAC, *T. erostris* + *A. micracantha* + *C. lingua*; TAG, *T. erostris* + *A. micracantha* + *G. longiintestinata*; TAM, *T. erostris* + *A. micracantha* + *M. similis*; TCG, *T. erostris* + *C. lingua* + *G. longiintestinata*; TCM, *T. erostris* + *C. lingua* + *M. similis*; TGM, *T. erostris* + *G. longiintestinata* + *M. similis*; ACG, *A. micracantha* + *C. lingua* + *G. longiintestinata*; ACM, *A. micracantha* + *C. lingua* + *M. similis*; AGM, *A. micracantha* + *G. longiintestinata* + *M. similis*; CGM, *C. lingua* + *G. longiintestinata* + *M. similis*; TACG, *T. erostris* + *A. micracantha* + *C. lingua* + *G. longiintestinata*; TACM, *T. erostris* + *A. micracantha* + *C. lingua* + *M. similis*; TCGM, *T. erostris* + *C. lingua* + *G. longiintestinata* + *M. similis*; ACGM, *A. micracantha* + *C. lingua* + *G. longiintestinata* + *M. similis*; TACGM, *T. erostris* + *A. micracantha* + *C. lingua* + *G. longiintestinata* + *M. similis*.

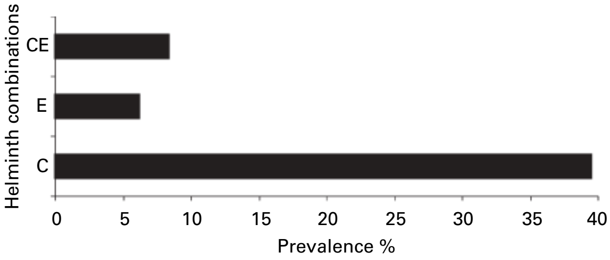

Fig. 3. The most frequent helminth combinations (prevalence > 9%) in the oesophagus of *Larus cachinnans* in Galicia. Abbreviations: C, *Cosmocephalus obvelatus*; E, *Eucoleus contortus*; CE, *C. obvelatus* + *E. contortus*.

and destruction of the lens, with consequent blindness. In fresh- or brackish-water aquaculture, this parasite causes severe losses, by inducing fish mortality and by reducing the commercial value of survivors. Crowden & Broom (1980) state that heavily infected fish tend to swim close to the surface, increasing the risk of predation by waterbirds (the definitive hosts). In contrast, metacercariae of another strigeid, *Cardiocephaloides longicollis*, encyst in the optical lobe cavity of various fresh- and brackish-water fish, although no reports of pathogenic effects in fish hosts have been published to date.

Cryptocotyle lingua uses as second intermediate hosts fish belonging to the families Gobiidae (Zander, 1993, 2003; Zander *et al.*, 1993, 2000, 2002), Gasterosteidae (Zander, 2003), Mugilidae (Wood & Matthews, 1987), Gadidae (Buchmann, 1986; Poynton, 1993; Lysne *et al.*, 1997; Mellergaard & Lang, 1999) and Clupeidae (Poynton, 1993). These parasites form melanized cutaneous cysts, but also encyst in the eyes, brain, muscle, gills and heart; cysts in the eyes may cause exophthalmus or blindness. Infection of the skin and/or vital organs may be very severe, particularly in fry and other small hosts (Poynton, 1993), so that this parasite may cause significant losses in fisheries and aquaculture. *Cryptocotyle concavum* has similar effects as metacercariae encyst in the skin, fins and kidneys of fish of families Gobiidae (Zander *et al.*, 2000; Malek, 2001; Zander, 2003), Pleuronectidae (Lang *et al.*, 1999), Zoarcidae, Syngnathidae (Zander *et al.*, 2000) and Gasterosteidae (Donoghue, 1988; Kesting *et al.*, 1996; Zander *et al.*, 2000). In fisheries or aquaculture, *C. concavum* reduces both the growth rates (Malek, 2001) and commercial value of fish.

The life cycle of *P. minuta* is not known, but the *Phagicola* species whose life cycle is known use fresh- and brackish-water fish as second intermediate hosts (Ostrowski de Nuñez, 1993, 1998; Scholz *et al.*, 1997a,b; Aguirre Macedo *et al.*, 2001; Steinauer & Font, 2003). Metacercariae of species within this genus, and those of the closely related genus *Ascocotyle* Looss, 1899, encyst throughout the abdominal viscera, and also in the heart, arterial trunk, pericardium, somatic musculature, gills and skin (Yamaguti, 1975; Font *et al.*, 1984; Salgado Maldonado & Aguirre Macedo, 1991; Scholz *et al.*, 1997a; Coleman & Travis, 1998). Some species show greater specificity than others in terms of location in the host. The fact that metacercariae of some species, for example *Phagicola longa* (Ransom) and *Ascocotyle pachycystis* Schroeder & Leigh, are located primarily in vital organs, such as the heart and adjacent structures (Yamaguti, 1975; Coleman & Travis, 1998), gives rise to significant pathological effects as thickening of tissue due to fibrogranulomatosis of the epicardium and arterial trunk walls may reduce the efficacy of the cardiac pump. This leads to significant blockage of blood flow, reducing the host's resistance to low temperatures and also its capacity to find food, and increasing its susceptibility to predation (Coleman & Travis, 1998).

Within the genus *Renicola*, several species use commercially important molluscs as second intermediate hosts. For example, the second intermediate hosts of *Renicola roscovita* (Stunkard) include not only snails of the genus *Littorina* (Martin, 1971) but also a number of commercially important bivalves, including the cockle *Cerastoderma edule* (Linnaeus), the mussel *Mytilus edulis* Linnaeus, and the oyster *Crassostrea gigas* (Thunberg) (Aguirre Macedo & Kennedy, 1999; Montaudouin *et al.*, 2000; Le Dréan-Quénec'hdu *et al.*, 2001; Desclaux *et al.*, 2002). Pathogenic effects include severe tissue damage resulting in abnormal behaviour and facilitating predation by avian definitive hosts, to the extent that *R. roscovita* is considered a regulator of natural cockle populations in various European regions (Bower, 1995). Stunkard (1964) studied the life cycle of *Renicola thaidus* Stunkard, which uses *M. edulis* and the bay scallop *Pecten irradians* Lamarck as second intermediate hosts. Species of *Renicola* are also pathogenic for the definitive host: for example, *R. heroni* induces degenerative changes, necrosis and vasculitis of the kidneys, as well as embolisms due to the presence of parasite eggs in the blood vessels (Mahdy & Shaheed, 2001).

Himasthla elongata likewise uses commercially important bivalves as second intermediate hosts, including *C. edule*, *M. edulis* and some species of clam, such as *Thapes phillipinarum* (Adams & Reeve) (Montaudouin *et al.*, 2000), producing various pathological effects, many of which make the bivalves more vulnerable to predation by gulls and other seabirds. The pathological effects on *C. edule* include a reduced tolerance to hypoxia (Wegeberg & Jensen, 1999). *Himasthla elongata* is considered to be one of the factors controlling cockle populations on the German North Sea coast (Lauckner, 1983). Young *M. edulis* infected with this species show reduced byssus production and poor shell cleanliness (Lauckner, 1984). Montaudouin *et al.* (2000) suggested that this and other species of the genus *Himasthla* may have a significant influence on the population dynamics of bivalves in the Bay of Arcachon (France) which, like the Galician estuaries, houses a significant bivalve culture industry. Specifically, these authors did not find *Himasthla* infections in young *C. edule* (< 10 mm) in natural populations, despite the fact that experimental infection is easy, and that infections were widespread amongst older individuals. This suggests that mortality may be very high in young cockles. Similar findings have been reported for *H. quissetensis*, whose metacercariae likewise encyst in *C. edule*, *M. edulis*, *P. irradians*, and various clam species (Stunkard, 1938; Desclaux *et al.*, 2002). *Himasthla quissetensis* encysts in the foot of bivalve molluscs, so that burrowing species (such as *C. edule*) are unable to re-enter the sand after coming to the surface, facilitating their predation by avian definitive hosts (Desclaux *et al.*, 2002).

Another species encysting in *C. edule* and *M. edulis* is *Psilostomum brevicolle* (Loos-Frank, 1968; Montaudouin *et al.*, 2000; Le Dréan-Quénec'hdu *et al.*, 2001) which, according to Goater *et al.* (1995), is more frequent in *C. edule*. The possible pathogenic effects of this species have not been described.

Several of the parasite species detected in the present study might at least in theory be transmitted to man, by ingestion of a fish or mollusc intermediate host, particularly in countries in which seafood products are traditionally eaten raw or only lightly cooked. The most well-known and important of these species is

Anisakis simplex, transmitted to man through ingestion of fish or cephalopods containing third-stage larvae. This species may have two main types of pathological effects (Iglesias, 1998): (i) due to the direct action of the larva as it penetrates the gastric and intestinal mucosa, with the aid of its tooth and secreted proteolytic enzymes, and (ii) associated with host immune responses, resulting in inflammatory and/or allergic reactions. Such reactions may provoke granulomatous lesions at the invasion site, often causing significant discomfort. Sometimes the parasite completely traverses the intestinal wall, giving rise to peritonitis and granulomatous tumours in other parts of the body.

Cercariae of various species of the genus *Gigantobilharzia* (Rohde, 1978; Kolárová *et al.*, 1999; Horák & Kolárová, 2001) and *O. canaliculata* (Rind, 1984) may cause the syndrome known as cercarial dermatitis or swimmer's itch, where cercariae penetrate the human skin, thereby constituting a risk for people who swim in fresh water (*Gigantobilharzia*) or sea water (*Ornithobilharzia*). The very low prevalence of these species in yellow-legged gull suggests that this bird is not the habitual definitive host for these species.

Another species potentially capable of infecting man is the trematode *P. minuta*. As pointed out by Snyder *et al.* (1989), adults of *Phagicola* species show scant host specificity, infecting a wide range of birds and mammals, like other genera of the family Heterophyidae. Many cases of human infection by species of this family have been reported, generally related to the ingestion of raw or undercooked food (Velasquez, 1982). Cases of human infection by species of the genus *Phagicola* have occurred in Brazil, and possibly in the south-west United States (Chieffi *et al.*, 1990, 1992). A case caused by *Ascocotyle coleostoma* (Looss) has also been reported in Egypt (Rousset *et al.*, 1983). Other species of this family that likewise show scant specificity as regards the definitive host are *C. lingua* and *C. concavum*.

Finally, in Australia there have been reports of infection of humans by *Brachylaima cribbi* Butcher & Grove, due to ingestion (generally accidental, through eating poorly washed green vegetables) of raw snails of the species *Cernuella virgata* (Müller), *Helix* (*Theba*) *pisana* (Müller), *Cochlicella barbara* (Linnaeus) and *Cochlicella acuta* (Müller) (Butcher *et al.*, 1996, 1998). Analogous infections by European *Brachylaima* species have not been reported to date, but the possibility that such infections may occur should be borne in mind.

Acknowledgements

This work was financed by projects XUGA 23702B97 and PGIDIT02RMA23701PR from the Xunta de Galicia (Spain).

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(Accepted 7 June 2005)