"Parasitic Lesions of the Alimentary System of Wild Birds of the Canary Islands"

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Abstract

Spain is one of the most biologically diverse countries in the European Union due to various factors such as its geographical position, its great climatic and the existence of islands. The Canary Islands are a place in which migratory bird species pass and feed during their intercontinental migratory movements. Altitude and the quality and diversity of the habitat are also factors that promote a much diverse species of birds inhabiting them. For all these reasons, the Canary Islands represent one of the hotspots of biodiversity of wildlife in Europe.

A retrospective study was carried out with the material collected by the University Institute of Animal Health and Food Safety (IUSA) in collaboration with the Red Canaria de Vigilancia Sanitaria de Fauna Silvestre. Gross necropsy examination was performed on each animal and histological samples were taken and routinely processed for analysis.

In this study, thirteen animals with parasitic lesions of the Alimentary System were classified by organs and systems. The animals evaluated were from 8 different avian species including four Eurasian Stone-curlew (*Burhinus oedicnemus*), three Canarian houbaras (*Chlamydotis undulata fuerteventurae*), one Eleonora's falcon (Falco eleonorae), one endemic subspecies of Long-eared owl (Asio otus canariensis), one Common kestrel (Falco tinnunculus), one Cattle egret (Bubulcus ibis), one endemic subspecies of common buzzard (Buteo buteo insularum) and one Laurel pigeon (Columba junoniae).

Gastritis (including proventriculus and ventriculus) caused by nematodes was the most frequent reported lesion.

Lesions observed in the proventriculus and ventriculus of different species caused by nematodes varied in chronicity, starting as heterophilic gastritis, continuing as heterophilic granulomas in submucosa and muscle layer and progressing to histiocytic granuloma and calcified granuloma.

CONTENTS

1. INTRODUCTION

Spain is one of the most biologically diverse countries in the European Union due to factors such as its geographical position, geological diversity, its great climatic, edaphic and orographic variability and the existence of islands. However, the high anthropogenic pressure exerted on the environment has caused several species in our country to be threatened or in danger of extinction. The conservation of species must be carried out in their natural habitat, but this work can be done outside their environments or through conservation of genetic material (Ministerio para la Transición Ecológica y el Reto Demográfico, 2022).

The Canary Islands are an archipelago of eight main islands and several islets, located in the North Atlantic Ocean, with a maximum age of 20 million years. The Canary Islands are included in the biogeographic zone called Macaronesia, together with the Azores, Madeira, Selvagens and Cape Verde. None of the Canary Islands has ever been connected to the African continent, but there are different hypotheses about its formation. For this reason, the Canary Islands have an abundance of native species, result of long-distance dispersal events form the neighboring archipelagos and the continents of Europe and Africa, with ulterior adaptation to the local conditions. Due to its geographical position, the Canary Islands are also a place in which migratory bird species pass and feed during their intercontinental migratory movements. Altitude and the quality and diversity of the habitat are also factors that probably promote a much diverse species of birds inhabiting them. For all these reasons, the Canary Islands represent one of the hotspots of biodiversity of wildlife in Europe (Illera et al., 2016).

Wild birds are commonly affected by multitude of parasites including protozoa, helminths, and arthropods, although low morbidity from parasitic lesions would be expected as these animals are well adapted to their parasites and vice versa (Atkinson et al., 2008). This host-parasite interaction and the factors that determine a parasitic infection do not always depend on the pathogenicity of the parasite, but also on the immune status and microbiota of the host. For example, *entamoeba* diseases are much more severe in host with an impaired microbiota or intestinal mucosal barrier (Cornick and Chadee, 2017). Environmental variables, parasite host specificity and parasite phylogenetic relationships determine the distribution and prevalence of haemosporidians (Padilla et al., 2017). If the host–parasite interaction is weak, the fittest phenotype of the host evolves to reduce phenotypic variances. In contrast, if there exists a sufficient degree of interaction, the phenotypic variances of hosts increase to escape parasite attacks (Nishiura and Kaneko, 2021). It has been proven that the parasite *Trichomona vaginalis* can secrete exosomes, which consist of conserved exosomal proteins, RNA and specific parasite proteins. *T. vaginalis* uses these exosomes to adhere to epithelial cells. In addition to activating adherence, the exosomes inhibit IL-8 secretion of ectocervical cells, consequently dampening neutrophil migration to infection sites (Wu et al., 2019). *Heligmosomoides polygyrus* is a nematode that exclusively locates in the intestinal tract of rodents and it is able to promote Th2 immune reactions with immunosuppressive effects. *H. polygyrus* can secrete miRNAs and Y RNAs through exosomes, which contains various stress related proteins such as heat shock proteins (HSPs) and tetraspanins that are found naturally in mammalian exosomes. Local injection of these exosomes in a murine model inhibits the type 2 innate response and eosinophil activation, repressing the host immune response (Wu et al., 2019). These recent discoveries in host-parasite interaction indicate that parasite may influence much more in animal population that we previously though and support the idea that a stressed population is more susceptible to parasitic diseases.

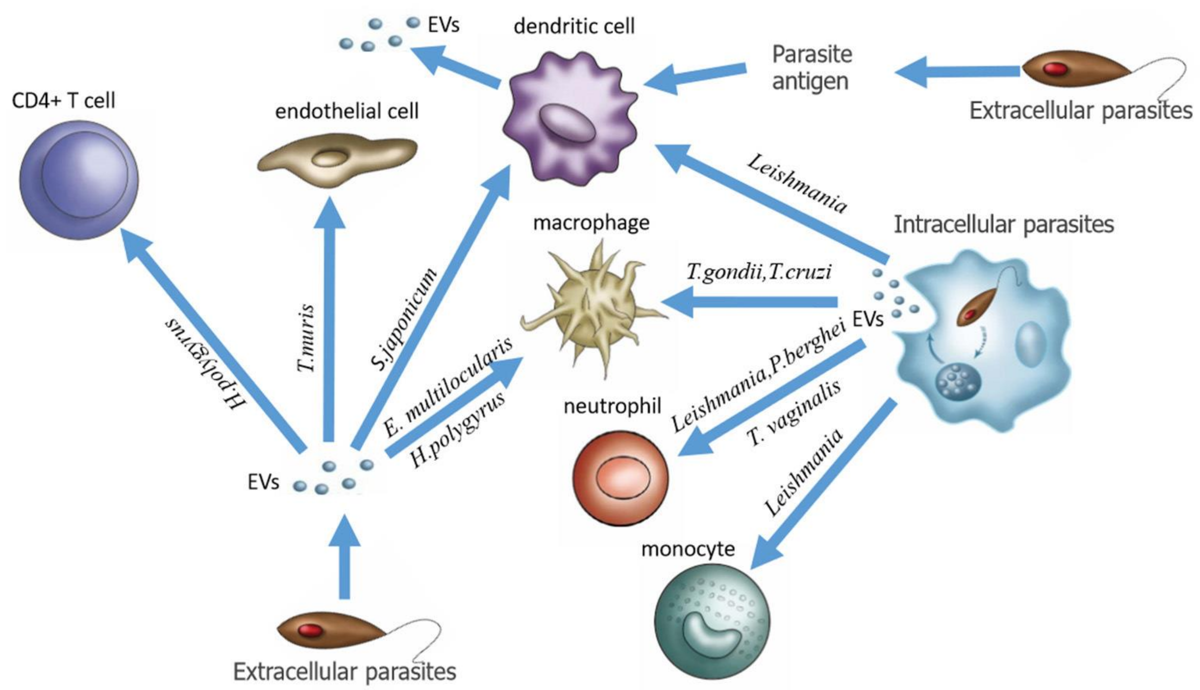

Figure 1. Schematic view of the host-parasite interaction for different extracellular and intracellular parasites (Wu et al., 2019).

In the literature, very few studies have focused on the lesions produced by parasites in the wild birds of Canary Islands. In 2004, Foronda et al. studied the prevalence and intensity of the parasites from 50 wild doves *(Columba livia*) from the city of Santa Cruz de Tenerife. They found the presence of ectoparasites such as: the acari *Dermanyssus gallinae* and

Tinaminyssus melloi, the louses *Columbicola columbae* and *Campanulotes bidentatus*. The endoparasites found were: *Haemoproteus columbae, Eimeria sp., Railletina micracantha* and four nematode species, *Tetrameres fissispina, Synhimantus spiralis*, *Ascaridia columbae* and *Aonchotheca sp* (Foronda et al., 2004). A year later, in 2005, Foronda et al. identified seven helminth species of the barbary partridge (*Alectoris Barbara*) in Tenerife Island. Those species were: two cestodes, *Choanotaenia infundibulum* and *Lyruterina nigropunctata*, and five nematode species, *Aonchotheca caudinflata, Baruscapillaria obsignata, Eucoleus annulatus*, *Ascaridia galli* and *Heterakis gallinarum*. The data on Alectoris spp. revealed that the ingestion of arthropods and earthworms is important for the life cycle of the parasites as they act as intermediate hosts (Foronda et al., 2005). In 2016, Fernández-Álvarez et al. identified a new coccidian present in a cynegetic farm of Alectoris barbara. The parasite develops along the intestine and causes severe pathologies in chickens (Fernández-Álvarez et al., 2016). Finally, in 2017 Padilla et al. demonstrated the relevance of the environmental variables, the parasite-host specificity and parasite phylogenetic relationships in the distribution and prevalence of haemosporidians (Haemoproteus, Plasmodium and Leucocytozoon) in the wild living avifauna of Tenerife. They discovered that the warmest temperature best predicted Plasmodium prevalence in the low altitude habitats, which had the highest incidence of Plasmodium. In the other hand, the prevalence of Leucocytozoon was associated with natural factors, but the two most important predictors for the parasite were anthropogenic such as poultry farms and distance to a water reservoir. Their data revealed that climatic and anthropogenic factor, plus the proximity to the African continent, are the main factors influencing the presence and distribution of avian haemosporidians (Padilla et al., 2017).

The present work is centered in the description of lesions of the alimentary system of wild birds from the Canary Islands caused by parasites and diagnosed in *post mortem* examination of bird carcasses.

2. OBJECTIVES

1. To identify the lesions caused by parasites in the alimentary system of wild birds from the Canary Islands.

2. To describe and characterize the macroscopic and histopathologic lesions of the alimentary system caused by parasites to wild birds from the Canary Islands.

3. MATERIAL AND METHODS

A retrospective study was carried out with the material collected by the University Institute of Animal Health and Food Safety (IUSA) in collaboration with the Red Canaria de Vigilancia Sanitaria de Fauna Silvestre (Red Vigía Canarias, Orden Nº134/2020 de 26 de mayo de 2020).

In this study, 196 animals were analyzed, of which 13 met the inclusion and exclusion criteria (see Table 1). These criteria where:

1) A very fresh and fresh conservation state of the carcass (code numbers 1 and 2)

2) Animals whose necropsy was performed between the years 2020 and 2021

3) Animals with parasitic lesions of the Alimentary System documented in the necropsy report.

Case ID	Species	Island of origin	Sex	Age category	Nutritional condition (1-5)
SA024/20	*Falco eleonorae*	Fuerteventura	Female	Adult	1
SA131/21	*Burhinus oedicnemus*	Lanzarote	Female	Adult	1
SA162/21	*Chlamydotis undulata fuerteventurae*	Lanzarote	Female	Adult	3
SA171/21	*Asio otus canariensis*	Gran Canaria	Female	Adult	3
SA334/21	*Burhinus oedicnemus*	Gran Canaria	Male	Adult	2
SA413/21	*Chlamydotis undulata fuerteventurae*	Lanzarote	Male	Adult	3
SA444/21	*Chlamydotis undulata fuerteventurae*	Lanzarote	Male	Adult	3
SA485/21	*Burhinus oedicnemus*	Lanzarote	Female	Adult	3
SA517/21	*Falco tinnunculus*	Lanzarote	Male	Sub-adult	2
SA597/21	*Burhinus oedicnemus*	Lanzarote	Male	Sub-adult	3
SA599/21	*Bubulcus ibis*	Lanzarote	Male	Adult	3
SA750/21	*Buteo buteo insularum*	Tenerife	Female	Sub-adult	2
SA844/21	*Columba junoniae*	Gran Canaria	Male	Sub-adult	4

Table 1. Animals in the study.

NECROPSY

There are various protocols to perform a necropsy examination depending on the circumstances and the specie under study. Independent of the chosen procedure, a *postmortem* examination must have a consistent and systematic analysis of the organs and organ systems (Terio et al., 2018).

For a detailed description of the necropsy protocol see Hernández et al., 2021. Briefly external examination if performed. The carcass is examined for fractures, the muscle condition (pectoralis muscle), pelvic limb joints and sciatic nerves (Paraschiv et al., 2020) are inspected. Then, the coelomic cavity is opened and visceras are inspected *in situ.* After that, the viscera are removed from the carcass in block or by organs and systems. The gastrointestinal tract is opened and inspected. The gastric contents of the proventriculus and gizzard are inspected and collected for toxicology. A closed bowel segment is sampled for microbiology and the rest of the intestine is opened and the presence of lesions and parasites is evaluated. Gently flush the intestinal mucosa with water to better evaluate for lesions. The rest of the entire intestine is fixed, including the bursa of Fabricius (Paraschiv et al., 2020).

HISTOPATHOLOGY

Samples of adrenal glands, encephalon, esophagus, eyes, heart, intestine, kidney, liver, lung, pancreas, skeletal muscle, skin, spleen, stomach, testicles, thyroid, tongue and trachea were collected and placed in 4% buffered formalin during 24h and routinely processed for histological analysis. Briefly the samples are dehydrated in seriated alcohols and xylols and embebed in paraffin. (Hernández et al., 2021) The tissue samples were cut at 4µm, stained with hematoxylin & eosin and visualized under an optic microscope.

4. RESULTS

ORAL CAVITY

In a Laurel pigeon (*Columba junoniae,* SA844/21) the following lesions caused by protozoa were found. Multifocally there is squamous metaplasia of the salivary glands which are markedly ectatic, dilated and filled with heterophils and protozoan about 2 micrometers of diameter.

Morphological diagnosis: Heterophilic sialadenitis with squamous metaplasia with intralesional protozoa (Figure 3).

Figure 2. Sialadenitis in the floor of the oral cavity.

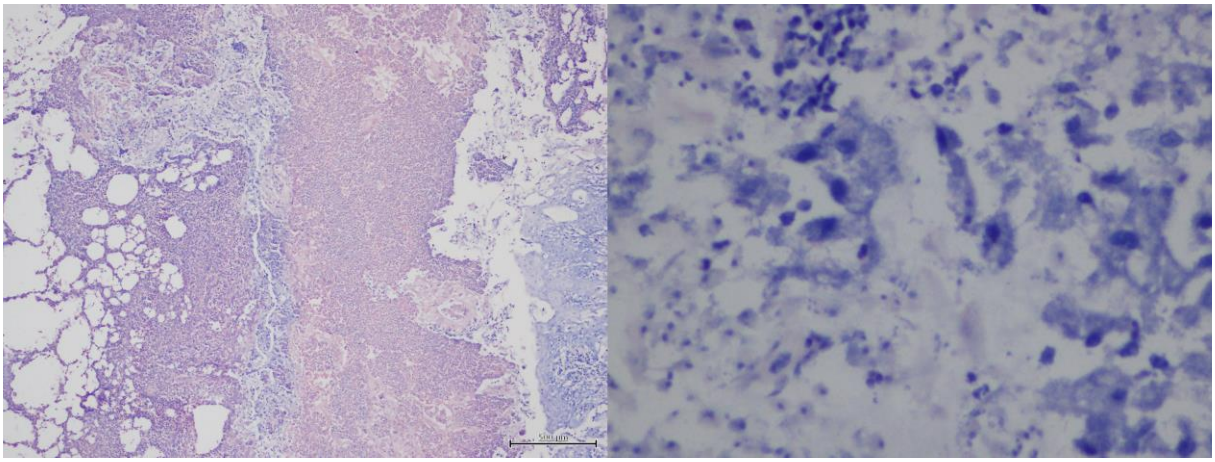

Figure 3. Heterophilic inflammation of salivary gland (left) with protozoa in the ectatic glands (right)

ESOPHAGUS

The following parasitic lesion was identified in an endemic subspecies of long-eared owl (*Asio otus canariensis*, SA171/21) affected by nematodes. Multifocal erosion and ulceration of the esophageal mucosa with infiltration of heterophile and lymphoplasmacytic cells and intraluminal nematodes.

Morphological diagnosis: Ulcerative-heterophilic esophagitis with intralesional nematodes (Figure 5).

Figure 4. Esophagus containing catarrhal exudate and numerous nematodes.

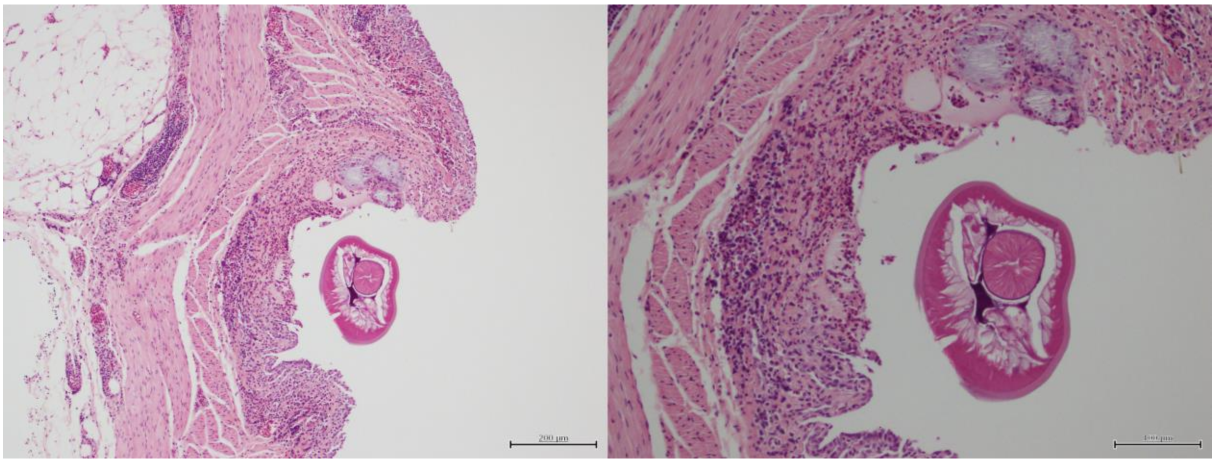

Figure 5. Esophageal mucosa is ulcerated and infiltrated by abundant heterophils and lymphoplasmacytic cells.

PROVENTRICULUS

Different parasitic lesions were found in the proventriculus of the following animals: a common kestrel (*Falco tinnunculus,* SA517/21), an Eurasian stone-curlew (*Burhinus oedicnemus*, SA597/21) and three Canarian houbaras (*Chlamydotis undulata fuerteventurae,* SA162/21, SA413/21 and SA444/21).

In both *Chlamydotis undulata fuerteventurae*, similar lesions produced by nematodes in the proventriculus were identified:

In the first *Chlamydotis undulata fuerteventurae* (SA413/21) the lesions were multifocal aggregates of heterophils infiltrating the proventricular mucosa whereas in the mucosal interstitium there are multiple foci of lymphoplasmacytic cells. There is diffuse caliciform cells hyperplasia in the mucosa and high number of nematodes immerse in the proventricular mucosa

Morphological diagnosis: Heterophilic proventriculitis with intralesional nematodes (Figure 7).

Figure 6. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine.

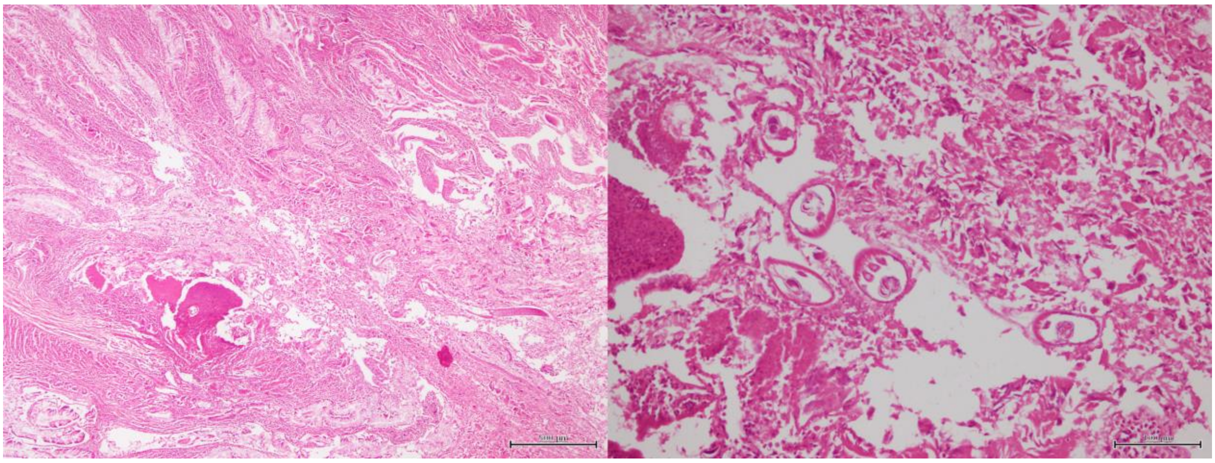

Figure 7. The mucosa of the proventriculus is hyperplasic with presence of heterophils and nematodes.

In the other *Chlamydotis undulata fuerteventurae* (SA444/21), there were multifocal aggregates of lymphoplasmacytic cells in the proventricular mucosa and multifocal heterophils with abundant mucous material and intralesional nematodes.

Morphological diagnosis: Heterophilic and lymphoplasmacytic proventriculitis with intralesional nematodes (Figure 9).

Figure 8. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine.

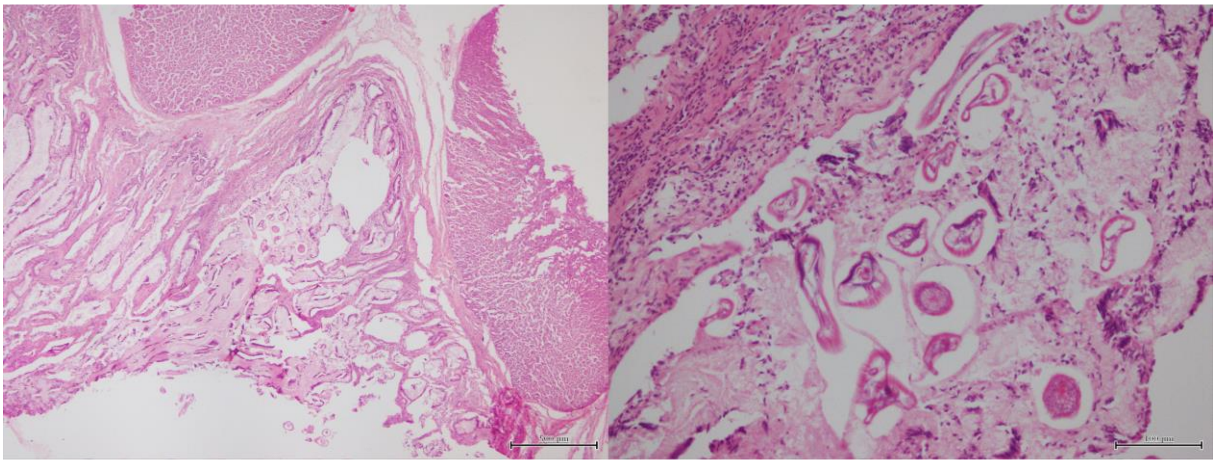

Figure 9. Nematodes in the mucosa of the proventriculus with abundant mucous material.

The *Falco tinnunculus* (SA517/21) presented parasitic lesions in the proventriculus of a more chronic nature than those previously mentioned. Focally there is an histiocytic granuloma in the mucosa of the proventriculus with intralesional nematodes.

Morphological diagnosis: Granulomatous proventriculitis with intralesional nematodes (Figure 11).

Figure 10. Presence of nematodes in coelomic cavity.

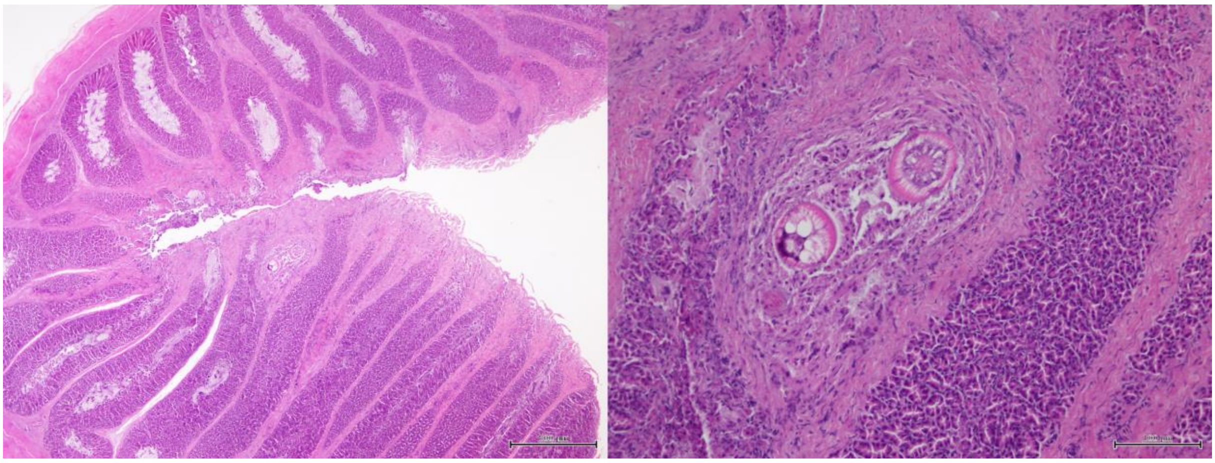

Figure 11. Nematodes causing a focal granuloma in the mucosa of the proventriculus.

The third *Chlamydotis undulata fuerteventurae* (SA162/21) presented the following lesions. Focal area of erosion and ulceration of the mucosa of the proventriculus with multifocal histiocytic and heterophilic granuloma and numerous interstitial plasma cells and intralesional nematodes.

Morphological diagnosis: Multifocal granulomatous proventriculitis with intralesional nematodes (Figure 13).

Figure 12. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine

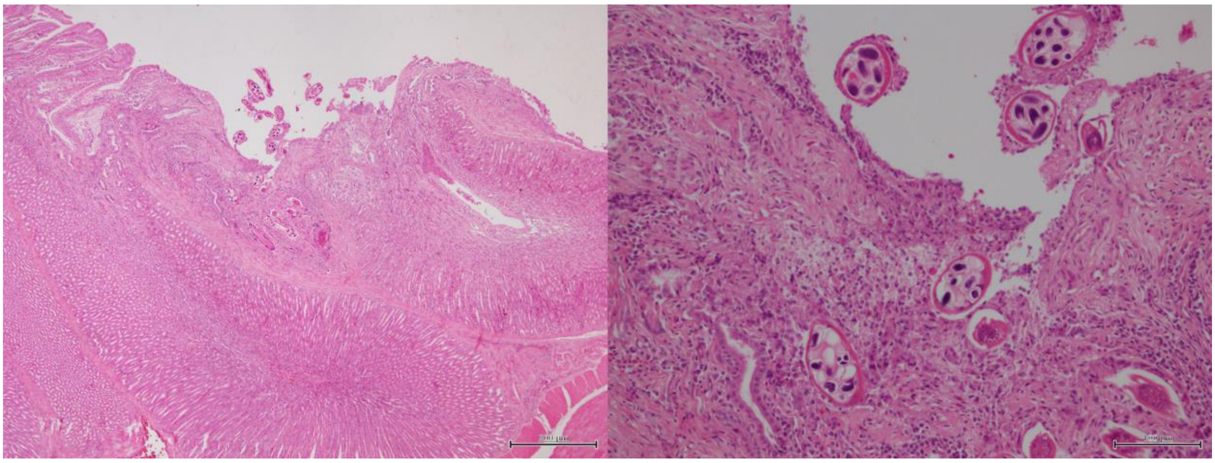

Figure 13. Proventriculus with nematodes. Note the presence of gravid females (right).

The last case of parasitic lesions in the proventriculus corresponds to the case of the *Burhinus oedicnemus* (SA597/21). Multifocally there are lymphoplasmacytic cells infiltrating the mucosa and multifocally there are nematodes inside the proventricular glands causing dilation of the primary ducts and compression atrophy of the glandular acini.

Morphological diagnosis: Multifocal lymphoplasmacytic proventriculitis with intralesional nematodes (Figure 15).

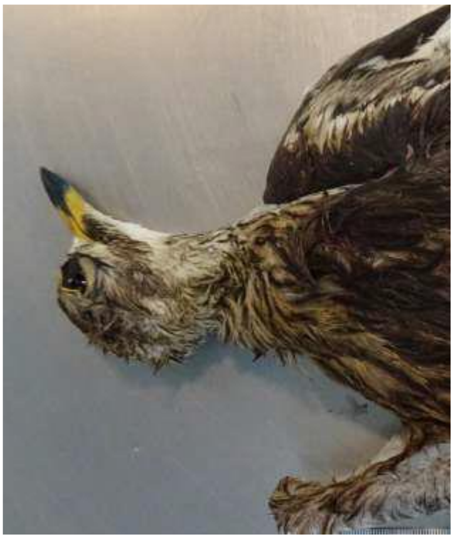

Figure 14. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine.

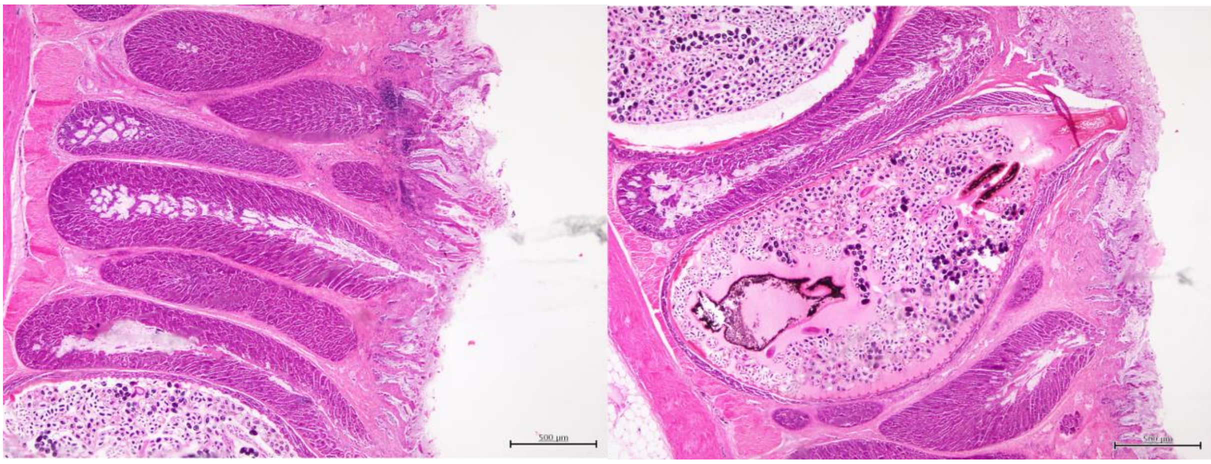

Figure 15. Proventricular gland dilated with an intraluminal nematode (gravid female).

VENTRICULUS

In the ventriculus, various parasitic lesions were identified in the next species: An Eleonora's falcon (*Falco eleonorae*, SA024/20), a Cattle egret (*Bubulcus ibis*, SA599/21), an endemic subspecies of Common buzzard (*Buteo buteo insularum*, SA750/21), a Common kestrel (*Falco tinnunculus*, SA517/21) and three Eurasian stone-curlew (*Burhinus oedicnemus*, SA131/21, SA334/21, and SA597/21).

The first *Burhinus oedicnemus* (SA334/21) presented an heterophilic ventriculitis with intralesional nematodes.

Morphological diagnosis: Heterophilic ventriculitis with intralesional nematodes (Figure 17).

Figure 16. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine.

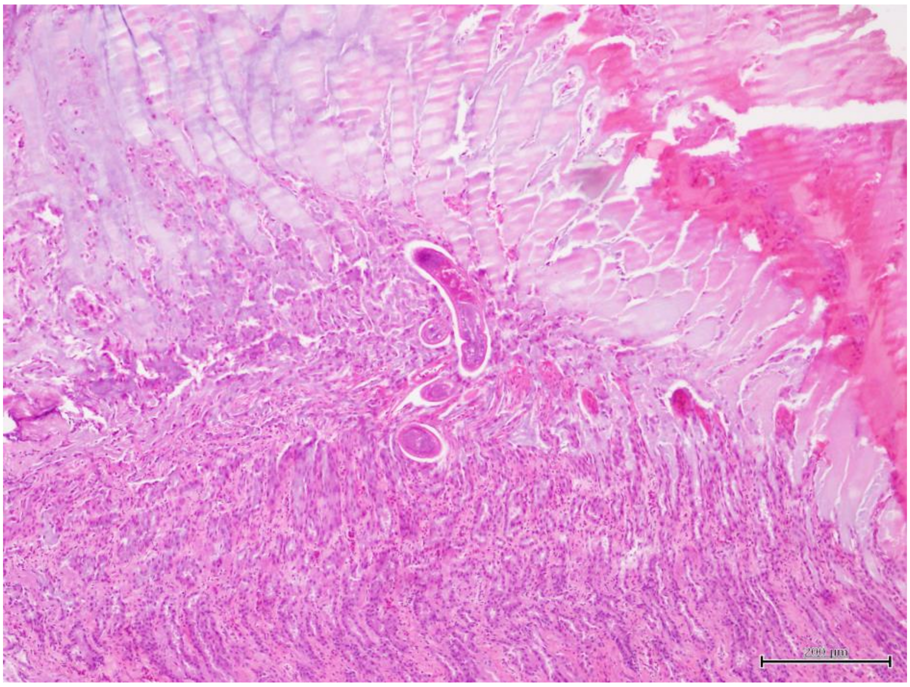

Figure 17. Nematode infiltrating in the ventricular mucosa.

In the second *Burhinus oedicnemus* (SA597/21), the following lesions were identified. Multifocally there is erosion of the koilin layer and diffuse infiltration of heterophiles between the koilin and the mucosa with multifocal intralesional nematodes.

Morphological diagnosis: Heterophilic ventriculitis with intralesional nematodes (Figure 19).

Figure 18. Detail of gastric contents.

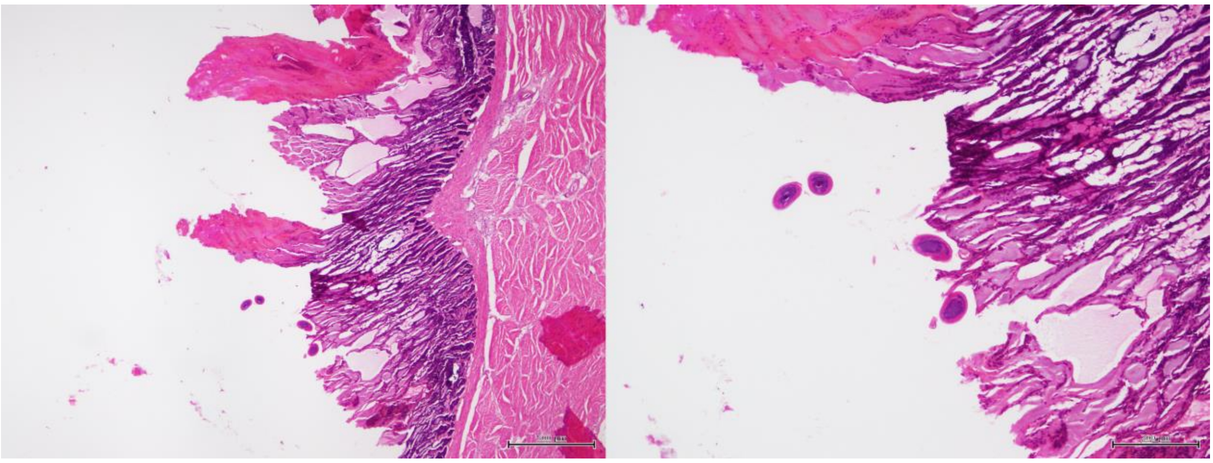

Figure 19

The next case corresponds to the *Buteo buteo insularum* (SA750/21). Focal heterophilic granuloma with intralesional nematodes in the submucosa of the ventriculus.

Morphological diagnosis: Multifocal granulomatous ventriculitis with intralesional nematodes (Figure 21).

Figure 20. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine

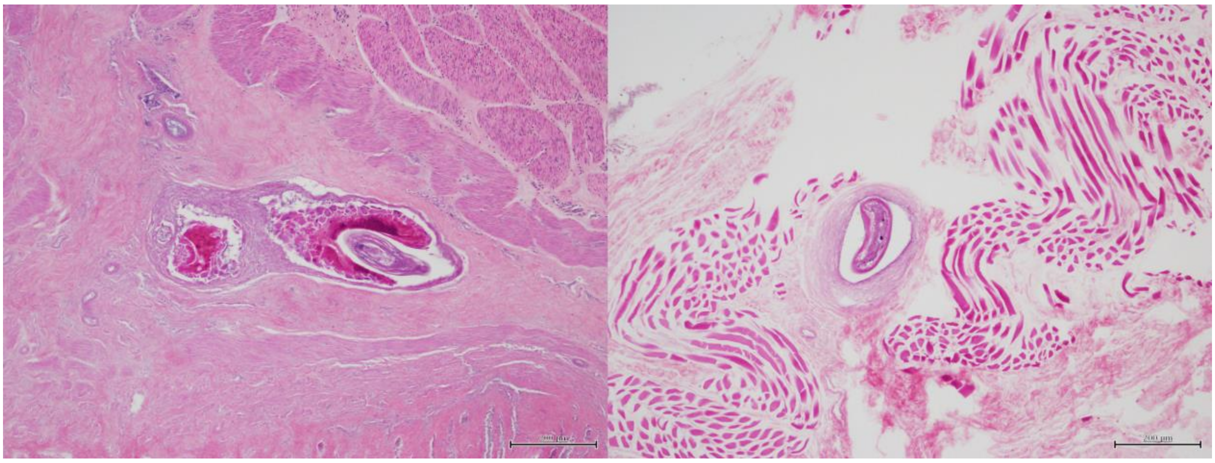

Figure 21. Nematode causing a mural histiocytic granuloma in the ventriculus (left). Similar nematodes wee found in skeletal muscle (right).

In the *Bubulcus ibis* (SA599/21), the lesions identified were the next. Multifocally in the submucosa there are histiocytic and heterophilic granulomas with intralesional nematodes.

Morphological diagnosis: Multifocal granulomatous ventriculitis with intralesional nematodes (Figure 23).

Figure 22. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine

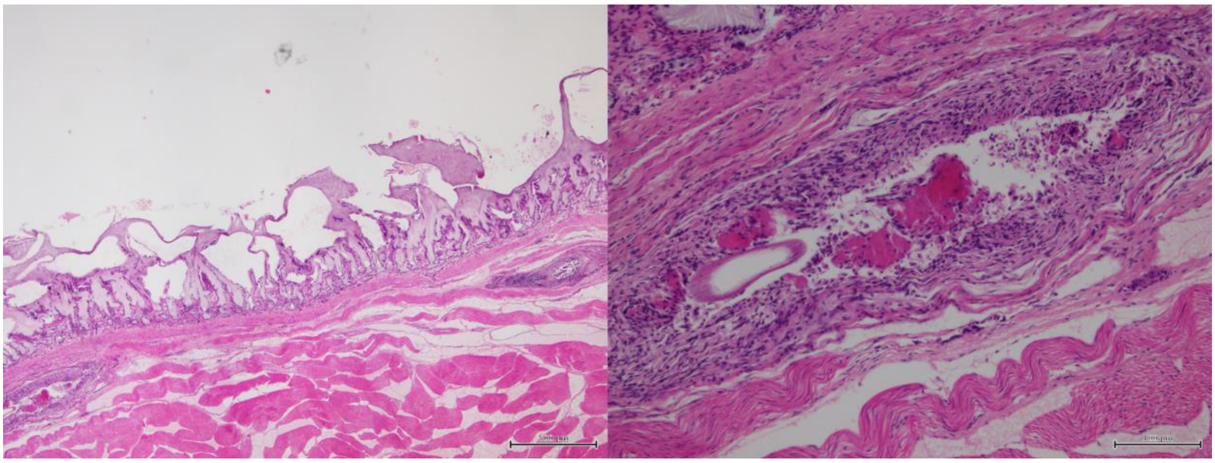

Figure 23

The next animal with ventriculus lesions is the *Falco eleonorae* (SA024/21). Multifocally, in the submucosa and muscle layer of the ventriculus there are numerous circular cavities with intracavitary nematodes, surrounded by numerous histocytes and thin layer of connective tissue. Multifocal neovascularization in the muscle layer. Multifocal catarrhal ventriculitis with intralesional nematodes, bacteria, and yeast.

Morphological diagnosis: Mural granulomatous and catarrhal ventriculitis with intralesional nematodes (Figure 25).

Figure 24. Detail of the nematodes observed in the ventriculus.

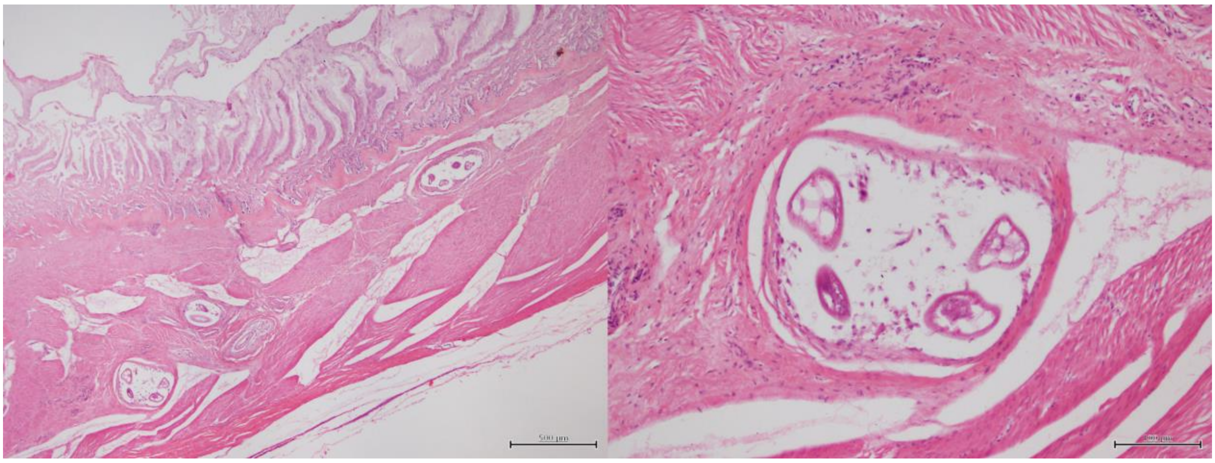

Figure 25. Nematodes present in the muscle layer of the ventriculus.

In the third Burhinus oedicnemus (SA131/21) the next lesions were identified. Focal heterophilic granuloma of the muscle layer of the ventricle with intralesional nematodes.

Morphological diagnosis: Mural granulomatous ventriculitis with intralesional nematodes (Figure 27).

Figure 26. Animal carcass in the Necropsy Room of the Faculty of Veterinary Medicine

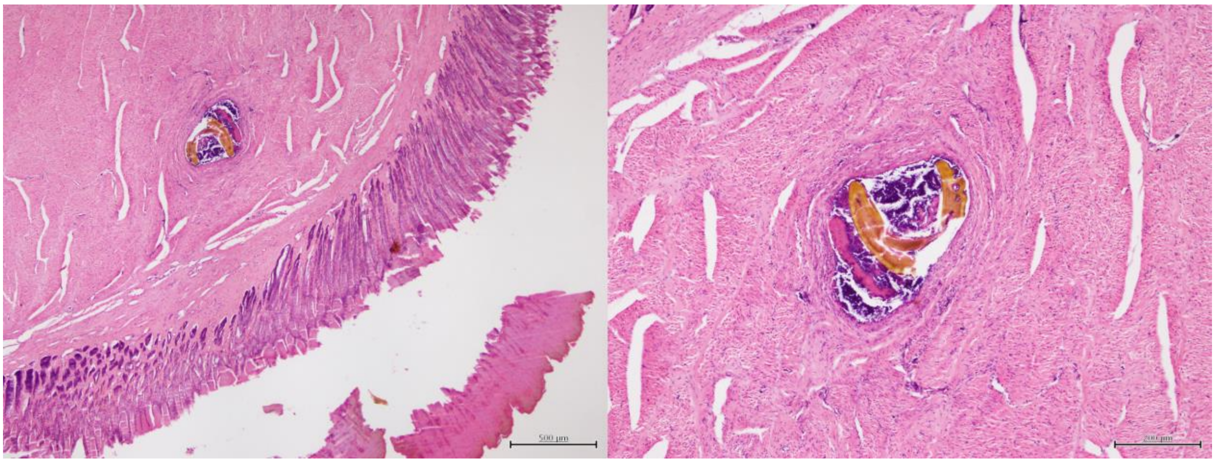

Figure 27. Chronic granuloma in the muscle layer of the ventriculus.

Finally, the *Falco tinnunculus* (SA517/21) presented the following lesions. There are multiple histiocytic granulomas in the muscle layer of the ventricle with intralesional nematodes.

Morphological diagnosis: Mural granulomatous ventriculitis with intralesional nematodes (Figure 29).

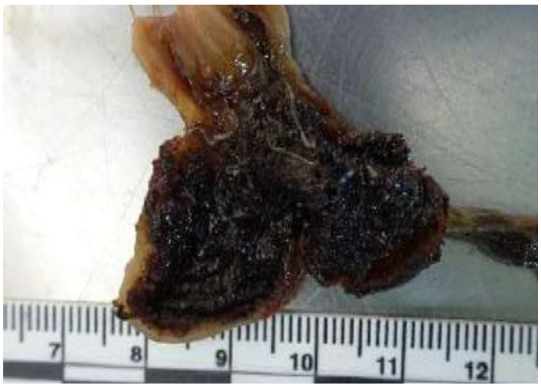

Figure 28. Detail of gastric contents.

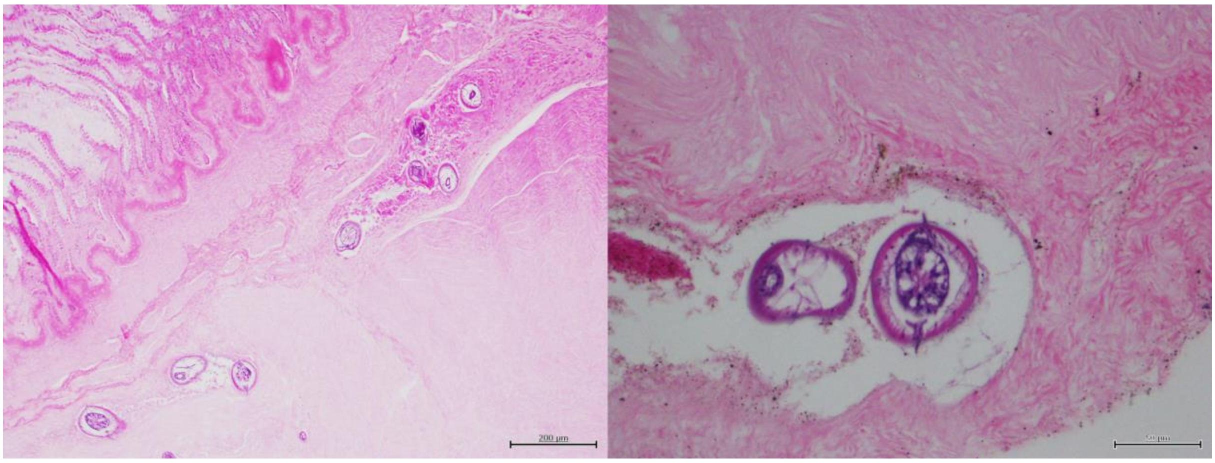

Figure 29.

INTESTINE

The last organ in which parasitic lesions were found was the intestine. The following species showed lesions: Three Canarian houbaras (*Chlamydotis undulata fuerteventurae*, SA 162/21, SA413/21, SA444/21) and two Eurasian stone-curlew (*Burhinus oedicnemus*, SA131/21, SA485/21).

In first place, the *Burhinus oedicnemus* (SA485/21) presented the following lesions. Focally there is an area of erosion in the mucosa with intralesional Acanthocephala.

Morphological diagnosis: Multifocal erosive-ulcerative enteritis with intralesional acanthocephala (Figure 31).

Figure 30. Detail of gastric contents.

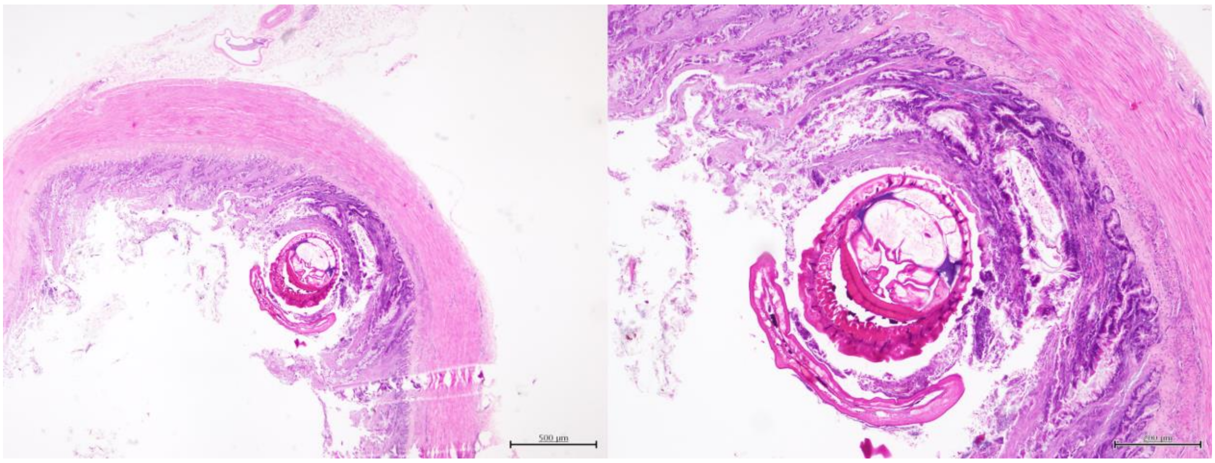

Figure 31.

The second *Burhinus oedicnemus* (SA131/21) presented the next lesions. Focally there is an area of erosion in the mucosa with intralesional Acanthocephala.

Morphological diagnosis: Multifocal erosive-ulcerative enteritis with intralesional acanthocephala (Figure 33).

Figure 32. Detail of intestinal acanthocephaliasis

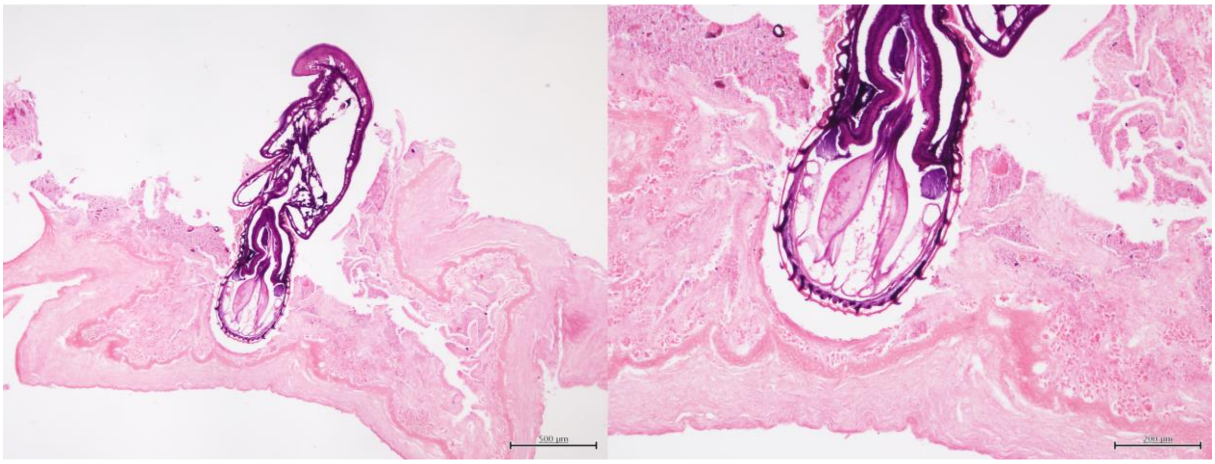

Figure 33.

In the first *Chlamydotis undulata fuerteventurae* (SA413/21), the next lesions were identified. In the serosa there is a cavity filled with histocytes and nematodes (histiocytic granuloma).

Morphological diagnosis: Intestinal granulomatous serositis with intralesional nematodes (Figure 35).

Figure 34. Detail of gastric contents

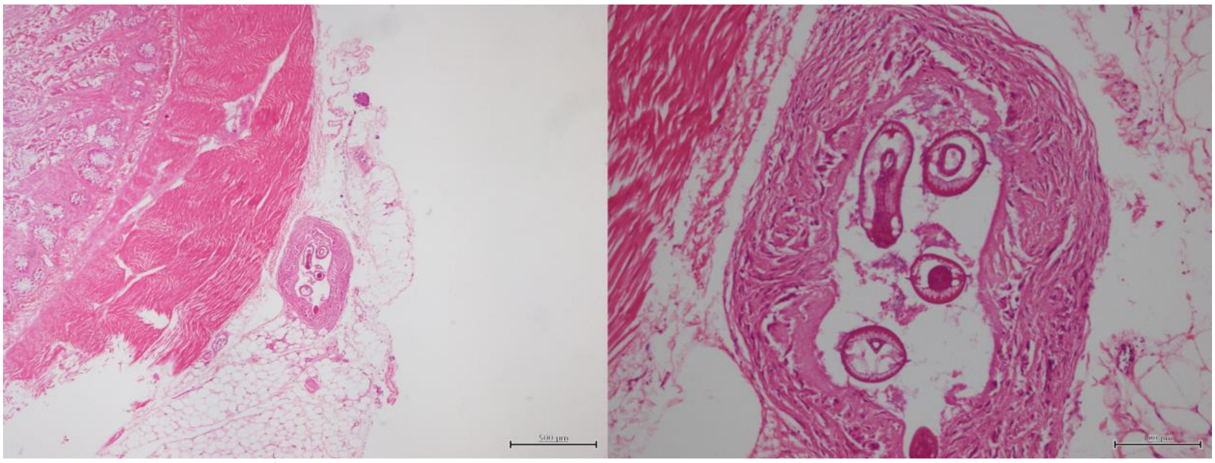

Figure 35.

The second *Chlamydotis undulata fuerteventurae* (SA162/21) presented various lesions. Multifocally the mucosa of the large intestine is ulcerated. There are abundant cell debris in the lumen with abundant bacteria and cestodes. Moderate multifocal lymphoplasmacytic enteritis. Dilatation of the Lieberkühn crypts with brown material. Intraluminal cestode. Focally there is a cyst in the muscle layer of the large intestine with an intralesional nematode.

Morphological diagnosis: Moderate multifocal lymphoplasmacytic enteritis. Mural erosive-haemorrhagic enteritis with intralesional nematodes (Figure 37).

Figure 36. Detail of intestinal parasites.

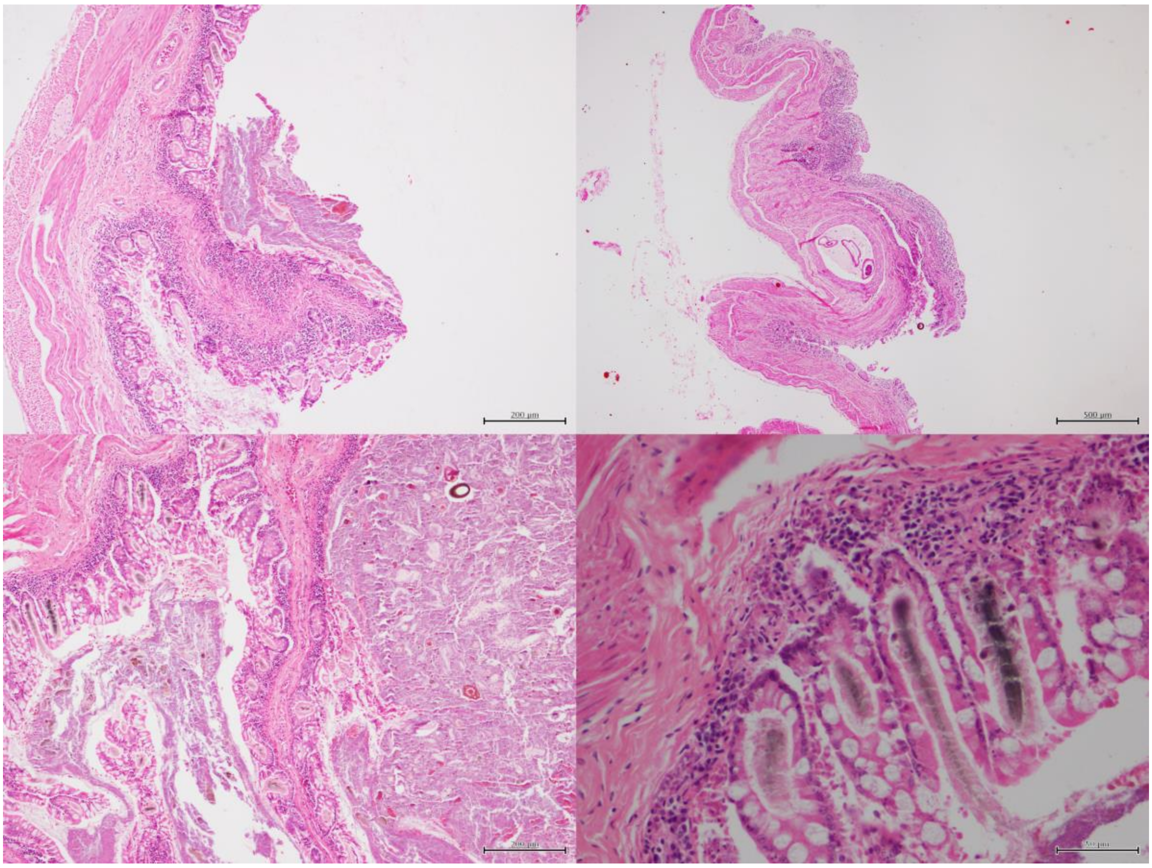

Figure 37. Enteritis in a houbara with intestinal cestodiasis.

The last *Chlamydotis undulata fuerteventurae* (SA444/21) presented at the intestinal level abundant parasitosis formed by cestodes, mainly located in the ileocecal region producing a catarrhal enteritis.

Morphological diagnosis: Catarrhal enteritis with intralesional cestodes.

5. DISCUSSION

In this study, thirteen animals with parasitic lesions of the Alimentary System were classified by organs and systems. The animals evaluated were from 8 different avian species including four Eurasian Stone-curlew (*Burhinus oedicnemus*), three Canarian houbaras (*Chlamydotis undulata fuerteventurae*), one Eleonora's falcon (Falco eleonorae), one endemic subspecies of Long-eared owl (Asio otus canariensis), one Common kestrel (Falco tinnunculus), one Cattle egret (Bubulcus ibis), one endemic subspecies of common buzzard (Buteo buteo insularum) and one Laurel pigeon (Columba junoniae). It was observed that the majority of parasitic lesions in the Alimentary System of wild birds in the Canary Islands are caused by nematodes.

In the oral cavity we had the case of the *Columba junoniae* (SA844/21). The lesion identified was an heterophilic sialadenitis with squamous metaplasia with intralesional protozoa. Outlines of oval or pear-shaped organism are characteristic of *Trichomonas gallinae*, an important pathogen of pigeons and free-living passerine birds (Fletcher and Abdul-Aziz, 2016). It has been observed that infection with mild strains of Trichomonas results in excessive salivation and some inflammation of the oral cavity (Forrester and Foster, 2008). This information may raise suspicions of *Trichomoniasis*, but further tests should be carried out. Squamous metaplasia is a reversible change in which glandular epithelium is replaced by squamous epithelium due to stress phenomena to better withstand adverse conditions. One of the most frequent causes of squamous metaplasia is vitamin A deficiency (Surman et al., 2020). This case is referred from the Recovery Centre for the Laurel pigeon in which squabs are fed with the crop milk produced by old mother turtledoves (*Streptopelia decaocto*). As they are different species, it is possible that the nutritional composition of the crop milk of the turtledove is not the same as the Laurel pigeon, which could lead to nutritional deficiencies, which could explain the squamous metaplasia. In addition, it is possible that these old turtledoves were infected with the parasites and infected the squabs by feeding them. However, stress and cell damaged caused by the parasite may also be the cause of squamous metaplasia. It is possible that squamous metaplasia may favor future reinfections if antiprotozoal therapy is performed, particularly if long-time treatments are not followed.

We identified an *Asio otus canariensis* with parasitic nematode lesions in the esophagus. Among the species of nematode that parasites the upper digestive tract of birds we highlight: *Capillaria spp*., and *Serratospiculum spp*. Capillarids are small hairlike nematodes that parasitize the gastrointestinal tract of all classes of vertebrates. Capillarid species that infect the upper gastrointestinal tract (oral cavity, esophagus, crop) can cause inflammation, dilatation of the crop or esophagus, thickening of mucosa, ulceration, bacterial colonization, exudation, and fibrinonecrotic plaques (Yabsley, 2008). On the other hand, for a bird to become infected by *Serratospiculum spp*., the eggs of this parasite must have been previously ingested by foraging insects and larval development of the worm takes place within the hemocoel. Infected insects are eaten by birds to complete the life cycle. Serratospiculiasis is characterized by necrosis of the crop and esophagus, edema in the media of the arterioles and bronchial passages, congested hepatic veins, squamous metaplasia of glandular epithelium, hyperplasia of the mesothelium, heterophile infiltration, focal hemorrhages in the lungs, lesions within the lungs and spinal cord, air sacculitis, and pneumonia (Sterner and Cole, 2008). The *Asio otus canariensis* feeds mainly on rodents (mice, rats and voles), although occasionally insects, reptiles and amphibians can be part of their diet. For this reason, it is important to mention that a recent study demonstrated the presence of anticoagulant rodenticides in 60% of raptors from the Canary Islands (Rial-Berrier, 2021). It is unknown how the chronic sublethal exposure of these toxins may affect the animal's immune system.

Regarding the gastric lesions caused by parasites, the lesions in the proventriculus of the Canarian houbara (SA162/21) and the Eurasian stone-curlew (SA597/21), and the lesions in the ventriculus of the Eurasian stone-curlew (SA131/21) and the Common kestrel (SA517/21) are noteworthy. This is because they all presented chronic lesions where the parasite had passed through the inner parenchymal layers of both organs, reaching the muscle layer and causing moderate to severe damage to the animals. It was observed that two of these animals were cachectic, which could be explained by the significant parasitism they exhibited together with a nutritional deficit, leading to a negative energy imbalance. There are several species of nematodes causing gastric lesions in wild birds. Eustrongylidosis is a disease of piscivorous birds caused by infection with a large dioctophymoid nematode of the genus *Eustrongylides*. When infested fish containing larval stages of *E. ignotus* are consumed by herons, egrets (like the *Cattle egret*) and long-legged wading birds, the parasites perforate the stomach wall and cause severe fibrinous to fibrous peritonitis (Spalding & Forrester, 2008). Nematodes of the genera *Dispharynx*, *Echinuria*, and *Streptocara* are parasitic in the proventriculus and ventriculus of many avian taxa. *D. nasuta* bury their heads into the lamina propria of the proventriculus and causes an inflammatory response that leads to thickening of the mucosa and functional obstruction of the digestive tract. Characteristic lesions consist of ulceration and inflammation of the proventriculus, the mucosa is often destroyed, and parasites are found buried in a mass of degenerated and necrotic tissue. The presence of *Echinuria* in the proventriculus results in a strong immune response that leads to formation of nodules that contain the worms. Infection with *E. uncinata* can result in the formation of encapsulated lesions in the proventriculus. Infective larvae of *Streptocara* spp. penetrate the cuticle of the ventriculus and burrow into the mucosa. Their presence gives rise to local hemorrhage, ulceration, and necrosis. The presence *of S. crassicauda* in the proventriculus and *S. incognita* in the ventriculus, proventriculus and esophagus can thus lead to destruction of tissue, inability of the host to feed properly, and death (Carreno, 2008). Ventriculus worms of the genera *Amidostomum* and *Epomidiostomum* are commonly found in waterfowls. Adult worms of both genera live under the koilin lining of the ventriculus and feed of blood. Intense infections can result in damage to the koilin lining and associated muscle and lead to ventriculus dysfunctions, emaciation, weakness, and potentially poor growth rates of juveniles (Fedynich and Thomas, 2008). The term tetrameridosis includes diseases caused by species of nematodes belonging to three genera of the family Tetrameridae: *Tetrameres, Microtetrameres,* and *Geopetitia.* Females of *Tetrameres* and *Microtetrameres* are typically found embedded in the gastric glands of the proventriculus. One or more of the much smaller males may be either associated with the females in the glands or free in the lumen of the proventriculus. Hematological changes occur when juveniles migrate through the wall of the proventriculus, followed by heterophilia and lymphocytopenia. Infections of high intensity with *Tetrameres spp.* are characterized by enlargement of the proventriculus (Kinsella and Forrester, 2008). Infections of ascaridoids in the alimentary tract can produce a severe inflammatory response, especially when juvenile worms of some species embed and migrate within the walls of the proventriculus, esophagus, or intestine. Infections can cause anemia and may lead to actual disease when the bird becomes stressed. Highly pathogenic cases usually involve high-intensity infections in nestlings or young juveniles, starved individuals, birds that are stressed by environmental contamination or other causes, and birds with peritonitis or secondary microbial infections that involve other vital organs (Fagerholm and Overstreet, 2008).

In the cases of the *Falco tinnunculus* (SA517/21) and the *Buteo buteo insularum* (SA750/21), we found identical nematodes in different anatomical locations. In the *Falco tinnunculus*, similar nematodes were found in the heart as in the proventriculus and the ventriculus, suggesting that this nematode travels intravascularly. In the same way, the *Buteo buteo* *insularum* presented nematodes in skeletal muscle and appear to be intravascular. A wide variety of helminths, including nematodes, infect the alimentary tract and other organ systems of birds of prey. Spirurid nematodes in the genus *Serratospiculum* and *Serratospiculoides* infect the air sacs o falcons and hawks. Adult worms colonize the air sacs where they lodge in the mesenchymal layer. Adult female nematodes are large, up to 20cm in length, and lay embryonated eggs in the air sacs. The eggs reach the lungs and are coughed up and swallowed, passing in the feces. Beetles ingest those eggs, and the raptors are infected via ingestion. L3 larvae are thought to penetrate the proventricular and ventricular wall and lodge in the air sacs, completing the life cycle (Wünschmann et al., 2018), which could explain the presence of nematodes in different organs in these cases.

Both Canarian houbaras (*Chlamydotis undulata fuerteventurae*) and Eurasian stone-curlews (Burhinus oedicnemus) are very susceptible to changes in their environment. The high anthropic pressure exerted on these species in the Canary Islands can lead to chronic stress, which is an important factor of immunosuppression and possible changes in the microbiota, which can cause the animals to be unable to eliminate the parasite and develop a parasitosis (Cornick and Chadee, 2017). In this study, it was observed that both species had significant nematode and acanthocephalan lesions in the intestine, which could be explained for the above-mentioned reasons.

The Canary Islands are an archipelago whose environment suffers great anthropic pressure due to its high population density and the large number of tourists that visit the islands every year. The high rate of urbanization, coupled with the sensitivity of certain species that inhabit the Canary ecosystem, causes high stress values in these species, which we have seen to negatively influence immunity (Cornick and Chadee, 2017). These immunocompromised birds are more susceptible to parasitism, which can lead to malabsorption and affect the condition of the animal. Poor body condition can lead to difficulty in obtaining food (wild birds need good musculature to move and obtain food), which will further weaken the animal, giving more opportunity for the parasite to continue causing lesions, which in turn will further worsen the animal’s condition, thus generating a catabolic vicious circle that can culminate in starvation and death.

6. CONCLUSIONS

1. Parasitic lesions of the digestive tract were found in 8 different species of wild birds including steppe birds, raptors, columbiform and pelecaniform.

2. Gastritis (including proventriculus and ventriculus) caused by nematodes was the most frequent reported lesion.

3. The Canarian houbaras and Eurasian stone-curlew showed high parasite loads in the digestive tract, including the presence of intestinal cestodes and acanthocephalan and gastric nematoda.

4. Raptors had nematodes in esophagus, proventriculus and ventriculus that caused mild to moderate lesions including ulcers and granulomas.

5. Lesions observed in the proventriculus and ventriculus of different species caused by nematodes varied in chronicity, starting as heterophilic gastritis, continuing as heterophilic granulomas in submucosa and muscle layer and progressing to histiocytic granuloma and calcified granuloma.

6. Histologically identical nematodes affecting the stomach and other organs such as skeletal muscle and heart were observed in a common kestrel and a common buzzard, suggesting that the nematode performs intravascular migrations to reach their definitive location.

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