

Parasites of marine, freshwater and farmed fishes of Portugal: a review

Parasitos de peixes marinhos, de água doce e de criação de Portugal: uma revisão

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Abstract

An extensive literature review is made of the parasites in marine and freshwater fish in mainland Portugal, the Portuguese archipelagos of the Azores and Madeira, as well as in farmed fish. The host(s) of each parasite species, its location in the host, site of capture of the host, whenever possible, and all the available bibliographic references are described. The economic importance of some parasites and the zoonotic relevance of some parasitic forms are discussed. A general overview of the data is provided, and some research lines are suggested in order to increase and complement the current body of knowledge about the parasites of fish from Portugal.

Keywords: Parasites, fish, pathology, economy, zoonotic diseases, Portugal.

Resumo

É feita uma revisão do conhecimento dos parasitas de peixes de Portugal com base em extensa compilação bibliográfica. São referidos os parasitas de peixes marinhos e de água doce do continente, dos Arquipélagos da Madeira e dos Açores, bem como os parasitas de peixes de piscicultura. Para cada espécie é indicado o hospedeiro, localização no hospedeiro, local de pesca quando possível, e referências bibliográficas disponíveis. Discute-se a importância econômica de alguns dos parasitas e a relevância zoonótica de algumas formas. É feita uma avaliação geral dos dados e sugerem-se linhas de pesquisa que aumentem e complementem o conhecimento atual sobre os parasitas de peixes de Portugal.

Palavras-chave: Parasitas, peixes, patologia, economia, zoonoses, Portugal.

Introduction

Portugal is a coastal nation in southwestern Europe, which covers an area of about 92,000 km² and includes the archipelagos of the Azores and Madeira in the Atlantic Ocean. It has a coastline of 943 km on the mainland, 250 km on Madeira and 667 km on Azores. Portugal has the third largest Exclusive Economic Zone (EEZ) in the European Union and the twentieth largest EEZ in the world, with a total of 1,727,408 km² divided between mainland Portugal (327,667 km²), the Archipelago of Azores (953,633 km²) and the Archipelago of Madeira (446,108 km²) (CARNEIRO et al., 2014). This area will probably increase significantly with new international regulations concerning the limits of the EEZs.

Portugal's marine waters are inhabited by a variety of fish whose exact extent is difficult to determine. For a comprehensive historical background on the knowledge and quantification of species, see Carneiro et al. (2014). According to these authors,

there are a total of 1191 different fish species, 734 off mainland Portugal, 857 off Açores and 766 off Madeira. According to Costa FO et al. (2012), based on the FishBase occurrence records, there are 828 different fish species in the three zones. This means that Portugal's marine ichthyofauna is probably one of the most diversified in European waters, and explains the high per capita fish consumption in the country, making it the European Union country with the highest average annual per capita consumption of seafood, about 56 kg, which corresponds to 160 g of seafood per day (CARDOSO et al., 2016). As for freshwater fish, there are 36 known species in mainland Portugal (ALMAÇA, 1996), but we have found no report about freshwater fish in Madeira and Azores.

Research on fish biology in Portugal was developed mostly in the early 20th century. To the best of our knowledge, the first researcher who studied fish parasites was Tendeiro (1955). Other researchers worked in the field, studying mainly marine fish, but for decades their research was very fragmentary and sporadic, and the resulting papers constitute a collection of different observations of several fish species that provide only elementary data on the occurrence

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of some parasites. Important questions such as the host-parasite relationship, parasite biology, pathological consequences of the infections, economic significance of the parasites, etc., were not studied, and for a long time research on fish parasites resulted in no more than a simple list of species infecting a small number of hosts.

This situation improved slightly with the studies of Carvalho Varela et al. (1981), Carvalho Varela (1975, 2005), Carvalho Varela & Cunha-Ferreira (1984, 1987), Machado Cruz (1959a, b), Menezes (1984, 1992, 1994, 2000), Menezes & Ré (1991) and Menezes et al. (1990a, b) (see list of References) in the 1970s, which marked the beginning of a new period of fish parasitological studies in Portugal. However, an integrated approach to fish parasitism was still lacking, and more consistent research by a group of young researchers began in the 1980s, most at them affiliated to universities. These researchers applied for national and international funding to support their projects, established fruitful relationships with colleagues at well known international research centers, engaged in cooperative research with some of them, and as part of their academic duties, invested strongly in the supervision of MSc and PhD students, which led to the production of a number of Dissertations and Thesis on fish parasitology. These efforts resulted in a significant increase in the body of knowledge about fish parasitology in Portugal, and a large increase in the number of qualified researchers. Consequently, numerous papers have been published in important international scientific journals and it can be stated that, today, the scientific community dealing with this field recognizes the studies performed in Portugal and the scientific collaboration developed with foreign researchers. For these reasons, it is important to name the main researchers that contributed significantly to the body of knowledge about fish parasites in the country and invested in the supervising of students who are well known in the field today: in alphabetical order, A Saraiva, C Azevedo, C Cruz, G Costa, JC Eiras and MJ Santos. PhD studies in this field were completed by CJ Francisco, F Cavaleiro, G Casal, HN Cabral, JF Marques, LJ Rangel, M Hermida and S Rocha. Their work resulted in a comprehensive body of research into the life cycle of parasites, descriptions of new species including their molecular characterization, parasites as biological markers, host-parasite relationships, life cycles, parasites in farmed fish, parasites as human pathogens, ultrastructure of parasites, the economic impact of parasites, histopathological studies, geographical distribution of parasites, etc.

Several papers on general aspects of fish parasitology in Portugal were produced by Rombert (1993), Carvalho Varela (1975, 2005), Eiras et al. (1987), Eiras (1990a, 1998), Menezes (1994, 2000), Nunes et al. (2003) and Ramos (2011).

The paper by Eiras (1998) provided a list of all the parasites identified in Portugal's fish until the date of publication. However, given the huge increase in these studies since then, the aforementioned list is now outdated. Therefore, the purpose of this paper is to provide an updated review of fish parasites in Portugal.

Materials and Methods

The data described in this paper were garnered from a thorough review of the literature. According to the rules of this journal, data contained in Abstracts, Dissertations and Thesis presented

at scientific Meetings are not included. However, it should be pointed out that practically all the data contained in Dissertations and Thesis have been published in scientific journals and have therefore been included in this paper, as have numerous Abstracts presented at international scientific Meetings. The name of the host(s) of each parasite species or genera, the parasite's location in the host, site of capture of the host, whenever possible, and references ranked by year of publication are listed. The names of the parasites were checked in the Worms World Register of Marine Species (2016), and are presented in alphabetical order within their respective groups (Isopod crustaceans are placed at the end of the list). The names of fish species were updated, according to FishBase, by Froese & Pauley (2016). Whenever the location of the parasite in the host is not indicated, this means it was not described by the authors. The capture sites of marine fish are not included because, in most cases, they are unknown – fish are usually captured along the coast, sometimes very far from the port where they are landed, making it impossible to determine their origin. To best present the data, the information is divided into several sections: parasites of marine fish and freshwater fish from mainland Portugal, parasites of fish from the Archipelago of Madeira, from the Archipelago of the Azores, and parasites of farmed fish. A general discussion is presented at the end of this paper.

Parasites of marine fish from mainland Portugal

Flagellata

Amyloodinium sp., *Dicentrarchus labrax*, gills, Duarte et al. (2000), Menezes (2000).

Ichthyodinium chabelardi Hollande & J. Cachon, 1952, *Sardina pilchardus*, eggs, Menezes & Ré (1991), Silva & Miranda (1992), Borges et al. (1996), Stratoudakis et al. (2000).

Ichthyobodo necator (Henneguy, 1833) Pinto (1928), *Dicentrarchus labrax*, gills, Santos (1996), Duarte et al. (2000).

Apicomplexa

Eimeria sardinae (Thélohan, 1890) Reichenow, 1921, *Sardina pilchardus*, testes, Pinto (1956), Pinto et al. (1961).

Eimeria sp., *Dicentrarchus labrax*, gut, Santos (1996).

Goussia cruciata (Thélohan, 1892) Labbé, 1896, *Trachurus trachurus*, liver, Gestal & Azevedo (2005), MacKenzie et al. (2008).

G. lusca Gestal & Azevedo (2006), *Trisopterus luscus*, liver, Gestal & Azevedo (2006).

Haemogregarina bigemina Laveran & Mesnil, 1901, *Lipophrys pholis*, *Coryphoblennius galerita*, blood, Sarasquete & Eiras (1985), Eiras (1987a, b), Eiras & Davies (1991), Davies et al. (1994), Dias et al. (2005).

Ciliophora

Cryptocaryon irritans Brown, 1951, *Halobatrachus didactylus* (= *Batrachus didactylus*), *Diplodus sargus*, *Caranx ascensionis*, *Dicentrarchus labrax*, *Trigla* sp., gills, tegument, Grazina Freitas et al. (1986).

Tetrahymina sp., *Dicentrarchus labrax*, *Solea vulgaris*, tegument, Grazina Freitas et al. (1986).

Trichodina sp., *Dicentrarchus labrax*, *Diplodus sargus*, gills, Grazina Freitas et al. (1986), Santos (1996), Duarte et al. (2000).

Myxozoa

Ceratomyxa diplodae Lubat, Radujkovic, Marques & Bouix (1989), *Dicentrarchus labrax*, gall bladder, Santos (1996).

C. labracis Sitjà-Bobadilla & Alvarez-Pellitero (1993), *Dicentrarchus labrax*, gall bladder, Santos (1996).

Ceratomyxa sp., *Aphanopus carbo*, *Pagellus bogaraveo*, gall bladder, Santos et al. (2009), Hermida et al. (2013b).

Myxobilatus sp., *Dicentrarchus labrax*, lumen of kidney ducts and urinary bladder, Santos (1996).

Myxobolus sp., *Mugil cephalus*, tegument, Menezes (1984).

Kudoa sp., *Sardina pilchardus*, *Merluccius merluccius*, *Trachurus trachurus*, muscles, Cruz e Silva & Grazina Freitas (1984), Grazina Freitas et al. (1986), Menezes et al. (1990b), Gilman & Eiras (1998), Cruz et al. (2003).

Zschokkela mugilis Sitjà-Bobadilla & Alvarez-Pellitero (1993), *Nereis diversicolor*, coelom, Rangel et al. (2009).

Monogenea

Amphibdella torpedinis Chatin, 1874, *Torpedo marmorata*, gills, Kearns & Vasconcelos (1979).

Ancyrocephalus sp., *Mugil* sp., gills, Kearns & Vasconcelos (1979).

Cemocotyle trachuri Dillon & Hargis (1965), *Trachurus trachurus*, gills, MacKenzie et al. (2008).

Choricotyle chrysophryi Van Beneden & Hesse, 1863, *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Diclidophora luscae (Van Beneden & Hesse, 1864) Diesing, 1858, gills, *Trisopterus luscus*, Kearns & Vasconcelos (1979).

Diplectanum aequans (Wagner, 1857) Diesing, 1858, *Dicentrarchus labrax*, gills, Kearns & Vasconcelos (1979). Santos (1996), Duarte et al. (2000).

Empruthotrema raiae (MacCallum, 1916) Johnston & Tiegs, 1922, *Raja microcellata*, gills, Kearns & Vasconcelos (1979).

E. torpedinis Kearns (1976), *Torpedo marmorata*, gills, Kearns & Vasconcelos (1979).

Entobdella soleae (Van Beneden & Hesse, 1864) Johnston, 1929, *Dicologlossa cuneata*, *Solea senegalensis*, *S. solea*, skin, Carvalho Varela & Cunha-Ferreira (1987), Kearns & Vasconcelos (1979), Marques et al. (2006c, 2009, 2011).

Epicotyle torpedinis Price, 1942, *Torpedo marmorata*, gills, Kearns & Vasconcelos (1979).

Gastrocotyle trachuri Van Beneden & Hesse, 1863, *Trachurus picturatus*, *T. trachurus*, stomach, MacKenzie et al. (2008), Hermida et al. (2015).

Grubea cochlear Diesing, 1858, *Scomber scombrus*, gills, Rego et al. (1985), Castro & Santos (2013).

Gyrodactylus elegans Von Nordman, 1832, *Gaidropsarus* sp., *Gobius niger*, *Solea solea*, *Trisopterus luscus*, gills, Carvalho Varela et al. (1981), Kearns & Vasconcelos (1979).

Gyrodactylus sp., *Pegusa lascaris* (= *Solea lascaris*), *Solea solea*, gills, Carvalho Varela & Cunha-Ferreira (1987), Marques et al. (2006b, c, 2009, 2011).

Haliotrema balisticus (Hargis, 1955) Looss, 1902, *Mugil cephalus*, gills, Kearns & Vasconcelos (1979).

Heteraxinoides atlanticus Gaevskaya & Kovaliova (1979), *Trachurus trachurus*, gills, MacKenzie et al. (2008).

Heterocotyle pastinacae Scott, 1904, *Dasyatis pastinaca*, gills, Kearns & Vasconcelos (1979).

Hexabothrium monteiri Tendeiro (1955), *Squalus blainville*, gills, Tendeiro & Valdez (1955b).

Kubnia scombri (Kuhn, 1829) Sproston (1945), *Scomber scombrus*, gills, Kearns & Vasconcelos (1979), Rego et al. (1985), Castro & Santos (2013).

K. sprostonae Price (1961), *Scomber scombrus*, pseudobranchs, Castro & Santos (2013).

Lamellodiscus virgula Euzet & Oliver (1967), *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Lamellodiscus sp., *Coris julis*, *Spondylisoma cantharus*, gills, Kearns & Vasconcelos (1979).

Leptocotyle minor (Monticelli, 1888) Gallen (1937), *Scyliorhinus* sp., tegument, Kearns & Vasconcelos (1979).

Mazocraes vilelai Tendeiro & Valdez (1955a), *Alosa alosa*, gills, Tendeiro & Valdez (1955b).

Microcotyle sp., *Coris julis*, *Diplodus* sp., *Pomadasys incisus* (= *Pomadasys bennedetti*), *Pomatomus saltator*, *Sparus aurata*, *Spondylisoma cantharus*, gills, Kearns & Vasconcelos (1979).

Ercocotyle catenulata (Guberlet, 1933), *Mustelus mustelus*, gills, Tendeiro & Valdez (1955b).

Neonchocotyle pastinacae Ktari & Maillard (1972), *Dasyatis pastinaca*, gills, Kearns & Vasconcelos (1979).

Pseudaxine trachuri Parona & Perugia, 1889, *Trachurus picturatus*, *T. trachurus*, gills, MacKenzie et al. (2008), Hermida et al. (2015).

Octoplectanocotyla aphanopi Pascoe (1987), *Aphanopus carbo*, gills, Santos et al. (2009).

Serranicotyle labracis (Van Beneden & Hesse, 1863) Maillard, Euzet & Silan, 1988, *Dicentrarchus labrax*, gills, Santos (1996).

Thaumatocotyle concinna Scott, 1904, *Dasyatis pastinaca*, nasal fossae, Kearns & Vasconcelos (1979).

Trochopus pini (Van Beneden & Hesse, 1863) Massa, 1903, *Lepidotrigla cavillone*, gills, Buhnrheim et al. (1973), Kearns & Vasconcelos (1979).

Winkenthughesia bramae (Parona & Perugia, 1896) Bychovsky, 1957, *Brama brama*, gills, Kearns & Vasconcelos (1979).

Digenea

Acanthostomum sp., *Pomatoschistus microps*, digestive tract, Costa JL et al. (2012).

Brachyenteron helicoleni Bray & Kuchta, 2006, *Pagellus bogaraveo*, intestine, Hermida et al. (2013b, 2014).

Bucephalus baeri Maillard & Saad-Fares, 1981, *Dicentrarchus labrax*, intestine, Santos (1996).

B. minimus (Stossich, 1887), *Mugil cephalus*, heart, liver, spleen, Pina et al. (2009).

Cryptocotyle lingua (Creplin, 1825), *Pleuronectes platessa*, digestive tract, CarvalhoVarela et al. (1981).

Cryptocotyle sp., *Pomatoschistus microps*, fins (Freitas et al. 2009), Costa JL et al. (2012).

Derogenes varicus (Müller, 1784) Looss, 1901, *Dicentrarchus labrax*, *Dicologlossa cuneata*, *Microchirus azevia*, *M. variegatus*, *Pagellus bogaraveo*, *Platichthys flesus*, *Scophthalmus rhombus*, *Solea kleinii*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, digestive tract, gills, Carvalho Varela & Cunha-Ferreira (1987), Santos (1996), Marques et al. (2006a, c, 2009, 2010, 2011), Hermida et al. (2013b, 2014).

Diplectanum aequans (Wagener, 1857) Diesing, 1958, *Dicentrarchus labrax*, gills, Grazina Freitas et al. (1986).

Didymobothrium rudolphi (Monticelli, 1890), *Pegusa lascaris* (= *Solea lascaris*), Marques & Cabral (2007).

Diptherostomum vividum (Nicoll, 1912) Bray & Gibson, 1986, *Pagellus bogaraveo*, intestine, Hermida et al. (2013b, 2014).

Diplostomum sp., *Platichthys flesus*, eyes, Cavaleiro et al. (2012).

Dolichoenterum manteri Tendeiro, 1955, *Conger conger*, intestine, Tendeiro (1955). *Ectenurus lepidus* Looss, 1907, *Solea solea*, *Trachurus picturatus*, *T. trachurus*, stomach, Carvalho Varela & Cunha-Ferreira (1987), MacKenzie et al. (2008), Hermida et al. (2015).

Glomericirrus macrouri (Gaevskaya, 1973) Gaevskaya, 1979, *Pagellus bogaraveo*, Hermida et al. (2013b).

Haploporus benedeni (Stossich, 1887), *Mugil cephalus*, digestive tract, Carvalho Varela et al. (1981).

Helicometra fasciata (Rudolphi, 1819) Odhner, 1902, *Lepidorbombus boscii*, *Lipophrys pholis*, digestive tract, intestine, Santos & Eiras (1995), Marques et al. (2006c, 2009, 2010, 2011).

Hemiptera sp., *Microchirus azevia*, *M. variegatus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, digestive tract, Marques et al. (2006b, c, 2009, 2011).

Hemiurus appendiculatus (Rudolphi, 1802) Looss, 1899, *Alosa alosa*, *A. fallax*, *Pomatoschistus microps*, stomach, Tendeiro & Valdez (1955a), Rodrigues et al. (1972), Costa JL et al. (2012).

H. communis Odhner, 1905, *Dicentrarchus labrax*, *Pagellus bogaraveo*, *Solea solea*, stomach, Carvalho Varela & Cunha-Ferreira (1987), Santos (1996), Hermida et al. (2013b, 2014).

Homalometron galaicus SanMartin, Alvarez, Quintero & Paniagua, 1995, *Dicologlossa cuneata*, *Microchirus azevia*, *M. variegatus*, *Solea senegalensis*, digestive tract, Marques et al. (2006b, c, 2009, 2011).

Hypoepaticola sp., *Helicolenus dactylopterus*, digestive tract, Sequeira et al. (2010).

Lecithochirium furcolabiatum (Jones, 1933) Dawes, 1947, *Lipophrys pholis*, *Pomatoschistus microps*, mesenteries, Santos & Eiras (1995).

L. musculus (Looss, 1907) Nasir & Diaz, 1971, *Dicentrarchus labrax*, *Pomatoschistus microps*, intestine, Santos (1996), Freitas et al. (2009), Costa JL et al. (2012).

L. rufoviridae (Rudolphi, 1819), *Arnoglossus laterna*, *Citharus linguatula*, *Conger conger*, *Dicologlossa cuneata*, *Lepidorbombus boscii*, *Microchirus azevia*, *Platichthys flesus*, *Scophthalmus maximus*, *S. rhombus*, digestive tract, gills, Tendeiro & Valdez (1955b), Marques et al. (2006b, c, 2009, 2010, 2011).

Lecithochirium sp., *Pomatoschistus microps*, digestive tract, Freitas et al. (2009).

Lecithocladium excisum (Rudolphi, 1819) Lühe, 1901, *Pagellus bogaraveo*, *Scomber scombrus*, gills, stomach, Rego et al. (1985), Hermida et al. (2013b, 2014).

Lecithocladium sp., *Helicolenus dactylopterus*, digestive tract, Sequeira et al. (2010).

Lepocreadium album (Stossich, 1890), *Pagellus bogaraveo*, stomach, pyloric caecae, anterior intestine, Hermida et al. (2013b, 2014).

Lomasoma stephanskii Dolffus, 1960, *Microchirus variegatus*, digestive tract, Marques et al. (2006b, 2009, 2011).

Macvicaria soleae (Dujardin, 1845) Gibson & Bray, 1982, *Dicologlossa cuneata*, *Microchirus azevia*, *M. variegatus*, *Platichthys flesus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, digestive tract, Durieux et al. (2007), Marques et al. (2006a, b, 2009, 2010, 2011).

Monascus filiformis (Rudolphi, 1819), *Trachurus picturatus*, intestine, Hermida et al. (2015).

Opechona bacillaris (Molin, 1859) Dollfus, 1927, *Scomber scombrus*, stomach, intestine, Rodrigues et al. (1972), Rego et al. (1985).

Otodistomum veliporum (Creplin, 1837) Stafford, 1894, *Torpedo torpedo*, stomach, Tendeiro & Valdez (1955b).

Otodistomum sp., *Synapturichthys kleinii* (= *Solea kleinii*), digestive tract, visceral cavity, Marques et al. (2009, 2011).

Pycnadenoides senegalensis Fischthal & Thomas, 1972, *Pagellus bogaraveo*, pyloric caecae, intestine, Hermida et al. (2013b, 2014).

Proctoeces maculatus (Looss, 1901), *Platichthys flesus*, digestive tract, Marques et al. (2009, 2010, 2011).

Prosorhynchus aculeatus Odhner, 1905, *Conger conger*, *Solea solea*, stomach, rectum, branchial arches, muscles, Santos & Gibson (2002), Durieux et al. (2007), Marques et al. (2006c, 2009), Francisco et al. (2010).

P. crucibulum (Rudolphi, 1819) Odhner, 1905, *Conger conger*, *Dicentrarchus labrax*, *Dicologlossa cuneata*, *Synapturichthys kleinii* (= *Solea kleinii*), *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, kidney, stomach, muscles, digestive tract, branchial arches, Santos (1996), Santos & Gibson (2002), Marques et al. (2006b, c, 2009), Durieux et al. (2007), Francisco et al. (2010, 2012).

Prosorhynchus sp., *Pomatoschistus microps*, muscle, Freitas et al. (2009), Costa JL et al. (2012).

Stephanostomum pristis (Deslongchamps, 1824) Looss, 1899, *Trisopterus luscus*, intestine, Rodrigues et al. (1975a).

Sterrhurus fusiformis [(= *Lecithochirium grandiporum* (Rudolphi, 1819) Lühe, 1901)], *Conger conger*, stomach, Tendeiro & Valdez (1955b).

Tergestia sp., *Trachurus picturatus*, intestine, Hermida et al. (2015).

Timoniella imbutiforme (Molin, 1859) Brooks, 1980, *Dicentrarchus labrax*, *Solea solea*, muscles, Durieux et al. (2007).

T. praeterita (Looss, 1901) Maillard, 1974, *Dicentrarchus labrax*, *Solea solea*, muscles, intestine, Santos (1996), Durieux et al. (2007).

Zoogonoides viviparus (Olsson, 1868) Odhner, 1902, *Pomatoschistus microps*, digestive tract, Costa JL et al. (2012).

Zoogonoides rubellus (Olsson, 1868) Odhner, 1902, *Dicologlossa cuneata*, *Platichthys flesus*, *Solea senegalensis*, digestive tract, Marques et al. (2006b, c, 2009, 2010, 2011).

Cestoda

Bothriocephalus andresi Porta, 1911, *Citharus linguatula*, digestive tract, Marques et al. (2009, 2010, 2011).

B. barbatus Renaud, Gabrion & Pasteur, 1983, *Scophthalmus rhombus*, digestive tract, Marques et al. (2009, 2010, 2011).

B. clavibothrium Ariola, 1899, *Arnoglossus laterna*, digestive tract, Marques & Cabral (2007), Marques et al. (2009, 2010, 2011).

B. gregarious Renaud, Gabrion & Pasteur, 1983, *Scophthalmus maximus*, digestive tract, Marques et al. (2009, 2011).

B. scorpis (Müller, 1776), *Lepidorhombus boscii*, *Dicologlossa cuneata*, *Platichthys flesus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, digestive tract, Marques et al. (2006b, c, 2009, 2010, 2011).

Bothriocephalus sp., *Pleuronectes platessa*, digestive tract, Carvalho Varela et al. (1981).

Clestobothrium crassiceps (Rudolphi, 1819), *Merluccius merluccius*, intestine, Tendeiro & Valdez (1955b).

Didymobothrium rudolphi (Monticelli, 1890) Nybelin, 1922, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, digestive tract, intestine, Marques et al. (2006b, c, 2007, 2009, 2011), Świdorski et al. (2010).

Diphyllobothrium sp., *Synaptura lusitanica*, digestive tract, Marques et al. (2006b, 2009, 2011).

Echeinobothrium sp., *Scomber scombrus*, intestine wall, Rego et al. (1985).

Hepatoxylon trichiuri (Holten, 1802), *Lepidotus caudatus*, intestine, gonads, Machado Cruz (1959b), Sequeira et al. (2010).

Heteronybelinia yamagutii (Dollfus, 1960), *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Grillotia sp., *Microchirus variegatus*, digestive tract, Marques et al. (2006b, 2009, 2011).

Lacistorhynchus tenuis (Van Beneden, 1858), *Scomber scombrus*, pyloric caecae, Rego et al. (1985).

Nybelinia lingualis Cuvier, 1817, *Citharus linguatula*, *Dicologlossa cuneata*, *Lepidorhombus boscii*, *Microchirus azevia*, *M. variegatus*, *Scophthalmus rhombus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, mesenteries, Durieux et al. (2007), Marques et al. (2006b, c, 2009, 2010, 2011).

Onchobothrium uncinatum (Rudolphi, 1819), *Raja undulata*, intestine, Tendeiro & Valdez (1955b).

Progrillotia dasyatidis Beveridge, Neifar & Euzet, 2004, *Dicologlossa cuneata*, *Halobatrachus didactylus*, *Lepidorhombus boscii*, *Microchirus azevia*, *M. variegatus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, intestinal lumen, digestive tract, Marques et al. (2005a,b, 2006b, c, 2009, 2010), Costa JL et al. (2012).

Scolex pleuronectis (Müller, 1758), *Dicologlossa cuneata*, *Microchirus azevia*, *Scomber scombrus*, *Solea senegalensis*, *S. solea*, *Trachurus trachurus*, digestive tract, intestine, Rego et al. (1985), Durieux et al. (2007), MacKenzie et al. (2008), Marques et al. (2006b, c, 2009, 2010, 2011).

Sphyricephalus tergestinus Pintner, 1913, *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Acanthocephala

Acanthocephaloides incrassatus (Molin, 1858), *Pegusa lascaris* (= *Solea lascaris*), digestive tract, Marques et al. (2006b).

A. geneticus (Buron, Renaud & Euzet, 1985), *Lepidorhombus boscii*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, digestive tract, Marques et al. (2006b, c, 2009, 2010, 2011).

A. propinquus (Dujardin, 1845), *Dicologlossa cuneata*, *Lepidorhombus boscii*, *Microchirus azevia*, *M. variegatus*, *Monochirus hispidus*, *Scophthalmus rhombus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, digestive tract, Durieux et al. (2007), Marques et al. (2006b, c, 2009, 2010, 2011).

Acanthocephalus incrassatus (= *Acanthocephaloides incrassatus* Molin, 1858), *Pegusa lascaris* (= *Solea lascaris*), digestive tract, Marques et al. (2009, 2011).

Bolbosoma vasculosum (Rudolphi, 1819), *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Bolbosoma sp., *Pagellus bogaraveo*, intestine, Hermida et al. (2013b).

Echinorhynchus clavula Dujardin, 1845, *Solea senegalensis*, *S. solea*, digestive tract, Carvalho-Varela & Cunha-Ferreira (1987)

Echinorhynchus gadi Zoega in Müller, 1776), *Citharus linguatula*, *Lepidorhombus boscii*, digestive tract, Marques & Cabral (2007), Marques et al. (2006c, 2009, 2010, 2011).

Neoechinorhynchus sp., *Mugil cephalus*, intestine, Carvalho Varela et al. (1981).

Pomphorhynchus laevis Müller, 1776, *Solea senegalensis*, *S. solea*, digestive tract, Carvalho Varela & Cunha-Ferreira (1987).

Rhadinorhynchus cadenati (Golvan & Houin, 1964), *Trachurus trachurus*, intestine, MacKenzie et al. (2008).

R. johni [= *Aspersentis johni* (Baylis, 1929)], *Merluccius merluccius*, intestine, Rodrigues et al. (1973, 1975c).

R. pristi (Rudolphi, 1802), *Pagellus bogaraveo*, pyloric caecae, intestine, Hermida et al. (2013b, 2014).

R. tenuicornis [= *Telosentis tenuicornis* (Linton, 1901)], *Scomber scombrus*, intestine, Rodrigues et al. (1975b,c), Rego et al. (1985).

Radinorhynchus sp., *Citharus linguatula*, *Microchirus azevia*, *Pegusa lascaris* (= *Solea lascaris*), *Trachurus picturatus*, digestive tract, intestine, Marques et al. (2009, 2011), Hermida et al. (2015).

Nematoda

Anisakis pegreffii Campana-Rouget & Biocca, 1955, *Arnoglossus imperialis*, *Citharus linguatula*, *Dicologlossa cuneata*, *Lepidorhombus boscii*, *Pagellus bogaraveo*, *Trachurus trachurus*, digestive tract, encapsulated on the outside of the viscera and fish body cavity, Marques et al. (2006a,b 2009), Mattiucci et al. (2008), Hermida et al. (2012b).

A. physeteris (Bayliss, 1923), *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

A. simplex s.s., *Arnoglossus laterna*, *A. imperialis*, *Citharus linguatula*, *Dicologlossa cuneata*, *Pagellus bogaraveo*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Marques et al. (2006a, b), Hermida et al. (2012b).

A. simplex (Rudolphi, 1809), *Arnoglossus imperialis*, *A. laterna*, *Citharus linguatula*, *Dicologlossa cuneata*, *Lepidorhombus boscii*, *L. whiffiagonis*, *Zeugopterus regius* (= *Phrynorhombus regius*), *Scomber scombrus*, *Synapturichthys kleinii* (= *Solea kleinii*), *Pegusa*

lascaris (= *Solea lascaris*), *Trachurus trachurus*, digestive tract, body cavity, liver, stomach, Rego et al. (1985), Mattiucci et al. (2008), Marques et al. (2009, 2011).

A. simplex x *A. pegreffii*, *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

A. typica (Diesing, 1860), *Pagellus bogaraveo*, *Platichthys flesus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, digestive tract, Marques et al. (2006a, c, 2009, 2010, 2011), Hermida et al. (2012b).

A. ziphidarum Pagi, Nascetti, Webb, Mattiucci, Cianchi & Bullini, 1988, *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

Anisakis sp., *Aphanopus carbo*, *Conger conger*, *Helicolenus dactylopterus*, *Merluccius merluccius*, *Micromesistius poutassou*, *Pomatoschistus microps*, *Sardina pilchardus*, *Scomber scombrus*, *Solea* sp., *Spondyliosoma cantharus*, *Trachurus picturatus*, *T. trachurus*, *Trigla lucerna*, *Trisopterus luscus*, surface of internal organs, visceral cavity, mesentery, liver, muscles, Grazina Freitas et al. (1986), Saraiva et al. (2000b), Silva & Eiras (2003), MacKenzie et al. (2008), Cruz et al. (2005, 2007, 2009), (Freitas et al. 2009), Santos et al. (2009), Sequeira et al. (2010), Hermida et al. (2015).

Camallanus sp., *Pagellus bogaraveo*, pyloric caecae, Hermida et al. (2013b, 2014).

Capillaria sp., *Citharus linguatula*, *Dicologlossa cuneata*, *Platichthys flesus*, *Synaptura lusitanica*, gut lumen, Marques et al. (2011).

Contracaecum aduncum (Rudolphi, 1802), *Alosa alosa*, *Pleuronectes platessa*, stomach, intestine, Tendeiro & Valdez (1955b), Carvalho Varela et al. (1981).

C. gadi (Müller, 1776), *Merluccius merluccius*, stomach, Tendeiro & Valdez (1955b).

C. magnum Smedley 1934, [= *Hysterothylacium magnum* (Smedley, 1934), *Solea solea*, intestine, Rodrigues et al. (1975a).

Contracaecum sp., *Pomatoschistus microps*, digestive tract, (Costa JL et al., 2012).

Cristitectus congeri Petter, 1970, *Conger conger*, stomach, intestine, Saraiva et al. (2000b).

Cucullanus campanae Lebre & Petter, 1984, *Dicologlossa cuneata*, *Microchirus azevia*, *M. variegatus*, *Platichthys flesus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, digestive tract, Durieux et al. (2007), Marques et al. (2006b, c, 2009, 2010, 2011).

C. heterochrous Rudolphi, 1802, *Microchirus azevia*, digestive tract, Marques et al. (2006b, c, 2009).

C. hians Dujardin, 1845, *Conger conger*, intestine, stomach, Tendeiro & Valdez (1955b), Saraiva et al. (2000b).

C. longispiculum Rodrigues, Carvalho Varela, Rodrigues & Cristóforo, 1973, *Conger conger*, stomach, intestine, Rodrigues et al. (1973), Saraiva et al. (2000b).

Cucullanus sp., *Arnoglossus laterna*, gut lumen, Marques et al. (2011).

Dichelyne minutus (Rudolphi, 1819), *Platichthys flesus*, digestive tract, Marques et al. (2006c, 2009, 2010, 2011).

Goezia sp., *Scomber scombrus*, intestine, Rego et al. (1985).

Huffmanella sp., *Trisopterus luscus*, intestine submucosa, Esteves et al. (2009).

Hysterothylacium aduncum (Rudolphi, 1802), *Halobatrachus dydactylus*, *Microchirus variegatus*, *Platichthys flesus*, *Pegusa lascaris* (= *Solea lascaris*), *Solea solea*, *Trachurus trachurus*, digestive tract, intestine, Carvalho Varela & Cunha Ferreira (1987), MacKenzie et al. (2008), Marques et al. (2005a, b, 2006c, 2009, 2010, 2011), Costa JL et al. (2012).

Hysterothylacium sp., *Solea senegalensis*, *S. solea*, intestine, Carvalho Varela & Cunha-Ferreira, 1987.

H. reliquens (Norris & Overstreet, 1975), *Microchirus azevia*, *M. boscanion*, *M. variegatus*, digestive tract Marques et al. (2006b, c, 2009, 2011).

Hysterothylacium sp., *Microchirus azevia*, *Micromesistius poutassou*, *Pagellus bogaraveo*, *Pegusa lascaris* (= *Solea lascaris*), *Trachurus trachurus*, digestive tract, liver, muscles, encapsulated in body cavity and outside of the viscera, Cruz et al. (2005, 2007), Marques et al. (2006a, 2009, 2011), Hermida et al. (2012a).

Luzonema cruzi Rodrigues, Varela, Rodrigues, Cristóforo, 1973, *Lethrinus atlanticus*, intestine, Rodrigues et al. (1973).

Philometra filiformis (Stossich, 1896), *Pagellus bogaraveo*, intestine, Hermida et al. (2013b).

Proleptus obtusus, Dujardin, 1845, *Scyliorhinus canicula*, stomach, Rodrigues et al. (1973).

P. robustus (Van Beneden, 1871), *Mustelus canis*, *Raja clavata*, stomach, spiral valve, Tendeiro & Valdez (1955b), Rodrigues et al. (1973).

Raphidascaris acus (Bloch, 1779), *Mugil cephalus*, *Pomatoschistus microps*, digestive tract, Carvalho Varela et al. (1981), Costa JL et al. (2012).

Thynnascaris aduncum [(= *Hysterothylacium aduncum* (Rudolphi, 1802)], *Scomber scombrus*, stomach, pyloric caecae, testes, intestine, Rego et al. (1985).

Hirudinea

Caliobdella sp., *Solea senegalensis*, skin, Marques et al. (2006b, 2009, 2011).

Hemibdella soleae (Van Beneden & Hesse, 1863), *Dicologlossa cuneata*, *Microchirus azevia*, *Pegusa lascaris* (= *Solea lascaris*), *Synapturichthys kleinii* (= *Solea kleinii*), *S. senegalensis*, *Synaptura lusitanica*, skin, Marques et al. (2006b, c, 2009, 2011).

Crustacea

Acanthochondria cornuta (Müller O.F., 1776), *Platichthys flesus*, gill chamber, gill arches, Marques & Cabral (2007), Marques et al. (2006c, 2009, 2011), Cavaleiro & Santos (2009, 2011).

A. solea (Krøyer, 1838), *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, gill arches, Marques et al. (2006b, c, 2009).

Bomolochus soleae Claus, 1864, *Dicologlossa cuneata*, *Synapturichthys kleinii* (= *Solea kleinii*), *S. senegalensis*, *S. solea*, gills, Durieux et al. (2007), Marques et al. (2006b, c, 2009, 2011).

Caligus brevicaudatus A. Scott, 1901, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *S. solea*, skin, Marques et al. (2006c, 2009, 2011).

C. dicentrarchi Cabral & Raibaut 1983, *Dicentrarchus labrax*, skin, Santos (1996).

C. elongatus Von Nordman, 1832, *Microchirus azevia*, *M. variegatus*, *Solea solea*, skin, Marques et al. (2006b, c, 2009, 2011).

C. minimus Otto, 1821, *Dicentrarchus labrax*, mouth cavity and gills, Santos (1996).

C. musaicus Cavaleiro, Santos & Ho, 2010, *Platichthys flesus*, skin and fins, Cavaleiro et al. (2010).

C. pageti Russell, 1925, *Dicentrarchus labrax*, mouth, Santos (1996).

C. pelamydis Krøyer, 1863, *Scomber scombrus*, *Trachurus trachurus*, gills, opercula, branchial chamber internal wall, MacKenzie et al. (2008), Castro & Santos (2013).

Caligus sp., *Dicentrarchus labrax*, *Platichthys flesus*, *Trachurus picturatus*, skin, gills, operculum, Santos (1996), Cavaleiro & Santos (2009).

Clavellisa scombri (Kurz, 1877), *Scomber scombrus*, gills, Castro & Santos (2013).

Colobomatus labracis Delamare Deboutville & Nunes Ruivo, 1952, *Dicentrarchus labrax*, pre-opercular channels, Santos (1996).

Ergasilus sp., *Dicologlossa cuneata*, gills, Marques et al. (2006b, 2009, 2011).

Holobomolochus confusus (Stock, 1953) [= *Cresseyus confusus* (Stock, 1953)], *Platichthys flesus*, nasal cavity, Cavaleiro & Santos (2009).

Lepophtheirus europaensis Zeddiam, Berrebi, Renaud, Raibaut & Gabrion, 1988, *Scophthalmus rhombus*, *Dicologlossa cuneata*, skin, Marques et al. (2006b, 2009, 2011).

L. pectoralis (Müller O.F., 1776), *Platichthys flesus*, *Solea senegalensis*, skin, Marques et al. (2006b, c, 2009, 2011), Cavaleiro & Santos (2007).

Lernanthropus kroyeri Van Beneden, 1851, *Dicentrarchus labrax*, gills, Santos (1996).

Lernaocera caparti Machado Cruz, 1959, *Merluccius merluccius*, gills, Machado Cruz (1959a).

L. luscii (Basset-Smith, 1896), *Lepidorhombus boscii*, *Trisopterus luscus*, tegument, Eiras (1984, 1986), Eiras & Santos (1990, 1992).

Lernaocera sp., *Microchirus azevia*, gills, Marques et al. (2006b, c, 2009, 2011).

Peniculus fistula Nordmann, 1832, *Pagellus bogaraveo*, *Trachurus picturatus*, *T. trachurus*, fins, Candeias (1955), MacKenzie et al. (2008), Hermida et al. (2013a, b).

Rebelula edwardsii (Kölliker, 1853) (= *Lophoura edwardsii* Kölliker, 1853), *Coelorhynchus caelorhynchus*, behind the posterior part of dorsal fin, Candeias (1952a).

Peroderma cylindricum Heller, 1865, *Sardina pilchardus*, tegument, Candeias (1952b).

Aega sp., *Citharus linguatula*, skin, Marques et al. (2009).

Gnathia maxillaris (Montagu, 1804), *Coryphoblennius galerita*, *Lipophrys pholis*, skin, Davies et al. (1994).

Gnathia sp., *Helicolenus dactylopterus*, *Lepidorhombus boscii*, *Microchirus azevia*, *Pagellus bogaraveo*, *Platichthys flesus*, *Pegusa lascaris* (= *Solea lascaris*), *S. solea*, *Zeugopterus punctatus*, mouth, oesophagous, gills, gill chamber, tegument, fins, Sequeira et al. (2010), Marques et al. (2006b, c, 2009, 2011), Hermida et al. (2013a, b).

Nerocila orbignyi (Guérin-Méneville, 1832), *Halobatrachus dydactylus*, *Monochirus hispidus*, *Platichthys flesus*, skin, Marques et al. (2005a, 2009), Cavaleiro & Santos (2009).

Paragnathia formica (Hesse, 1864), *Mugil cephalus*, tegument, Menezes & Cascalho (1984).

Rocinela danmoniensis Leach, 1818, *Pagellus bogaraveo*, tegument, Hermida et al. (2013a, b).

Rocinela sp., *Arnoglossus laterna*, *Citharus linguatula*, *Microchirus azevia*, *Scophthalmus maximus*, *S. rhombus*, *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *Synaptura lusitanica*, skin, Marques et al. (2006b, c, 2009, 2011).

Parasites of freshwater fish from mainland Portugal

Flagellata

Trypanosoma granulosum Laveran & Mesnil, 1902, *Anguilla anguilla*, blood, rivers Ancora, Ardena, Este, Febros, Olivais and Tamente, França (1907), Eiras (1988, 1990b), Saraiva & Eiras (1996), Cruz & Eiras (1997), Saraiva & Chubb (1989).

Apicomplexa

Babesiosoma bettencourti (França, 1908), *Anguilla anguilla*, blood, rivers Ancora, Este, Febros and Olivais, Cruz & Davies (1998).

Ciliophora

Ichthyophthirius multifiliis Fouquet, 1876, *Anguilla anguilla*, skin and gills, river Este, Saraiva & Eiras (1996), Saraiva & Chubb (1989).

Trichodina jadratica Raabe, 1958, *Anguilla anguilla*, gills, river Este, Saraiva & Eiras (1996), Saraiva & Chubb (1989).

Myxozoa

Actinomyxon Actinospore type, *Tubifex tubifex*, host fish unknown, river Sousa, Székely et al. (2005).

Hoferellus gilsoni (Debaisieux, 1925), *Anguilla anguilla*, urinary bladder, river Este, Saraiva & Eiras (1996), Saraiva (1995), Saraiva et al. (1998).

Myxidium giardi Cépède, 1906, *Anguilla anguilla*, gills and other organs, Aveiro lagoon, river Este, Azevedo et al. (1989), Saraiva (1995), Saraiva & Eiras (1996), Saraiva & Chubb (1989), Hermida et al. (2008).

M. rhodei Léger, 1905, *Pseudochondrostoma polylepis* (= *Chondrostoma polylepis*), kidney, urinary ducts, river Ave, Saraiva et al. (2000a).

Myxobolus branchialis (Markewitsch, 1932), *Luciobarbus bocagei*, gills, river Sousa, Molnár et al. (2012).

M. branchilateralis Molnár, Eszterbauer, Marton, Székely & Eiras, 2012, *Luciobarbus bocagei*, gills, river Sousa, Molnár et al. (2012).

M. cutanei Alvarez-Pellitero & González-Lanza, 1985, *Luciobarbus bocagei*, fins, scales, river Sousa, Molnár et al. (2012).

M. cyprini Doflein, 1898, *Pseudochondrostoma polylepis* (= *Chondrostoma polylepis*), muscle, kidney, gills, urinary bladder, Ermal reservoir, Cruz et al. (1998).

M. musculi Keysselit, 1908, *Luciobarbus bocagei*, muscles, river Sousa, Molnár et al. (2012).

M. pfeifferi (Thélohan, 1895), *Luciobarbus bocagei*, muscles, brânquias, river Sousa, Molnár et al. (2012).

M. portucalensis Saraiva & Molnár, 1990, *Anguilla anguilla*, edge of fins, river Este, Saraiva & Molnár (1990), Saraiva (1995), Saraiva et al. (1998), Saraiva & Eiras (1996).

M. tauricus Miroshnichenko, 1979, *Luciobarbus bocagei*, fins, muscles, river Sousa, Molnár et al. (2012).

Myxobolus sp., *Anguilla anguilla*, *Pseudochondrostoma polylepis* (= *Chondrostoma polylepis*), *Squalius cephalus* (= *Leuciscus cephalus*), muscles, gills, kidney, fins, urinary ducts, liver, river Este, Saraiva & Chubb (1989), Cruz et al. (2000).

Zschokkella stettinensis Wierbicka, 1987, *Anguilla anguilla*, urinary bladder, river Este, Saraiva (1995), Saraiva et al. (1998), Saraiva & Eiras (1996).

Monogenea

Pseudodactylogyryus anguillae (Yin & Sproston, 1948), *Anguilla anguilla*, gills, rivers Este and Sousa, Aveiro lagoon, Saraiva (1995), Saraiva et al. (1998), Rodrigues & Saraiva (1996), Saraiva & Chubb (1989), Hermida et al. (2008).

Pseudodactylogyryus bini (Kikuchi, 1929), *Anguilla anguilla*, rivers Este and Sousa, gills, Saraiva (1995), Rodrigues & Saraiva (1996), Saraiva et al. (1998).

Digenea

Deropristis inflata (Molin, 1859), *Anguilla anguilla*, stomach, intestine, Aveiro lagoon, Hermida et al. (2008).

Helicometra fasciata (Rudolphi, 1819) Odhner, 1902, *Anguilla anguilla*, intestine, Aveiro lagoon, Hermida et al. (2008).

Lecithochirium rufoviridae (Rudolphi, 1819) Lühe, 1902, *Anguilla anguilla*, stomach, Aveiro lagoon, Hermida et al. (2008).

Lecithochirium sp., *Anguilla anguilla*, gills, Aveiro lagoon, Hermida et al. (2008).

Podocotyle sp., *Anguilla anguilla*, intestine, Aveiro lagoon, Hermida et al. (2008).

Cestoda

Bothriocephalus claviceps (Goeze, 1782), *Anguilla anguilla*, intestine, river Este, Saraiva & Eiras (1996), Saraiva & Chubb (1989), Saraiva et al. (2005).

Khawia baltica Szidat, 1941, *Luciobarbus bocagei* (= *Barbus barbatus bocagei*), intestine, rivers Este, Lima, Paiva and Sousa, Chubb et al. (1997).

Acanthocephala

Acanthocephalus clavula Dujardin, 1845, *Anguilla anguilla*, intestine, river Este, Aveiro lagoon, Saraiva & Eiras (1996), Saraiva et al. (2005), Hermida et al. (2008).

A. lucii (Müller, 1777), *Anguilla anguilla*, intestine, river Este, Saraiva & Chubb (1989).

Pomphorhynchus laevis (Müller, 1776), *Anguilla anguilla*, intestine, Aveiro lagoon, Hermida et al. (2008).

Nematoda

Anguillicola crassus Kuwahara, Niimi & Hagaki, 1974, *Anguilla anguilla*, swimbladder, Aveiro lagoon, Cruz & Silva et al. (1992), Cardoso & Saraiva (1998).

Anisakis pegreffii Campana-Rouget & Biocca, 1955, *Alosa alosa*, *A. fallax*, visceral organs, rivers Minho and Mondego, Bao et al. (2015).

A. simplex (Rudolphi, 1809), *Alosa alosa*, *A. fallax*, visceral organs, rivers Minho and Mondego, Bao et al. (2015).

Contracecum sp., *Anguilla anguilla*, intestinal wall, Aveiro lagoon, Hermida et al. (2008).

Cucullanus truttae Fabricius, 1794, *Anguilla anguilla*, intestine, river Este, Saraiva & Eiras (1996), Saraiva et al. (2005).

Paraquimperia tenerrima (Linstow, 1878), *Anguilla anguilla*, intestine, river Este, Saraiva & Chubb (1989), Saraiva et al. (2005).

Philometra ovata (Zeder, 1803), *Gobio lozanoi*, body cavity, river Febros, Saraiva et al. (2008).

Pseudocapillaria tomentosa (Dujardin, 1843), *Anguilla anguilla*, intestine, river Este, Saraiva & Eiras (1996).

Rhabdochona anguillae Spaul, 1927, *Anguilla anguilla*, intestine, river Sousa, Carvalho Saraiva & Moravéc (1998), Saraiva et al. (2002c).

R. gnedini Skrjabin, 1946, *Luciobarbus bocagei* (= *Barbus barbatus bocagei*), intestine, river Sousa, Saraiva et al. (2002).

Raphidascaris acus (Bloch, 1779), *Salmo trutta fario*, intestine, river Mezio, Eiras & Reichenbach-Klinke (1982), Saraiva et al. (1998).

Spinitectus inermis (Zeder, 1800), *Anguilla anguilla*, intestine, river Sousa, Saraiva et al. (2002a, b, 2005).

Crustacea

Acanthochondria cornuta (Müller, 1776), *Platichthys flesus*, tegument, fins, gill arches, nasal cavities, pseudobranchiae, Viana do Castelo, Matosinhos, Aveiro, Figueira da Foz, Cavaleiro & Santos (2007).

Caligus diaphanus Nordmann, 1832, *Platichthys flesus*, tegument, Aveiro, Cavaleiro & Santos (2007).

Caligus sp., *Platichthys flesus*, tegument, fins, Matosinhos, Cavaleiro & Santos (2007).

Ergasilus gibbus Nordmann, 1832, *Anguilla anguilla*, gills, river Este, Aveiro lagoon, Saraiva (1995, 1996), Saraiva & Eiras (1996), Saraiva & Chubb (1989), Hermida et al. (2008).

Holomobolochus confusus (Hemmingsen & MacKenzie 2001), *Platichthys flesus*, nasal cavities, Matosinhos, Cavaleiro & Santos (2007).

Lepeophtheirus pectoralis (Müller, 1776), *Platichthys flesus*, tegument, fins, Viana do Castelo, Matosinhos, Aveiro Figueira da Foz, Cavaleiro & Santos (2007).

L. salmonis (Krøyer, 1838), *Salmo trutta*, tegument, river Minho catchment, Bao et al. (2016).

Lernaea cyprinacea Linnaeus 1758, *Salmo trutta*, tegument, river Minho catchment, Bao et al. (2016).

Lernaea sp., *Leuciscus cephalus*, skin, river Frio, Saraiva & Valente (1988).

Nerocila orbignyi (Guérin-Méneville, 1832), *Platichthys flesus*, fins, gill arches, Matosinhos, Cavaleiro & Santos (2007).

Parasites of marine fish from the Archipelago of Madeira

Apicomplexa

Goussia cruciata (Thélohan, 1894) Labbé, 1896, *Trachurus picturatus*, liver, Costa et al. (2013b).

Myxozoa

Ceratomyxa sparusaurati Sitjà-Bobadilla, Palenzuela & Alvarez-Pellitero, 1995, *Sparus aurata*, gall bladder, Costa et al. (1998).

C. tenuispora Kabata, 1960, *Aphanopus carbo*, gall bladder, Costa et al. (1996), Casal et al. (2007).

Ceratomyxa sp., *Aphanopus carbo*, *Pagellus bogaraveo*, gall bladder, Santos et al. (2009), Hermida et al. (2013b).

Monogenea

Choricotyle chrysophryi Van Beneden & Hesse, 1863, *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Grubea cochlear Diesing, 1858, *Scomber japonicus*, gills, Costa et al. (2007), Oliva et al. (2008).

Heteraxinoides atlanticus Gaevskaya & Kovaliova, 1979, *Trachurus picturatus*, gills, Costa G et al. (2012).

Kuhnia scombri Kuhn, 1829 (Sproston, 1945), *Scomber japonicus*, gills, Costa et al. (2007), Oliva et al. (2008).

K. sprostonae Price, 1961, *Scomber japonicus*, gills, Costa et al. (2007).

K. scombercolias Nasir & Fuentes Zambrano, 1983, *Scomber japonicus*, gills, Costa et al. (2007), Oliva et al. (2008).

Lamellodiscus virgula Euzet & Oliver, 1967, *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Octoplectanocotyla aphanopi Pascoe, 1987, *Aphanopus carbo*, gills, Santos et al. (2009).

Pseudaxine trachuri Parona & Perugia, 1889, *Trachurus picturatus*, gills, Costa G et al. (2012).

Pseudokuhnia minor (Goto, 1984), *Scomber japonicus*, gills, Costa et al. (2007), Oliva et al. (2008).

Digenea

Diptherostomum vividum (Nicoll, 1912) Bray & Gibson, 1986, *Pagellus bogaraveo*, Hermida et al. (2013b).

Halvorsenius exilis Gibson, MacKenzie & Cottle, 1981, *Scomber japonicus*, intestine, Oliva et al. (2008).

Lecithochirium fusiforme Lühe, 1901, [= *Lecithochirium grandiporum* (Rudolphi, 1819) Lühe, 1901] *Conger conger*, stomach, Costa et al. (2009b).

L. musculus (Looss, 1907) Nasir & Diaz, 1971, *Conger conger*, stomach, Costa et al. (2009b).

Nematobothrium scombri (Taschenberg, 1879), *Scomber japonicus*, intestine, Oliva et al. (2008).

Pachycreadium carnosum (Rudolphi, 1819) Cortini & Ferretti, 1959, *Pagellus bogaraveo*, pyloric caecae, intestine, Hermida et al. (2013b, 2014).

Prodistomum orientale (Layman, 1930) Bray & Gibson, 1990, *Scomber japonicus*, intestine, Oliva et al. (2008).

Schikhhobalotrema longivesiculatum Orecchia & Paggi, 1975, *Parablennius parvicornis*, intestine, Gibson & Costa (1997).

Cestoda

Campbelliella heteropociloacantha Palm, 2004, *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Gryllostia sp., *Cataetix laticeps*, in cysts on the outer wall of stomach, Costa et al. (2016).

Heteronybelinia yamagutii Dollfus, 1960, *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Heteronybelinia sp., *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Nybelinia lingualis Cuvier, 1817, *Aphanopus carbo*, *Pseudaxine trachuris*, *Trachurus picturatus*, stomach wall, digestive tract, Santos et al. (2009), Costa G et al. (1996, 2003b, 2012, 2013b).

N. thyrstites Korotaeva, 1971, *Aphanopus carbo*, *Trachurus picturatus*, external stomach wall, digestive tract, Costa et al. (2003b), Santos et al. (2009).

Nybelinia sp., *Mauligobius maderensis*, *Scomber japonicus*, intestine, Gibson & Costa (1997), Oliva et al. (2008).

Pseudogryllostia epinepheli Scholz, Garippa & Scalla, 1993, *Serranus atricauda*, inside nodules attached to the wall of internal organs, Costa et al. (2013a).

Scolex pleuronectis Müller, 1788, *Abudefduf luridus*, *Scomber japonicus*, *Sphoeroides marmoratus*, *Thalassoma pavo*, intestine, Costa & Biscoito (2003), Oliva et al. (2008).

Sphyriocephalus tergestinus Pintner, 1913, *Aphanopus carbo*, stomach wall, digestive tract, Costa et al. (2003b, 1996), Santos et al. (2009).

Tentacularia coryphaenae (Bosc, 1802), *Aphanopus carbo*, *Centrophorus squamosus*, *Scomber japonicus*, *Trachurus picturatus*, stomach wall, Costa et al. (1996), Oliva et al. (2008), Santos et al. (2009), Costa G et al. (2003b, 2012, 2014).

Acanthocephala

Bolbosoma vasculosum (Rudolphi, 1819), *Aphanopus carbo*, *Scomber japonicus*, *Serranus atricauda*, *Trachurus picturatus*, connective tissues of viscera, digestive tract, Oliva et al. (2008), Santos et al. (2009), Costa G et al. (2000, 2012, 2013a).

Bolbosoma sp., *Aphanopus carbo*, *Pagellus bogaraveo*, *Scomber japonicus*, external stomach wall, Costa et al. (1996), Oliva et al. (2008), Hermida et al. (2013b).

Rhadiorhynchus cadenati (Golvan & Houin, 1964), *Trachurus picturatus*, intestine, Costa et al. (2013b).

R. pristis (Rudolphi, 1802), *Conger conger*, *Scomber japonicus*, stomach, Oliva et al. (2008), Costa et al. (2004b, 2009b).

Nematoda

Anisakis brevispiculata Dollfus, 1968, *Aphanopus carbo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa et al. (2003a).

A. pegreffii Campana Rouget & Biocca, 1955, *Aphanopus carbo*, *Pagellus bogaraveo*, *Scomber japonicus*, *Trachurus picturatus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa et al. (2003a, 2004a), Pontes et al. (2005), Hermida et al. (2012b).

A. physeteris (Bayliss, 1923), *Pagellus bogaraveo*, *Scomber japonicus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa et al. (2003a), Pontes et al. (2005), Hermida et al. (2012b).

A. simplex s.l., *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa et al. (2004a, 2009b), Hermida et al. (2012b).

A. simplex s.s., *Aphanopus carbo*, *Centrophorus squamosus*, *Conger conger*, *Pagellus bogaraveo*, *Scomber japonicus*, *Trachurus picturatus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Pontes et al. (2005), Hermida et al. (2012b), Costa et al. (2003a, 2004a, 2014).

A. typica (Diesing, 1860), *Pagellus bogaraveo*, *Scomber japonicus*, *Trachurus picturatus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Mattiucci et al. (2002), Costa et al. (2003a), Pontes et al. (2005), Hermida et al. (2012b).

A. ziphidarum Paggi, Nascetti, Webb, Mattiucci, Cianchi & Bullini, 1988, *Aphanopus carbo*, *Pagellus bogaraveo*, *Scomber japonicus*, *Trachurus picturatus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa et al. (2003a), Pontes et al. (2005), Hermida et al. (2012b).

Anisakis sp., *Aphanopus carbo*, *Helicolenus dactylopterus*, *Pagellus bogaraveo*, *Scomber japonicus*, *Trachurus picturatus*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa et al. (1996), Pontes et al. (2005), Oliva et al. (2008), Cruz et al. (2009), Santos et al. (2009), Sequeira et al. (2010), Hermida et al. (2012b), Costa G et al. (2003a, 2012, 2013b).

Clavellisa scombri (Kurz, 1877), *Scomber japonicus*, intestine, Oliva et al. (2008).

Cristitectus congeri Petter, 1970, *Conger conger*, stomach, Costa et al. (2009b).

Hysterothylacium fabri (Rudolphi, 1819), *Scomber japonicus*, intestine, Oliva et al. (2008).

Hysterothylacium sp., *Boops boops*, *Diplodus vulgaris*, *Pagellus bogaraveo*, *Scomber japonicus*, *Serranus atricauda*, *Thalassoma pavo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Costa & Bischoito (2003), Oliva et al. (2008), Hermida et al. (2012b), Costa et al. (2004a, 2013a).

Onchophora melanocephala (Rudolphi, 1819), *Scomber japonicus*, body cavity, Costa et al. (2009a).

Onchophora sp., *Scomber japonicus*, intestine, Oliva et al. (2008).

Procammallanus (Spirocammallanus) halitrophus Fusco & Overstreet, 1978, *Serranus atricauda*, intestine, Costa et al. (2013a).

Pseudoterranova ceticola (Deardorff & Overstreet, 1981), *Centrophorus squamosus*, stomach, Costa et al. (2014).

Spirocammallanus sp., *Mauligobius maderensis*, intestine, Gibson & Costa (1997).

Hirudinea

Hirudinella ventricosa (Pallas, 1774) Baird, 1853, *Helicolenus dactylopterus*, gonads, Sequeira et al. (2010).

Crustacea

Hatschekia pagellibogneravei (Hesse, 1878), *Pagellus bogaraveo*, gills, Hermida et al. (2012a, 2013a, b).

Aega deshaysiana (= *Aegapheles deshaysiana*) (Milne Edwards, 1840), *Pagellus bogaraveo*, tegument, Hermida et al. (2013a, b).

Gnathia maxillaris (Montagu, 1808), *Coryphoblennius galerita*, *Lipophrys pholis*, skin, Davies et al. (1994).

Gnathia sp., *Helicolenus dactylopterus*, *Pagellus bogaraveo*, mouth, oesophagus, gills, gill chamber, tegument, fins, Sequeira et al. (2010), Hermida et al. (2013a, b).

Meinertia oestroides (Risso, 1826), *Boops boops*, Costa & Bischoito (2003).

Rocinela danmoniensis Leach, 1818, *Pagellus bogaraveo*, tegument, Hermida et al. (2013a, b).

Parasites of marine fish from the Archipelago of the Azores

Myxozoa

Ceratomyxa sp., *Aphanopus carbo*, gall bladder, Santos et al. (2009).

Monogenea

Choricotyle chrysophryi Van Beneden & Hesse, 1863, *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Lamellodiscus virgula Euzet & Oliver, 1967, *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Digenea

Accacladocoelium petasiporum Odhner, 1928, *Pagellus bogaraveo*, stomach, Hermida et al. (2013b, 2014).

Derogenes varicus (Müller, 1784) Looss, 1901, *Pagellus bogaraveo*, stomach, Hermida et al. (2013b, 2014).

Lecithochirium musculus (Looss, 1907) Nasir & Diaz, 1971, *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Lecithocladium excisum (Rudolphi, 1819) Lühe, 1901, *Pagellus bogaraveo*, stomach, Hermida et al. (2013b, 2014).

Lepocreadium album (Stossich, 1890), *Pagellus bogaraveo*, stomach, pyloric caecae, anterior intestine, Hermida et al. (2013b, 2014).

Odrhenium sp., *Helicolenus dactylopterus*, mesenteries, Sequeira et al. (2010).

Pachycreadium carnosum (Rudolphi, 1819) Cortini & Ferretti, 1859, *Pagellus bogaraveo*, pyloric caecae, Hermida et al. (2013b, 2014).

Pycnadenoides senegalensis Fischthal & Thomas, 1972, *Pagellus bogaraveo*, pyloric caecae, intestine, Hermida et al. (2013b, 2014).

Cestoda

Heteronybelinia yamagutii, (Dollfus, 1960), *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Nybelinia lingualis Cuvier, 1817, *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Acanthocephala

Bolbosoma vasculosum (Rudolphi, 1819), *Aphanopus carbo*, digestive tract, Santos et al. (2009).

Bolbosoma sp., *Pagellus bogaraveo*, intestine, Hermida et al. (2013b).

Rhadinorhynchus pristin (Rudolphi, 1802), *Pagellus bogaraveo*, stomach, pyloric caecae, intestine, Hermida et al. (2013b, 2014).

Nematoda

Anisakis pegreffii Campana-Rouget & Biocca, 1955, *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

A. physeteris (Bayliss, 1923), *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

A. simplex s.l., *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

A. simplex s.s., *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

A. simplex x *A. pegreffii*, *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

Anisakis sp., *Aphanopus carbo*, *Helicolenus dactylopterus*, digestive tract, surface of viscera, Cruz et al. (2009), Santos et al. (2009), Sequeira et al. (2010).

Contraecum sp., *Pagellus bogaraveo*, most larvae encapsulated in fish body cavity, mesenteries, on the outside of the viscera, Hermida et al. (2012b).

Crustacea

Argulus foliaceus Linnaeus, 1758, *Perca fluviatilis*, *Oncorhynchus mykiss*, *Cyprinus carpio*, *Esox lucius*, tegument, Menezes et al. (1990a) (freshwater).

Argulus sp., *Pagellus bogaraveo*, pectoral fin, Hermida et al. (2013a, b).

Aega antillensis Schioedte & Meinert, 1879 [= *Aegaphelles antillensis* (Schioedte & Meinert, 1879)], *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Gnathia sp., *Pagellus bogaraveo*, mouth, oesophagus, gills, gill chamber, tegument, fins, Hermida et al. (2013a, b).

Hatschekia pagellibogneravei (Hesse, 1878), *Pagellus bogaraveo*, gills, Hermida et al. (2013a, b).

Rocinela danmoniensis Leach, 1818, *Pagellus bogaraveo*, tegument, Hermida et al. (2013a, b).

Parasites of farmed fish

Flagellata

Amyloodinium ocellatum (Brown, 1931), *Coris julis*, *Diplodus puntazzo*, *D. sargus sargus* (= *D. sargus*), *D. vulgaris*, *Sparus aurata*, *Solea senegalensis*, gills, Menezes (1992), Pereira et al. (2011), Soares et al. (2011).

Hexamita intestinalis Dujardin, 1841, *Oncorhynchus mykiss*, intestine, Carvalho Varela et al. (1981).

Ichthyobodo sp., *Anguilla anguilla*, *Coris julis*, *Salmo trutta fario*, tegument, Cruz e Silva et al. (1986), Menezes (1992), Saraiva et al. (1998).

Apicomplexa

Eimeria truttae (Léger & Hesse, 1919) Stankovitch, 1924, *Oncorhynchus mykiss*, gut mucosa, Carvalho Varela et al. (1981).

Eimeria sp., *Anguilla anguilla*, *Coris julis*, gut mucosa, Cruz e Silva et al. (1986), Menezes (1992).

Ciliophora

Ichthyophthirius multifiliis Fouquet, 1876, *Anguilla anguilla*, *Oncorhynchus mykiss*, gills, tegument, fins, Grazina Freitas & Martins (1983), Ventura & Paperna (1985), Cruz e Silva et al. (1986).

Trichodina anguillae Ergens, 1960, *Anguilla anguilla*, gills, Carvalho Varela et al. (1981).

T. truttae Müller, 1937, *Oncorhynchus mykiss*, gills, Carvalho Varela et al. (1981).

Trichodina sp., *Coris julis*, *Sparus aurata*, gills, skin, Cruz e Silva et al. (1977), Menezes (1992).

Myxozoa

Ceratomyxa auratae Rocha, Casal, Rangel, Castro, Severino, Azevedo & Santos, 2015, *Sparus aurata*, gall bladder, Rocha et al. (2015a).

Ceratomyxa sp., *Sparus aurata*, gall bladder, Rocha et al. (2015b).

Myxidium giardi Cépède, 1906, *Anguilla anguilla*, skin, gills cartilage, liver, spleen, kidney, urinary bladder, intestine, Ventura & Paperna (1984), Cruz e Silva et al. (1986).

Ortholinea auratae Rangel, Rocha, Borkhanuddin, Cehh, Castro, Casal, Azevedo, Severino, Székely, Santos, 2014, *Sparus aurata*, urinary bladder, Rangel et al. (2014).

Zschokkella auratis Rocha, Casal, Rangel, Severino, Castro, Azevedo, Santos, 2013, *Sparus aurata*, gall bladder, Rocha et al. (2013).

Monogenea

Dactylogyrus sp., *Anguilla anguilla*, tegument, Cruz e Silva et al. (1986).

Diplectanum aequans (Wagener, 1857), *Dicentrarchus labrax*, gills, Saraiva et al. (2015a, b).

Gyrodactylus elegans Nordmann, 1832, *Solea solea*, gills, Carvalho Varela et al. (1981).

Gyrodactylus sp., *Oncorhynchus mykiss*, *Salmo trutta*, skin, Eiras (1999).

Lamellogadus ignoi Palombi, 1943, *Sparus aurata*, gills, skin, Cruz e Silva et al. (1997).

Lamellogadus sp., *Coris julis*, gills, Menezes (1992).

Microcotyle sp., *Coris julis*, *Sparus aurata*, gills, skin, Menezes (1992), Cruz e Silva et al. (1997).

Cestoda

Bothriocephalus sp., *Pleuronectes platessa*, intestine, Carvalho Varela et al. (1981).

Hirudinea

Platybdella soleae (Grassé, 1959), *Pegusa lascaris* (= *Solea lascaris*), *S. senegalensis*, *Solea solea* (= *S. vulgaris*), skin, Barahona-Fernandes & Dinis (1992).

Nematoda

Contracaecum aduncum, (Rudolphi, 1802) Railliet & Henry, 1912, *Pleuronectes platessa*, intestine, Carvalho Varela et al. (1981).

Cucullanus minutus (Rudolphi, 1819) Tornquist, 1931, *Solea solea*, intestine, Carvalho Varela et al. (1981).

Raphidascaris sp., *Mugil cephalus*, intestine, Carvalho Varela et al. (1981).

Crustacea

Caligus minimus Otto, 1821, *Dicentrarchus labrax*, gills, Saraiva et al. (2015a, b).

Discussion

With regard to marine fish, 180 different parasites have been detected in 74 host species in mainland Portugal, 61 parasites in 20 host species in Madeira, and 29 parasites in 3 host species in the Azores. Considering all the marine species common to the three

regions, we find that parasites have been found only in 86 different hosts. As for freshwater fish, 52 parasite species were reported in mainland hosts, and one parasite species was observed infecting 5 freshwater hosts in the Azores. As far as we know, there are no reports of parasite species in freshwater fish in Madeira. On the other hand, 22 parasites have been observed in both marine and freshwater farmed fish.

It is evident that most of the reports from the three different “sampling sites” refer to hosts of major economic importance. This is not surprising. Most of the findings resulted from research projects funded by government agencies and, on a competitive basis, the study of important economic species is naturally favored. On the other hand, a large proportion of the findings were included in MSc and PhD studies, which also concerned hosts of high economic impact.

It is also obvious that, in general, the study of protistan parasites has been overlooked. Only 11 species in mainland waters, only one in Madeira, and none in the Azores have been reported. This was probably due to the sampling conditions of most of the fish, which were purchased from fishermen or collected at experimental fisheries, and the hosts were examined at a later date. These sampling conditions are not suitable for the search of protists, namely those that are ectoparasites. This limitation must be taken into account in future research, and whenever possible, the “neglected” protistan parasites must be included in research projects. On the other hand, the monogeneans, digeneans, cestodes, nematodes and crustaceans were generally the most prevalent parasites among the metazoan species.

Considering the parasites from mainland hosts, it is evident that the number of host species examined is very low relative to the number of hosts reported for the area. Moreover, most of the described parasites came from a small number of the 74 reported hosts. This means that research into fish parasites should be extended to other species, even if they are not economically relevant.

Some parasites deserve special attention for several reasons. First, some species are dangerous parasites in farming or aquarium conditions. That is the case particularly of the protists *Amyloodinium ocellatum* (SARAIVA et al., 2011) and *Cryptocaryon irritans*, which are responsible for numerous cases of high mortality rates at farms and aquaria (COLORNI & BURGESS, 1997).

Several monogeneans and copepods that locate on the gills of the hosts are also detrimental to the hosts, especially in cases of high infection intensity, and may be important at farms.

Kudoa sp. (most probably *K. thyrssites*) was described in several hosts, causing a variable degree of post-mortem myoliquefaction of the host, thus rendering them unsuitable for consumption (CRUZ E SILVA & GRAZINA FREITAS, 1984; GRAZINA FREITAS et al., 1986; GILMAN & EIRAS, 1998; MENEZES et al. 1990b; CRUZ et al., 2003). Gilman & Eiras (1998) showed that this parasite is responsible for the rejection of large quantities of fish by the canning industry. This type of infection, and infection with related species, is impossible to fight and may have serious economic consequences in the exploitation of wild stocks of some species (see MORAN et al., 1999).

Nematodes are another extremely important group of parasites, especially those with a zoonotic potential (*Anisakis* spp.,

Hysterothylacium spp. and *Contracaecum* spp.). This problem will be discussed further on.

In Madeira, 61 parasites were reported infecting 19 hosts. However, most of the parasites were found in only four host species, i.e., *Trachurus picturatus*, *Aphanopus carbo*, *Pagellus bogaraveo* and *Scomber japonicus*, all of them species of high economic value. Once again, it was easier to obtain funding to study these valuable species. Nematodes were the most prevalent parasites, followed by cestodes, monogenea and digenea. It should be noted that most of the findings on fish parasites in Madeira are mainly due to the work of Costa G. et al. (1996, 1998, 2000, 2003a, b, 2004a, b, 2007, 2009a, b, 2012, 2013a, b, 2014, 2016), and also of Hermida et al. (2008, 2012a, b, 2013a, b, 2014, 2015), Santos et al. (2009) and Oliva et al. (2008).

An interesting issue that was addressed was the use of parasites as biological tags for the discrimination of *Aphanopus carbo* fish stocks from mainland Portugal, Madeira and Azores. The results of this cooperative research involving several institutions suggested that 6 parasites (*Tentacularia coryphaenae*, *Sphyricephalus tergestinus*, *Campbelliella heteropociloacantha*, *Anisakis* spp., *Bolbosoma vasculosum* and unidentified Acanthocephala larvae) can be used as biological tags to discriminate *Aphanopus carbo* stocks from Portugal (SANTOS et al., 2009). This study illustrates the usefulness of several institutions cooperating to solve an interesting biological problem of potential economic interest, and parasites can probably be used for similar purposes involving other fish species.

Surprisingly, the 29 parasite species reported for the Azores (excluding *Argulus foliaceus* described in freshwater fish) were detected in only three marine host species – *Aphanopus carbo* (21 parasites), *Pagellus bogaraveo* (6) and *Helicolenus dactylopterus* (2) – Hermida et al. (2013a, b, 2014), Hermida et al. (2012a, b, 2013). Furthermore, the papers by Hermida and Hermida et al. resulted from her PhD studies on the parasites of *P. bogaraveo*. This means that research on fish parasites in the Azores is practically nonexistent, in spite of the great diversity of fishes, and the marked economic importance of the fish in Azorean waters. This is a research field that obviously needs the attention of researchers from the central and local Fisheries authorities and from the academic sector.

According to Almaça (1996), there are 36 freshwater fish species in Portugal, most of them belonging to the family Cyprinidae (19 species). Research on fish parasites has focused only on ten fish species, resulting in the detection of 51 different parasites, 26 of which are described in *Anguilla anguilla*. This does not necessarily mean that this eel is more infected than other host species, but simply reflects a greater research effort directed towards this species, possibly because the economic potential of this host is greater than that of others. However, in general, the economic importance of Portugal's freshwater fishes is very low, and professional fisheries are almost nonexistent, with a few exceptions in some reservoirs and in major rivers.

The number of parasites detected so far is very small and, interestingly, the myxozoans are the most abundant parasites reported considering the number of species, a result that is in large part due to the paper by Molnár et al. (2012) about the myxozoans of *Luciobarbus bocagei*. Some species that occur in the wild may be dangerous in the case of fish farming, namely eel farming (especially *Ichthyophthirius multifiliis*, *Pseudodactylogyrus anguillae*,

P. bini, *Anguillicola crassus* and several species of crustaceans, namely *Lernaea cyprinacea*).

Most of the papers concerning freshwater fish were produced for academic purposes, and there are no major research projects on the parasites of freshwater fish. On the other hand, practically all the data pertaining to hosts were collected in the north of the country, mostly in the vicinity of Porto, and only fragmentary data are available about hosts from the country's center and southern regions. Clearly, an integrated study should be conducted comprising the diversity of parasites and their geographic distribution, and host-parasite relationships – this could easily be done given the small number of host species, the facility of sampling by electrofishing and net fishing, and the small size of the country. The costs involved would not be high, and a number of qualified researchers with broad experience in the field would ensure the success of such a project.

The importance of fish parasites in fish farming stems from the injuries and mortality rates they can cause on farmed species. Fish farming is scantily developed in Portugal, and the number of parasites described in aquaculture facilities is very low, i.e., only 25 different species. Some of them are not particularly dangerous and do not require special care. However, some are very important for the fish farmer and may, in favorable conditions, pose a threat to exploitation if adequate measures are not taken in time. The abundance of those species requires continuous monitoring in order to deploy adequate disinfection procedures to keep infection rates at levels that do not interfere with the survival of the hosts.

Several parasites have been linked to abnormal mortality rates in fish farming in this country. The monogeneans *Microcotyle* sp., *Lamellodiscus ignoratus* and the ciliate *Trichodina* sp. caused mortality in *Sparus aurata*, mostly in association with poor environmental conditions involving the penetration of freshwater into marine aquaculture premises, which led to a decrease in the salinity of the water. At several trout farms, the monogenean *Gyrodactylus* sp. caused mortality in spring and summer due to the increase in water temperature. Yearly high mortality rates have been caused by *Amyloodinium ocellatum* in farmed *Diplodus sargus*, *D. vulgaris*, *D. puntazzo* and *Solea senegalensis* in spring and summer owing to high water temperatures. Ciliates belonging to the order Philasteridae caused high mortality rates in *Scophthalmus maximus* (RAMOS et al., 2007).

The ciliate *Ichthyophthirius multifiliis* is considered to be possibly the most important ectoparasite in freshwater fish farming, and has been reported in all the freshwater fish farms in the country, causing White Spot Disease. Despite the high mortality levels this ectoparasite may cause, monitoring of the fish and adequate prophylactic measures are usually the means to prevent high economic losses. However, several cases of mortality have been observed in *Oncorhynchus mykiss* (EIRAS, unpublished observations) and *Anguilla anguilla*, and stressed *O. mykiss* were reported by Ventura & Paperna (1985). Another case of mortality was observed in the marine fish *Coris julis* due to infection by *Amyloodinium ocellatum* (MENEZES, 1992).

Some observations have revealed that parasites may adversely affect several organs of farmed fish, and this problem requires

particular attention because of the lesions they produce. This is the case of *Diplectanum aequans* and *Caligus minimus*, which have been found to contribute to severe histological gill alterations in farmed *Dicentrarchus labrax* (SARAIVA et al., 2015ab), and of *Myxidium giardi*, which cause pathological lesions in the kidney of elvers (VENTURA & PAPERNA, 1984).

It should be noted that *Lepeophtheirus salmonis*, the “salmon louse,” has been detected in wild *Salmo trutta* in Minho catchment (BAO et al., 2016). The importance of this parasite, which causes heavy losses especially in net-cage farmed *Salmo salar* (COSTELLO, 2009; SKILBREI et al., 2013), is well known and must be taken into consideration in future farms of the host.

Overall, it can be stated that, despite the occurrence of some cases of mortality, the influence of parasites in Portuguese fish farming is negligible. This is due to the scanty development of fish farming in the country and to the action of the fish-farmers who monitor farm premises constantly in order to adopt the necessary measures to prevent parasite outbreaks. For a general overview of the influence of parasites on fish farms, see Eiras (1994) and Carvalho Varela (2005).

As stated earlier, a large number of hosts were infected by potentially zoonotic nematodes (*Anisakis* spp., *Hysterothylacium* spp. and *Contracaecum* spp.) at all the sampling sites. The problem of human infection by fish nematodes in Portugal was discussed by Carvalho Varela & Cunha Ferreira (1984), Ramos (1998, 2011), Rombert (1993), Silva & Eiras (2003), Nunes et al. (2003) and Bao et al. (2015). Human infection is acquired by ingesting raw or poorly cooked fish, and infections have different symptomatology according to the nematodes ingested. The symptoms of infection are often difficult to recognize because they are similar to those of other diseases.

As far as the author knows, there are no notified cases of human infections by fish nematodes in Portugal. However, Nunes et al. (2003) found 8 individuals showing specific antibodies to *Anisakis simplex* in the bloodstream. It must be kept in mind that allergic reactions to *Anisakis*, including anaphylaxis, may occur even when properly cooked fish is ingested (AUDICANA et al., 2002). Portuguese dishes do not usually include raw fish. However, “sushi” and “sashimi” restaurants, which have become “fashionable,” can be considered places that pose a probable risk factor for infection (RAMOS, 2011).

Our data indicate that infection of fish by zoonotic nematodes is frequent in Portuguese waters, and we agree with the opinion of the European Food Safety Authority, which considers that “All wild caught seawater and freshwater fish must be considered at risk of containing any viable parasites of human health concern if these products are to be eaten raw or almost raw” (EFSA, 2010). More particularly, “For wild-caught fish, no sea fishing grounds can be considered free of *A. simplex*” (EFSA, 2010). Furthermore, all fish species should be considered potentially dangerous and processed accordingly for human consumption. Therefore, some precautions should be adopted to prevent infection and we suggest following the recommendations of the US Food and Drug Administration for consumption of raw fish (US Food and Drug Administration, 2011).

Conclusions

1. The studies of fish parasites in Portugal (mainland, and the archipelagos of Madeira and Azores) have been developed mostly over the last three decades. A total of 180 parasite species of marine fish have been reported in the mainland coastal waters, 52 in Madeira, 29 in the Azores, 52 in freshwater fish in the mainland, and 22 in farmed fish. This means that the great majority of fish species have never been studied from the parasitological point of view.
2. Knowledge about parasitic protists is very scanty when it comes to metazoan parasites, and this is a gap that must be filled.
3. Most of the studies on marine fish have involved only important commercial species. The parasite fauna in other species are mostly unknown.
4. Most of the studies on freshwater parasites have involved *Anguilla anguilla*, while the parasites of the majority of freshwater fish species have never been studied.
5. A number of nematodes with zoonotic potential are common parasites in marine fish in mainland coastal waters, Madeira and Azores. This fact must be taken into account when cooking fish, and the consumption of raw or undercooked fish should be avoided.

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