diversity

Review

Sturgeon Parasites: A Review of Their Diversity and Distribution

György Deák, Elena Holban, Isabela Sadîca and Abdulhusein Jawdhari *

National Institute for Research and Development in Environmental Protection, 294 Splaiul Independenței Str., 060031 Bucharest, Romania; dkrcontrol@yahoo.com (G.D.); holban.elena@yahoo.com (E.H.); isabelasadica01@gmail.com (I.S.)

* Correspondence: h.jawdhari20@s.bio.unibuc.ro

Abstract: Sturgeon species have inhabited the world's seas and rivers for more than 200 million years and hold significant taxonomic significance, representing a strong conservation interest in aquatic biodiversity as well as in the economic sector, as their meat and eggs (caviar) are highly valuable goods. Currently, sturgeon products and byproducts can be legally obtained from aquaculture as a sustainable source. Intensive farming practices are accompanied by parasitic infestations, while several groups of parasites have a significant impact on both wild and farmed sturgeons. The present article is a review of common sturgeon parasites from the genus: Protozoa, Trematoda, Crustacea, Nematodes, Monogenea, Hirudinea, Copepoda, Acanthocephala, Cestoda, Polypodiozoa, and Hyperoartia, while also addressing their pathology and statistical distribution.

Keywords: sturgeons; parasites; pathology; statistical distribution; freshwater

check for updates

Citation: Deák, G.; Holban, E.; Sadîca, I.; Jawdhari, A. Sturgeon Parasites: A Review of Their Diversity and Distribution. *Diversity* **2024**, *16*, 163. https://doi.org/10.3390/d16030163

Academic Editor: Simon Blanchet

Received: 5 January 2024
Revised: 26 February 2024
Accepted: 28 February 2024
Published: 5 March 2024

1. Introduction

Sturgeons are members of the *Acipenseriformes* order, which is over 200 million years old and comprises twenty-seven species and two families, the *Acipenseridae* and *Poyodontidae* [1]. The species has a long life cycle and is native to the Northern Hemisphere [2,3]. The natural habitats of sturgeons are the freshwaters of Europe, Asia and North America. The species inhabit inland water, bays, estuaries, and the coastal regions of seas and oceans. Although most sturgeon species migrate and spawn in freshwater, they also spend a significant amount of their life cycle in brackish water. The Caspian basin accounted for up to 90% of caught sturgeon, but as many fisheries have collapsed, many individual species or populations are now endangered. Two such examples are the *Huso* and *Acipenser* genera, with a total of 17 species [4], the most well-known of which are *Acipenser ruthenus*, *Acipenser stellatus*, *Acipenser gueldenstaedti*, *Acipenser oxyrhynchus*, *Huso huso*, *Acipenser persicus*, *Acipenser sturio*, and *Acipenser naccarii*. Sturgeon species differ significantly from other fish species not solely because of their anatomy, but also because of their longevity and behavior. The Danube is a well-known habitat for sturgeon populations, although in recent years only four species were found [5] out of the six previously known [6]. Such decreases in sturgeon populations are mainly due to dams, pollution, and overfishing [7,8]. With the effective wild population decreasing, the sturgeon parasitic infestations are becoming more important and, like in many other fish species, they are becoming more prominent as aquaculture is expanding [9].

Sturgeons are host to many parasites, such as protozoans, trematodes, nematodes, monogeneans, helminths, and argulidaes [10]. These parasites are among the most significant factors responsible for weight loss, impotence, strange behaviour, deformed gills, and epithelial lesions [11], ultimately resulting in the diminishing of wild stocks or in financial losses in the case of fish farming. In addition, external parasites have the potential to spread bacteria, viruses, and other pathogens, resulting in a boost of secondary fungal, bacterial, and viral infections [12,13]. Sturgeons are susceptible to viral, parasitic, and bacterial infections, fungal infections being generally rare [14]. Parasites and parasite communities are important environmental quality bioindicators because they are part of the aquatic biodiversity and are influenced by it, either directly or indirectly, through their hosts, despite the fact that they are frequently ignored as a biological component for ecological assessment [15]. Therefore, environmental monitoring programs are more effective when parasites and parasitic fish communities are also regarded [16].

Protozoan parasites are a diverse group of single-celled organisms that can reside either inside or on the surface of their host. They do not always cause disease in fish, but they may be present in a subclinical or carrier state [17,18]. Certain species of ciliate protozoa are known to consume bacteria and other microorganisms that may cause infections in fish. By controlling the population of potentially harmful microorganisms, these protozoa may contribute to supporting fish health. On the other hand, some protozoa can be harmful to sturgeon, causing disease and other health problems, for example, *Ichthyophthirius multifiliis*, which can infect sturgeon as well as other fish, causing the white spot disease that causes the skin and gills of these species to be susceptible to other parasites during different stages of rearing, thereby severely affecting their normal growth and development [12]. Due to their varied life cycles, which include time spent in freshwater, brackish water, and marine water, sturgeon in the wild are more disease-resistant than other fish species [19] but still subject to parasitic infestation. The current review documents the presence of both ecto- and endoparasitic species that occur on sturgeon in their natural environments. A comprehensive list of sturgeon parasites and organs affected is presented in Table 1.

Table 1. Parasitic species (ecto- and endoparasites species) of sturgeons and the infected organs.

Sturgeon Species	**Parasitic Species**	**Infected Organs**	**Reference**
Acipenser stellatus (Pallas, 1771)	Protozoa *Ichthyophthirius multifiliis*	G. S. F	[20]
Acipenser oxyrhynchus (Mitchill, 1815)	Protozoa *Trichodina* sp., *Apiosoma* sp., Monogenea *Gyrodactylus* sp. Crustacea *Ergasilus siebold*, *Argulus coregoni*	G. S. F	[21]
Acipenser persicus (Borodin, 1897) *Acipenser guldenstadti* (Brandt & Ratzeburg, 1833) *Acipenser stellatus*	Protozoa *Cryptobia acipenseris*, *Haemogregarina acipenseris*	BL	[22]
Acipenser oxyrinchus	Protozoa *Chilodonella* sp.	S. D	[23]
Acipenser gueldenstaedti and Acipenser baerii (Brandt, 1869)	Protozoa *Trichodina reticulate*, Trematoda *Diplostomum spathaceum*	G. S. N	[24]
Acipenser persicus (Borodin, 1897)	Protozoa *Trichodina* sp., *Ichthyophthirius multifiliis* Trematoda *Diplostomum spathaceum* Nematoda *Cucullanus sphaerocephlaus*, *Anisakis* sp., *Skyrjabinopsilus semiarmatus* and *Leptorhynchoides plagicephalus*	S. F. G. I	[25]
Acipenser persicus	Protozoa *Trichodina reticulate* Trematoda *Diplostomum spathaceum*	S. F. G. E	[26]
Acipenser oxyrinchus	Monogenea *Nitzschia sturionis*	S. G	[27]
Acipenser gueldenstaedtii Acipenser persicus Acipenser stellatus, *Acipenser sturio* (Linnaeus, 1758)	Protozoa *Ichthyobodo necatrix*, *Trichodinidae*, *Apiosoma*, *Epistylis* Monogeneans *Diclybothrium*, *Dactylogyrus* and Crustaceans *Agulus foliaceus*	G. S. F	[19]
Acipenser ruthenus (Linnaeus, 1758)	Protozoa *Ichthyophthirius multifiliis* Trematoda *Skrjabinopsolus semiarmatus*, *Acrolichanus auriculatus*	S. GU	[28]
Acipenser persicus	Protozoan *Ichthyophthirius multifiliis*	G	[29]

Table 1. *Cont.*

Sturgeon Species	Parasitic Species	Infected Organs	Reference
Acipenser ruthenus	Protozoa *Cryptobia acipenseris*, *Haemogregarina acipenseris*, *Trichodina* sp. Cestoda *Proteocephalus* sp. Trematoda *Crepidostomum auriculatum*, *Diplostomum chromatophorum*, Nematoda *Capillospirura ovotrichuria*, Acanthocephala *Echinorhynchus cinctulus*, Hirudinea *Piscicola geometra*, Copepoda *Ergasilus sieboldi*	BL. F. I.	[30]
Acipenseridae	Trematoda *Skrjabinopsolus semiarmatus*, *Sanguinicola Posthodiplostomum*, Cestoda *Amphilina foliacea* Nematoda *Contracaecum* sp., *Acanthocephala*, *Pomphorhynchus bosniacus.*	I	[11]
Acipenser fulvescens (Rafinesque, 1817)	Trematoda *Pristicola bruchi*	I	[31]
Acipenser fulvescens	Trematoda *Acipensericola glacialis*	H	[32]
Acipenser persicus	Trematode *Skrjabinopsolus semiarmatus* Nematodes *Cucullanus sphaerocephalus*, *Eustrongylides*, *Anisakis* sp. cestode *Amphilina foliacea* Monogenea *Diclybothrium armatum*, *Nitzschia storionis* Acanthocephalan *Leptorhynchoides plagicephalus* Crustacea *Pseudotracheliastes stellatus*	G. S. F. I	[33]
Acipenser ruthenus	Trematoda *Skrjabinopsolus semiarmatus*	Ds	[34]
Acipenser schrenkii (Brandt, 1869)	Trematoda *Crepidostomum oschmarini*	I	[35]
Acipenser sturio, *Acipenser ruthenus*, *Acipenser fulvescens*	Trematoda *Skrjabinopsolus semiarmatus*, *Distomum hispidum*, *Deropristis hispida*, *Cestrahelmins rivularis*, *Homalometron armatum.*	I	[36]
Acipenser oxyrinchus	Trematoda *Skrjabinopsolus nudidorsalis* sp.	I	[37]
Acipenser stellatus Acipenser gueldenstaedtii *Acipenser nudiventris* (Lovetsky, 1828) *Acipenser Huso huso dauricus* (Georgi, 1775)	Trematode *Skrjabinopsolus semiarmatus* Nematode *Cucullanus sphaerocephalus*, *Eustrongylides excisus* Cestodes *Amphilina foliacea*, *Bothrimonus fallax* Acanthocephalan *Leptorhynchoides plagicephalus*	I	[38]
Acipenser persicus	Trematoda *Skrjabinopsolus*. Nematode *Cucullanus sphaerocephalus*, *Eustrongylides excisus* Cestodes *Amphilina foliacea*, *Bothrimonus fallax* Acanthocephalan *Leptorhynchoides plagicephalus*	I	[39]
Acipenser oxyrinchus	Copepoda *Dichelesthium oblongum* Monogenea *Nitzschia* sp.	G. F.	[40]
Acipenser oxyrinchus	Copepoda *Dichelesthium oblongum*	S	[41]
Husu huso	Copepoda *Argulus*	G. S. F	[42]
Acipenser oxyrinchus	Copepoda *Argulus flavescens*	G	[43]
Acipenser oxyrinchus	Copepoda *Dichelesthium oblongum*	G	[44]
Huso huso, *Acipenser ruthenus*, *Acipenser gueldenstaedtii*	Copepoda *Lernaea cyprinacea*, *Argulus* sp., *Ergasilus* sp.	G. S. F	[45]
Acipenseriformes	Copepoda *Tracheliastes gigas*	B	[46]
Acipenser fulvescens	Copepoda *Argulus* sp.	G. S	[47]
Acipenser oxyrinchus	Copepoda *Dichelesthiidae oblongum*	G	[48]
Acipenser oxyrinchus	Copepoda *Caligus elongatus*, *Dichelesthium Oblongum* Hirudinea *Calliobdella vivida* Crustacea *Argulus stizostethii* and Monogenea *Nitzschia sturionis*	F. S. B	[49]
Acipenser ruthenus	Polypodiozoa *Polypodium hydriforme*	Eg	[50]

Table 1. *Cont.*

Sturgeon Species	Parasitic Species	Infected Organs	Reference
Acipenser ruthenus	Polypodiozoa *Polypodium hydriforme*	Eg	[51]
Acipenser mikadoi (Hilgendorf, 1892)	Polypodiozoa *Polypodium hydriforme* Cestoda *Amphilina japonica* Hirudinea *Limnotrachelobdella* sp.	Eg. B. I	[52]
Acipenser fulvescens	Polypodiozoa *Polypodium hydriforme*	Eg	[51]
Acipenser fulvescens	Polypodiozoa *Polypodium hydriforme*	Eg	[53]
Acipenseriform	Polypodiozoa *Polypodium hydriforme*	Eg	[54]
Acipenser fulvescens	Polypodiozoa *Polypodium hydriforme*	Eg	[55]
Acipenser fulvescens	Polypodiozoa *Polypodium hydriforme*	Eg	[56]
Acipenser, *Huso dauricus*, *Acipenser schrenckii* (Brandt, 1869)	Polypodiozoa *Polypodium hydriforme*	Eg	[57]
Acipenser mikadoi	Polypodiozoa *Polypodium hydriforme* Hirudinea *Limnotrachelobdella*	Eg. B	[58]
Acipenseriformes	Polypodiozoa *Polypodium hydriforme*	Eg	[59]
Acipenser gueldenstaedtii	Hirudinea *Acipenserobdella volgensis*	F	[60]
Acipenser oxyrinchus	Hirudinea *Caspiobdella fadejewi*	B	[61]
Acipenser brevirostruin (Lesueur, 1818)	Hirudinea *Placobdella montifera*, *Piscicola geometra*	B	[62]
Acipenser oxyrinchus	Hirudinea *Calliobdella vivida*	G	[63]
Acipenser baerii, *Acipenser ruthenus*	Nematoda *Raphidascaris acus*	I	[64]
	Cestodes *Amphilina foliacea*, *Bothrimonus fallax*, Nematoda *Cucullanus sphaerocephalus*, *Leptorhynchoides plagicephalus and* Acanthocephalan *Eustrongylides excisus*	I	[65]
Acipenser ruthenus	Nematoda *Cystidicoloides ephemeridarum*	I	[66]
Acipenser stellatus	Nematoda *Eustrongylides excisus*	Gu	[67]
Acipenser persicus	Nematoda *Cucullanus sphaerocephalus*, Trematode *Skrjabinopsolus semiarmatus*, Cestoda *Eubothrium acipenserinum.* Acanthocephala *Leptorhynchoides plagicephalus*	I	[26]
Acipenser fulvescens	Nematoda *Capillospirura* sp.	I	[68]
Acipenser filvescens	Nematoda *Cucullanus sphaerocephala* Trematoda *Skrjabinopsolus semiarmatus* Acanthocephala *Leptorhynchoides plagicephalus* Cestoda *Amphilina foliacea*	I	[69]
Acipenser transmontanus (Richardson, 1836)	Nematoda *Cystoopsis acipenseri*	I	[70]
Acipenser fulvescens	Monogenea *Diclybothrium atriatum* Trematoda *Skrjabinopsolus semiarmatus*	G. S. I	[71]
Acipenser persicus Acipenser stellatus Acipenser gueldenstaedti Acipenser nudiventris	Monogenea *Nitzschia sturionis*, *Diclybothrium*	G. I	[72]
Acipenser baerii	Monogenea *Diclybothrium armatum*	G	[73]
Acipenser stellatus	Monogenea *Nitzschia sturionis*	G	[74]
Acipenser nudiventris	Acanthocephala *Leptorhynchoides polycristatus*	I	[75]
Acipenser naccarii (Bonaparte, 1836)	Acanthocephala *Leptorhynchoides plagicephalus*	T	[76]
Acipenser nudiventris	Cestoda *Bothrimonus fallax*	I	[77]
Acipenser stellatus	Cestoda *Amphilina foliacea*	I	[78]

Table 1. *Cont.*

Sturgeon Species	Parasitic Species	Infected Organs	Reference
Acipenser ruthenus	Cestoda *Amphilina foliacea*	I	[79]
Acipenser gueldenstadti	Cestoda *Bothrimonus fallax*, *Eubothrium acipenserinum*	I	[80]
Acipenser fulvescens	*Hyperoartia* (*Lamprey*) *Petromyzon marinus*	B	[81]
Acipenser fulvescens	*Hyperoartia* (*Lamprey*) *Petromyzon marinus*	B	[82]
Acipenser fulvescens	*Hyperoartia* (*Lamprey*) *Petromyzon marinus*	B	[83]
Acipenser fulvescens	*Hyperoartia* (*Lamprey*) *Petromyzon marinus*	B	[84]
Acipenser transmontanus (Richardson, 1836)	Nematoda *Cystoopsis acipenseri*	I	[85]
Acipenser transmontanus	Trematoda *Crepidostomum auriculatum* Cestoda *Diphyllobothrium* sp, *Amphilina bipunctata.* Nematoda *Anisakis simplex.* Acanthocephala *Corynosoma strumosum*	I	[86]
Acipenser transmontanus	Allocreadiidae *Crepidostomum auriculatum* Monogenea *Nitzschia quadritestes* sp. Cestoda *Amphilina foliacea*	I	[87]

G gill, S skin, F fin, I intestine, E eye, SP Spleen, H heart, N nose, Eg eggs, B body, BL blood T testes, GU gut, Ga gastrointestinal, Ds digestive system.

Various types of texts, such as abstracts, reviews, and original research articles, were examined and evaluated individually to determine their eligibility based on specific criteria. These included recording information about the sturgeon species, the parasite species, the site of infection, and the country of origin.

2. Sturgeons and Parasites

2.1. Protozoa, Monogenea and Crustaceans

Protozoa comprise a diverse group of predominantly single-celled eukaryotic organisms [75]. Depending on their species, protozoa can be either ectoparasites or endoparasites. Among cultured fish, ectoparasitic protozoa are the most commonly encountered parasites [88]. These parasites induce a reactive hyperplasia of the fish epithelium, and excessive mucus infestation can lead to gill hyperplasia, including epithelial hyperplasia of the entire gill filament, inflammation, hemorrhage, and necrosis [89]. Protozoa pose a significant threat to fish health, causing diseases in both farmed and wild populations [90]. Within fish populations, parasitic protozoa can rapidly spread, particularly those with direct life cycles and broad host specificity [91]. Some protozoa act as ectoparasites, residing on the skin, fins, and gills, while others invade internal organs, such as the intestine [92]. Parasite invasion can impede fish development, cause weight loss, and disrupt reproductive processes. In severe cases, infections can lead to long-term mortality and substantial damage to fish populations [93].

In a study conducted by Vasile et al. (2019) [20], the protozoan parasite *Ichthyophthirius multifiliis* was identified in *Acipenser stellatus* at a research hatchery in Romania. *Ichthyophthirius multifiliis* is a parasitic ciliate that was initially described by the French parasitologist Fouquet in 1876. This parasite has the ability to infect a wide range of freshwater fish species, including sturgeon. Upon infecting sturgeon, the parasite attaches itself to the skin and gills, where it feeds on bodily fluids, resulting in the formation of visible white spots on the outer layer of the fish, commonly referred to as "white spot disease".

Ichthyophthirius multifiliis can cause significant harm to the fish, including irritation, inflammation, tissue damage, reduced growth, weakened immune function, and even death [94,95]. The disease caused by this tissue-feeding parasite is referred to as ichthyophthiriasis [96]. Outbreaks of *I. multifiliis* occur when conditions are favorable for rapid multiplication, making it a major concern in aquaculture settings [97].

In another study conducted by Popielarczyk and Kolman (2013) [21] with *Acipenser oxyrinchus oxyrinchus* specimens obtained from an open system pond in Kuźniczka, Poland, protozoa, monogenean, and crustacean parasites were identified. The protozoa *Trichodina* sp. and *Apiosoma* sp., as well as the monogenean *Gyrodactylus* sp. and the crustaceans *Ergasilus sieboldi* and *Argulus coregoni*, were observed in specimens from various water habitats. A high number of *Trichodina* sp. parasites with varying morphology and size were found. These parasites resemble caps and range in size from 18 to 50 µm, with some specimens measuring up to 80 µm. They possess partial ciliation and have a saucer-shaped body, which enables them to move along the skin, fins, and gills of fish. *Trichodina* sp. parasites reproduce through binary fission; after reproduction they can either reattach to the same host or seek a new host in the water column.

The parasite possesses cilia arrangements on its body, which include a distinctive ring of denticles, morphological features that are crucial for species identification. Additionally, this parasite is classified as an ectoparasite that exhibits rapid movement on the gills, fins, and body surface of its host (in certain species, it can even inhabit the urinary tract). The *Trichodinidae* family, to which this parasite belongs, is known to cause trichodinosis [98] (also known as trichodinads), characterized by hyperplasia of the epithelium [99].

Apiosoma sp. parasites are not typically considered highly dangerous, but they can still inflict damage on sturgeons by attaching to their fins, gills, or skin surface, which leads to the destruction of the epithelial tissue and impairment of organ function. These ciliates are ectocommensals, living on the gills and body surface of aquatic organisms, particularly the fry of freshwater fish [100]. They are large, bell-shaped organisms measuring approximately 50–70 µm in length and 18–40 µm in width. The species have a free-living lifestyle but frequently attach themselves to various organisms in the water, including fish [98]. When sturgeons become infected with *Trichodina* sp. and *Apiosoma* sp., mucus accumulates on the skin surface, especially around the pectoral fin, gills, and gastrointestinal tract, as well as the oviduct and urinary bladder [96].

In aquaculture-related studies conducted in Romania, a total of 22 species of *Gyrodactylus* sp. within the monogenea group have been identified [101]. However, it should be noted that some sources report 145 species for the *Gyrodactylus* genus [102], while others mention up to 400 species [103]. The exact number remains uncertain due to synonyms and variations in taxonomic interpretation [103]. *Gyrodactylus* sp. is an ectoparasitic flatworm with a length of less than 1 mm and a body width of approximately 0.1 mm. It is characterized by a four-lobed head and an opisthaptor, which includes one prominent pair of large hooks and up to 12 smaller hooks. Infections caused by *Gyrodactylus* sp. can result in skin irritation and tissue damage. Additionally, in a study conducted by Choudhury (1997) [71], the monogenean species *D. atriatum* and the trematode *Skrjabinopsolus* sp. were identified in the gill of *Acipenser fulvescens* in Canada.

The copepod crustacea *Ergasilus sieboldi*, commonly known as "fish lice" [104], has been reported to infect sturgeons [21]. This parasite can have detrimental effects on the gills, as it attaches to the skin or gills and can cause physical damage, potentially leading to suffocation. Pazooki and Msoumian (2018) [22] identified the protozoa *Haemogregarina acipenseris* and *Cryptobia acipenseris* in *Acipenser persicus* and *Acipenser guldenstadti* in the southern part of the Caspian Sea. *Haemogregarina acipenseris* has an oval body shape, measuring 6.5–8.2 $\times$ 2.2–3.0 µm, with two rounded ends or one rounded and one sharpened end. The nucleus typically consists of a few chromatin granules, and it is commonly found in erythrocytes. *Haemogregarina acipenseris* has been previously recorded in sturgeons in the Caspian and Black seas, and it has been found in sterlet in the Volga and Danube rivers [30]. *Cryptobia acipenseris* is a parasitic protozoan measuring 11–16.4 µm in size [105]. The vegetative and sexual stages of this protozoan have been found in the blood of various sturgeon species [22]. While the majority of *Cryptobia acipenseris* live in the host's blood, some can also be found in the intestines and gills. Infections caused by *Haemogregarina acipenseris* and *Cryptobia acipenseris* can lead to severe consequences, including anemia and, finally, death [106]. Mohler et al. (2000) [23] identified the protozoan *Chilodonella* sp. in

Acipenser oxyrinchus oxyrinchus in the eastern side of Esopus Island in the Hudson River, New York. *Chilodonella* sp. is a single-celled organism belonging to the ciliate class of Alveolata. It is covered in cilia and possesses a dual nuclear structure. *Chilodonella* sp. is the causative agent of Chilodonelloza, a disease that affects the gills and skin of freshwater fish [107].

In the study conducted by Kayiş et al. (2017) [24], the protozoan *Trichodina reticulata* was identified in *Acipenser gueldenstaedtii* and *Acipenser baerii* in the Black Sea region of Turkey. This parasite infects the gill, skin, and fins, as mentioned in the previous reference [21]. Furthermore, Baska (1999) [28] discovered the presence of the protozoan *Ichthyophthirius multifiliis* and the nematode *Goussia acipenseris* in *Acipenser ruthenus* specimens in Hungary. Dobson and May (1987) [74] identified the monogenea *Nitzschia sturionis* in *Acipenser stellatus* specimens in the USA. Chebanov et al. (2013) [19] identified various protozoans, including *Ichthyobodo necatrix*, *Trichodinidae*, *Apiosoma* sp., and *Epistylis* sp., as well as the monogeneans *Diclybothrium* and *Dactylogyrus*, and the crustacean *Argulus foliaceus* in *Acipenser gueldenstaedti*, *Acipenser persicus*, and *Acipenser stellatus* in Russia. In Iran, Rahmati et al. (2021) [73] identified the monogenean *Diclybothrium armatum* in the gills of *Acipenser baerii*, and Matsche et al. (2010) [27] identified the protozoa *Nitzschia sturionis* in *Acipenser oxyrinchus oxyrinchus*.

2.2. Cestode, Trematode and Nematode

Fish-borne cestodes that can infect humans primarily belong to the order *Diphyllobothriidea* and are commonly referred to as broad tapeworms. These tapeworms have a three-host life cycle, with teleost fishes (excluding spirometra) serving as the second intermediate hosts and a source of human infection [27]. The larval form of the cestode penetrates the tissue of a crustacean host and undergoes metamorphosis into a proceroid. The fish becomes infected by consuming the crustacean. Once inside the fish, the adult cestodes gradually migrate to body organs and intestines, causing diseases and reducing the fish's lifespan [79].

The trematode *Diplostomum spathaceum* is responsible for a disease called diplostomatosis, or eye fluke disease [108]. This parasite has been found to be widespread among fish in Utah [109]. *Diplostomum spathaceum* has a complex life cycle involving multiple hosts and can cause significant harm. It attaches to the eye tissue of the fish and feeds on blood, leading to inflammation, swelling, and the formation of dark spots on the eye's surface [110]. Choudhury (2009) [31] identified the trematoda *Pristicola bruchi* in *Acipenser fulvescens* in Wisconsin, USA. *Pristicola bruchi* is smaller in size (ranging from 1.660 to 2.110 µm) than *Pristicola sturionis*. It possesses a single row of prominent peg-like oral spines instead of two rows, and its vitelline follicles dorsally converge over a small region without extending beyond the posterior testes. This is the first recorded occurrence of this genus in North America and appears to be the first report of the genus in sturgeon since the description of *Pristicola sturionis* in 1930 [111]. Warren et al. (2017) [32] identified the trematoda *Acipensericola glacialis* in *Acipenser fulvescens* during a survey of the Great Lakes Basin, specifically the Lake Winnebago system in the USA. *Acipensericola glacialis* derives its name from the Latin-specific epithet "glacialis" (glacier). The impact of this parasite on sturgeon can vary depending on the severity of the infestation and the overall health of the fish.

Nematodes and trematodes were identified in sturgeon by Sattari et al. (2006) in *Acipenser Persicus* (Persian sturgeon) in the southwest of the Caspian Sea, off the Guilan province of Iran [33]. The nematodes *Cucullanus sphaerocephalus*, *Eustrongylides excisus*, and *Anisakis* sp. were identified, along with the trematodes *Skrjabinopsolus semiarmatus* and *Skrjabinopsolus nudidorsalis* [37] in *Acipenser ruthenus*, and the monogean trematodes *Diclybothrium armatum* and *Nitzschia storionis*. Of particular zoonotic significance was *Anisakis* sp., a parasite capable of infecting humans and causing anisakidosis [112].

Ibrahimov and Mamedova (2021) [80] identified the cestodes *Bothrimonus fallax* and *Eubothrium acipenserinum* in *Acipenser gueldenstadti* in Azerbaijan. Skóra et al. (2018) [64]

identified nematoda *Raphidascaris acus* in *Acipenser baerii* and *Acipenser ruthenus* in Poland. McCabe (1991) [70] identified the nematoda *Cystinosis acipenseri* in *Acipenser transmontanus* in the USA. Noei et al. (2011) [38] identified six species, from which there were two nematodes, *Cucullanus sphaerocephalus* and *Eustrongylides excisus*, two cestodes, *Amphilina foliacea* and *Bothrimonus fallax*, one trematode, *Skrjabinopsolus semiarmatus*, and one acanthocephalan, *Leptorhynchoides plagicephalus*, in the Caspian sea, Iran.

Nasirov and Bunyatova (2017) [65] identified two nematodes, *Cucullanus* sp. and *Eustrongylides* sp., in Azerbaijan.

Lenhardt et al. (2009) [34] identified the trematoda *Skrjabinopsolus semiarmatus* in *Acipenser ruthenus* in Belgrade, and Foata et al. (2004) [76] identified *Acanthocephala* in the testes of *Acipenser naccarii* in Italy.

Adel et al. (2016) [25] identified the protozoa *Trichodina* sp. and *Ichthyophthirius multifiliis*, the trematode *Diplostomum spathaceum*, the nematodes *Cucullanus sphaerocephalus*, *Anisakis* sp., and *Skrjabinopsolus semiarmatus*, and the Acanthocephala *Leptorhynchoides plagicephalus* in the skin, fin, eyes, and intestines of *Acipenser persicus* in Iran. Atopkin and Shedko (2014) [35] identified the trematode *Crepidostomum oschmarini* in *Acipenser schrenkii* in Russia, and Moghaddam (2013) [26] identified four types of internal helminth parasites, *Cucullanus sphaerocephalus*, *Skrjabinopsolus semiarmatus*, *Eubothrium acipenserinum*, and *Leptorhynchoides plagicephalus* in *Acipenser persicus* in Iran. Rahanandeh et al. (2019) [113] identified the monogenean *Diclybothrium armatum* in the gills of farmed *Huso huso*. Aghaee Moghadam et al. (2014) [114] identified the nematodes *Cucullanus sphaerocephalus* and the Trematoda *Skrjabinopsolus semiarmatus* in the intestines of *Huso huso* in the Caspian sea, Iran, as previously reported by Sattari (2003) [115], who identified *Skrjabinopsolus semiarmatus*, *Leptorhynchoides plagicephalus*, *Cucullanus sphaerocephalus*, *Eubothrium acipenserinum*, *Bothrimonus fallax*, *Eustrongylides excess*, *Anisakis* sp., *Amphilina foliacea*, and *Corynosoma strumosum* in *Acipenser stellatus* in the Caspian Sea, Iran.

2.3. Copepods

Small crustaceans called copepods are commonly found in freshwater and marine habitats [42]. The calanoid copepod is the most common form of copepod found in sturgeon fish. It is a tiny planktonic creature that is an important food source for many fish species, including sturgeon. Cyclopoid copepods, Harpacticoid copepods, and Poecilostomatoid are other copepod species that can be found in sturgeon fish. In addition, copepod parasites have been shown to affect the physiological health of the sturgeon and cause anemia. In particular, these ectoparasites can reduce host osmotic competence both directly by damaging and necrosing the epithelium and indirectly by increasing host stress hormone levels [40].

Vasilean et al. (2012) [42] identified the copepoda *Argulus* sp. in *Huso huso* in Romania. The parasite is popularly called "fish lice" and is shaped like a pear, wide at the front and narrow at the end. Its length is about 3.7 mm and it has a pair of tentacles and hooks that are the size of the parasite's body. These crustaceans have bodies adapted to parasitic life in general. Andres et al. (2019) [43] found the copepoda *Argulus flavescens* in *Acipenser oxyrinchus* in the Pascagoula river, USA. The *Argulus flavescens* attaches itself to the gills and skin using its sharp claws and proboscis, causing irritation and inflammation of the skin and feeding on the blood, which can lead to anemia if the infestation is severe [116].

Ergasilus sieboldi, *Paraergasilus rylovi*, *Lernaea cyprinacea*, *L. elegans*, *Caligus lacustris* and *Argulus foliaceus* are also copepods that occur on different fishes and are well known to be pathogenic to fishes in aquaculture. Three species are specific to sturgeons, but only one of them, *Pseudotracheliastes stellatus*, is pathogenic. A rather high infection of *A. stellatus* and *A. gueldenstaedtii* by *Pseudotracheliastes stellatus* was noted in the Azov sea. Infection by these species results in quantitative and qualitative changes in white and red blood cells, as diseased fish present anemia [117].

Bauman et al. (2011) [47] identified the copepoda *Argulus* sp. on the gills and skin of *Acipenser fulvescens* in the Marys river, USA. Brown (2010) [48] identified the copepoda

Dichelesthium oblongum on the gills of *Acipenser oxyrinchus oxyrinchus* in New York. Munroe et al. (2011) [49] identified the copepoda *Caligus elongatus* and *Dichelesthiumoblongum*, the Hirudinea *Calliobdella vivida*, the Crustacea *Argulus stizostethii*, and the Monogenea *Nitzschia sturionis* in *Acipenser oxyrinchus* in Canada. Bozorgnia (2018) [118] identified the Copepoda *Lernaea cyprinacea* in the gills of *Acipenser stellatus* in the Caspian sea, Iran.

2.4. Hirudinea and Polypodiozoa

The Hirudinea *Caspiobdella fadejewi* was identified in wild *Acipenser oxyrinchus* specimens in the Drwêca river, Poland, by Bielecki et al. (2011) [49]. *Caspiobdella fadejewi* can cause physical harm to fish, particularly sturgeon. These leeches attach themselves to the skin of sturgeons and feed on their blood, which can lead to irritation, inflammation, and tissue damage. In severe cases, a large number of leeches can weaken the fish, making it more vulnerable to other predators or diseases. Additionally, leeches can transmit diseases or parasites to the fish, as they can carry a range of harmful pathogens [119]. Bolotov et al. (2022) [60] identified the Hirudinea *Acipenserobdella volgensis* in the pectoral fin of *Acipenseridae* in the Volga river basin in Russia. This species was also found on *Acipenser baerii*, *A. gueldenstaedtii*, and *A. nudiventris* [120].

Raikova (2002) [50] identified the polypodiozoa *Polypodium hydriforme* in *Acipenseriformes* in the Volga river as well. This is the only cnidarian species adapted to intracellular parasitism in fish oocytes. It is a diploblastic animal that possesses stinging cells known as cnidocytes, with a life cycle that consists of two stages: a parasitic stage and a free-living phase. The parasitic stage occurs within host oocytes throughout oogenesis, starting from early previtellogenesis until the hatching stage. The parasite reproduces through longitudinal fission, with the number of tentacles doubling before each division [121]. *Polypodium hydriforme* can affect the reproductive health of the sturgeon in particular, with the infected female sturgeon experiencing reduced egg production and poor egg quality [122,123].

The parasite was also reported by Hoffman et al. (1974) [53] on the eggs of *Acipenser fulvescens* in the USA, as well as by Okamura et al. (2020) [54] and Judd et al. (2022) [56]. Dick et al. (1991) [55] identified the parasite on *Acipenser fulvescens* eggs in Canada. Koshelev et al. (2014) [57] identified *Polypodium hydriforme* on the eggs of *Huso huso dauricus* in Russia, and Mikodina and Ruban (2021) [58] identified them along with the hirudinea *Limnotrachelobdella* in *Acipenser mikadoi*.

2.5. Hyperoartia

Hyperoartia, commonly known as lampreys, are parasitic jawless fish that feed by attaching themselves to the body of fish and sucking their blood and body fluids [84]. When lampreys attach themselves to sturgeons, they create open wounds that can become infected and weaken the fish. This makes the fish more susceptible to predation and disease and can also impair their ability to swim and reproduce. Lampreys can also compete with sturgeons for food and habitat, further contributing to population reduction [81]. *Petromyzon marinus* lampreys have been identified by Briggs et al. [81] on *Acipenser fulvescens* in the USA, as well as by Patrick et al. [82], Sepúlveda et al. [83], and Dobiesz et al. (2018) [84]. Almeida et al. (2023) [124], Briggs et al. (2023) [81], and Ionescu et al. (2022) [125] identified the lamprey *Petromyzon marinus* in *Acipenser fulvescens* in Lake Sturgeon, Canada.

3. Discussion

According to the literature, sturgeon fish are infected with various ecto- and endoparasite species that live in freshwater, marine areas, lakes, and fish farms. The most commonly reported microhabitats of fish hosts were external organs such as the gills, skin, and the surface of fins. The skin surface, gills, blood, eggs, intestines, gut, and digestive system were the most commonly infected sites (Table 2). Overall, the literature has recognized sturgeon parasite species to include Protozoa, Trematoda, Crustacea, Nematodes, Monogenea, Hirudinea, Copepoda, Acanthocephala, Cestoda, Polypodiozoa, and Hyperoartia (Lamprey).

Table 2. Parasites sites of infection.

Parasites	Infected Organs														
	G	**F**	**S**	**I**	**Eg**	**B**	**BL**	**E**	**GU**	**Ds**	**N**	**SP**	**H**	**T**	**Ca**
Protozoa	X	X	X	X		X	X	X	X	X	X				
Monogenea	X	X	X	X											
Acanthocephala				X										X	
Trematoda	X	X	X	X		X				X			X		X
Nematodes	X			X		X			X	X					
Copepoda	X	X	X			X									
Cestoda				X		X									
Polypodiozoa					X										
Hirudinea	X	X	X			X									
Hyperoartia (Lamprey)						X									

G gill, S skin, F fin, I intestine, E eye, SP Spleen, H heart, N nose, Eg eggs, B body, BL blood T testes, GU gut, Ga gastrointestinal, Ds digestive system.

By considering all taxonomic groups of parasites (Table 3) that have been the subject of studies concerning the occurrence and absence of parasites in different organs, it is presented in Figure 1 that the intestines are the most susceptible to infestation (30.49%). This is followed by the skin (21.95%), gills (18.29%), and fins (16.46%), while eggs (4.27%), blood (1.83%), and heart (0.61%) are the least susceptible to infestation.

Table 3. The taxonomy of parasites hosted by sturgeons.

Phylum	Class	Order	Family	Species
Ciliophora	Oligohymenophorea	Hymenostomatida	Ichthyophthiriidae	*Ichthyophthirius multifiliis* (Fouquet 1876)
Ciliophora	Oligohymenophorea	Mobilida	Triochodinidae	*Trichodina* sp. *Trichodina Ehrenberg*, 1830 and *Trichodina* (reticulata Hirschmann & Partsch, 1955)
Ciliophora	Oligohymenophorea	Peritrichida	Epistylididae	*Apiosoma* sp. (Blanchard, 1885)
Ciliophora	Oligohymenophorea	Sessilida	Epistylididae	*Epistylis* sp. (Ehrenberg, 1830)
Platyhelminthes	Trematoda	Diplostomida	Diplostomidae	*Diplostomum spathaceum* (Rudolphi, 1819), Olsson, 1876)
Platyhelminthes	Trematoda	Diplostomida	Schistosomatidae	*Schistosoma japonicum* (Katsurada, 1904)
Platyhelminthes	Trematoda	Plagiorchiida	Allocreadiidae	*Crepidostomum auriculatum* (Wedl, 1858) Lühe, 1909
Platyhelminthes	Trematoda	Plagiorchiida	Deropristidae	*Pristicola bruchi* (Choudhury, 2009)
Platyhelminthes	Trematoda	Diplostomida	Aporocotylidae	*Acipensericola glacialis* (Warren & Bullard, 2017)
Platyhelminthes	Trematoda	Plagiorchiida	Deropristidae	*Skrjabinopsolus semiarmatus* (Molin, 1858) Ivanov, 1937
Platyhelminthes	Trematoda	Diplostomata	Aporocotylidae	*Sanguinicola* sp. (Plehn, 1905)
Platyhelminthes	Trematoda	Diplostomida	Diplostomidae	*Posthodiplostomum* sp. (Dubois, 1936)
Platyhelminthes	Trematoda	Plagiorchiida	Allocreadiidae	*Crepidostomum auritum* (MacCallum, 1919)

Table 3. *Cont.*

Phylum	Class	Order	Family	Species
Platyhelminthes	Trematoda	Plagiorchiida	Allocreadiidae	*Crepidostomum oschmarini* (Zhokhov & Pugacheva, 1998)
Platyhelminthes	Trematoda	Plagiorchiida	Deropristidae	*Skrjabinopsolus nudidorsalis* (Ivanov, 1937)
Platyhelminthes	Monogenea (Monogenoidea)	Capsalidea	Capsalidae	*Nitzschia sturionis* (Abildgaard, 1794) Krøyer, 1852
Platyhelminthes	Monogenea (Monogenoidea)	Diclybothriidea	Diclybothriidae	*Diclybothriidae gen.* sp. (Bykhovskii and Gusev. 1950)
Platyhelminthes	Monogenea (Monogenoidea)	Diclybothriidea	Diclybothriidae	*Diclybothrium* sp. (Leuckart, 1835)
Platyhelminthes	Monogenea (Monogenoidea)	Dactylogyridea	Dactylogyridae	*Dactylogyrus* sp. (Diesing, 1850)
Platyhelminthes	Monogenea (Monogenoidea)	Diclybothriidea	Diclybothriidae	*Diclybothrium* sp. (Leuckart, 1835)
Platyhelminthes	Monogenea (Monogenoidea)	Dactylogyridea	Dactylogyridae	*Dactylogyrus* sp. (Diesing, 1850)
Platyhelminthes	Monogenea (Monogenoidea)	Diclybothriidea	Diclybothriidae	*Diclybothrium armatum* (Leuckart, 1835)
Platyhelminthes	Monogenea (Monogenoidea)	Diclybothriidea	Diclybothriidae	*Diclybothrium hatum* (Leuckart, 1835)
Platyhel mintes	Monogenea	Gyrodactylidea	Gyrodactylidae	Gyrodactylus sp. von Nordmann, 1832
Platyhelminthes	Monogenea	Diclybothriidea	Diclybothriidae	*Paradiclybothrium pacificum* (Bychowsky & Gusev, 1950)
Platyhelminthes	Monogenea	Capsalidea	Capsalidae	*Nitzchia* Gervais, 1846
Nematoda	Chromadorea	Rhabiditida	Cystidicolidae	*Capillospirura* sp. (Skrjabin, 1924)
Nematoda	Chromadorea	Rhabiditida	Cucullanidae	*Truttaedacnitis* (Cucullanus) (Müller, 1777)
Nematoda	Chromadorea	Rhabiditida	Cucullanidae	*Cucullanus sphaerocephlaus* (Rudolphi, 1809) Baylis, 1939
Nematoda	Chromadorea	Rhabiditida	Anisakidae	Anisakis sp. (Dujardin, 1845)
Nematoda	Enoplea	Dioctophymatida	Dioctophymatidae	*Eustrongylides excisus* (Jägerskiöld, 1909)
Nematoda	Chromadorea	Rhabiditida	Raphidascarididae	*Raphidascaris acus* (Bloch, 1779) Railliet & Henry, 1915
Nematoda	Enoplea	Trichinellida	Cystoopsidae	*Cystoopsis acipenseri* (Wagner, 1867)
Nematoda	Chromadorea	Rhabiditida	Anisakidae	*Contracaecum bidentatum* (Ward & Magath, 1917)
Nematoda	Chromadorea	Rhabiditida	Anisakidae	*Contracaecum sinipercae* (Dogiel & Achmerov, 1946)
Nematoda	Chromadorea	Rhabiditida	Cystidicolidae	*Spinitectus gracilis* Fourment, 1883
Myzozoa	Conoidasida	Eucoccidiorida	Eimeriidae	*Goussia vargai* Cynthia R., Blazer, Vicki S. (2019)
Myzozoa	Conoidasida	Eucoccidiorida	Eimeriidae	*Goussia acipensris* (labbe 1896)
Myzozoa	Conoidasida	Eucoccidiorida	Haemogregarinidae	*Haemogregarina acipenseris* (Danilewsky, 1885)

Table 3. *Cont.*

Phylum	Class	Order	Family	Species
Euglenozoa	Kinetoplastea	Eubodonida	Cryptobiaceae	*Cryptobia acipenseris* (Joff, Lewashow, Boschenko, 1926)
Euglenozoa	Kinetoplastea	Prokinetoplastida	Bodonidae	*Ichthyobodo necatrix* (Henneguy, 1883)
Annelida	Clitellata	Rhynchobdellida	Piscicolidae	*Limnotrachelobdella* sp. (Epshtein, 1968)
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Placobdella montifera* (Moore, 1906)
Annelida	Clitellata	Rhynchobdellida	Piscicolidae	*Acipenserobdella volgensis* (Epstein, 1969)
Annelida	Clitellata	Rhynchobdellida	Piscicolidae	*Piscicola geometra* (Linnaeus, 1761)
Arthropoda	Copepoda	Cyclopoida	Ergasilidae	*Ergasilus* sp. (Nordmann, 1832)
Arthropoda	Copepoda	Cyclopoida	Lernaeidae	*Lernaea cyprinacea* (Linnaeus, 1758)
Arthropoda	Copepoda	Siphonostomatoida	Lernaeopodidae	*Pseudotracheliastes stellatus* (Mayor, 1824)
Arthropoda	Ichthyostraca	Arguloida	Argulidae	*Argulus foliaceus* (Linnaeus, 1758)
Arthropoda	Ichthyostraca	Arguloida	Argulidae	*Argulus* sp. (Müller O.F., 1785)
Arthropoda	Ichthyostraca	Arguloida	Argulidae	*Argulus flavescens* (Wilson C.B., 1916)
Arthropoda	Ichthyostraca	Arguloida	Argulidae	*Argulus stizostethii* (Kellicott, 1880)
Arthropoda	Copepoda	Siphonostomatoida	Caligidae	*Caligus elongatus* (von Nordmann, 1832)
Arthropoda	Copepoda	Siphonostomatoida	Dichelesthiidae	*Dichelesthium oblongum* (Abildgaard, 1794)
Arthropoda	Copepoda	Siphonostomatoida	Lernaeopodidae	*Tracheliastes gigas* Richiardi, 1881, Pseudotracheliastes stellatus (Mayor, 1824)
Platyhelminthes	Cestoda	Amphilinidea	Amphilinidae	*Amphilina* sp. (Wagener, 1858)
Platyhelminthes	Cestoda	Amphilinidea	Amphilinidae	*Amphilina foliacea* (Rudolphi, 1819) Wagener, 1858
Platyhelminthes	Cestoda	Spathebothriidea	Acrobothriidae	*Bothrimonus fallax* (Lühe, 1900)
Platyhelminthes	Cestoda	Amphilinidea	Amphilinidae	*Amphilina japonica* (Goto & Ishii, 1936)
Platyhelminthes	Cestoda	Bothriocephalidea	Triaenophoridae	*Eubothrium acipenserinum* (Cholodkovsky, 1918) Dogiel & Bychowsky, 1939
Annelida	Clitellata	Rhynchobdellida	Piscicolidae	*Caspiobdella fadejewi* (Epshtein, 1961)
Annelida	Clitellata	Rhynchobdellida	Piscicolidae	*Calliobdella vivida* (=Cystobranchus vividus) (Verrill, 1872)
Acanthocephala	Palaeacanthocephala	Echinorhynchida	Leptorhynchoididae	*Leptorhynchoides polycristatus* (Amin, Heckmann, Halajian, El-Naggar & Tavakol, 2013)
Acanthocephala	Palaeacanthocephala	Echinorhynchida	Paracanthocephalidae	*Acanthocephalus anguillae* (Müller, 1780)
Acanthocephala	Palaeacanthocephala	Echinorhynchida	Pomphorhynchidae	*Pomphorhynchus bosniacus* (Kistaroly & Cankovic, 1969)

Table 3. *Cont.*

Phylum	Class	Order	Family	Species
Acanthocephala	Palaeacanthocephala	Echinorhynchida	Leptorhynchoididae	*Leptorhynchoides plagicephalus* (Westrumb, 1821)
Chordata	Petromyzonti	Petromyzontiformes	Petromyzontidae	Petromyzon marinus (Linnaeus, 1758)
Ciliophora	Phyllopharyngea	Chlamydodontida	Chilodonellidae	*Chilodonella* sp. (Strand, 1928)
Cnidaria	Polypodiozoa	Polypodiidea	Polypodiidae	*Polypodium hydriforme* (Ussow, 1887)

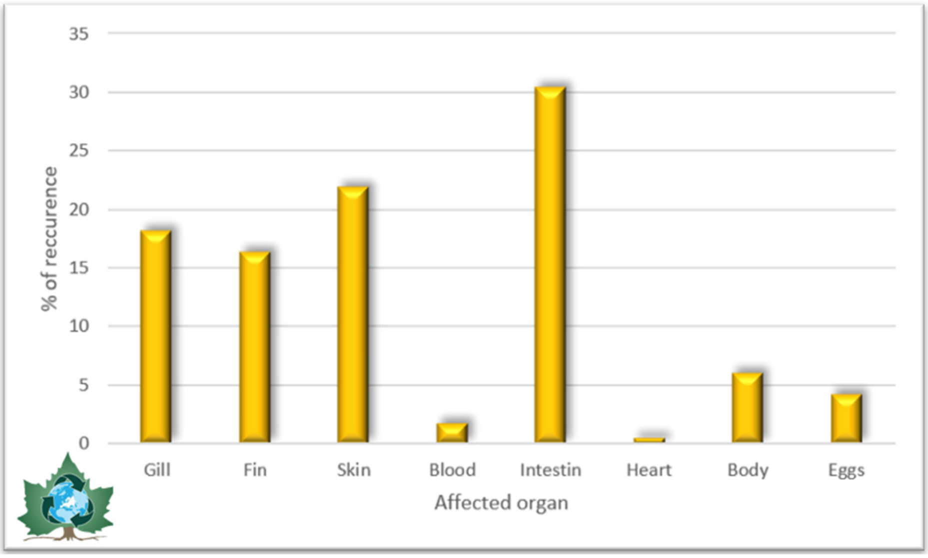

Figure 1. Percentage of parasite recurrence by affected organs (all taxonomic groups).

Figure 2 shows that the majority of identifications in the studies have been attributed to protozoa (21%), followed by monogeneans (15%), copepods (14%), cestodes (10%), crustaceans (9%), trematodes (8%), nematodes (7%), hirudines (6%), acanthocephalans (5%), and polypodiozoa (4%). The Hyperoartia group is recorded as having the lowest percentage of identified infestations, at 1%. However, these statistics do not reflect the real in situ scenario, where percentages can vary substantially; rather, they indicate the level of parasite identification based on the literature.

Considering the extent of infestation manifested by various organs of sturgeons in accordance with each taxonomic group of parasites, the scientific literature provides the subsequent data, also presented in the chart in Figure 3:

Protozoa affects the skin the most (48.57%), followed by the fins (22.86%), gills (20%), and blood (8.57%). No species of this group were identified in the intestines, heart, or eggs of sturgeons.

Monogenea affects the skin the most (36%), followed equally by the gills and fins (32%). No species of this group were documented in other organs in sturgeons.

Crustacea affects the skin, gills and fins equally (31.25%), followed by the intestines (6.25%). There were no species of this taxonomic group documented or identified in the blood, heart, or eggs of sturgeons.

Trematoda affects mostly the intestines (92.86%), followed by the heart (7.14%). No species of this group were identified in the gills, fins, skin, blood, or eggs of sturgeons.

Copepoda affects the gills the most (37.5%), followed by the fins and skin equally (25%). The rest of the studies document the infestation of the body as a whole by this group of parasites, while there are no studies about the recurrence of infestation in the blood, intestines, heart, or eggs of sturgeon species.

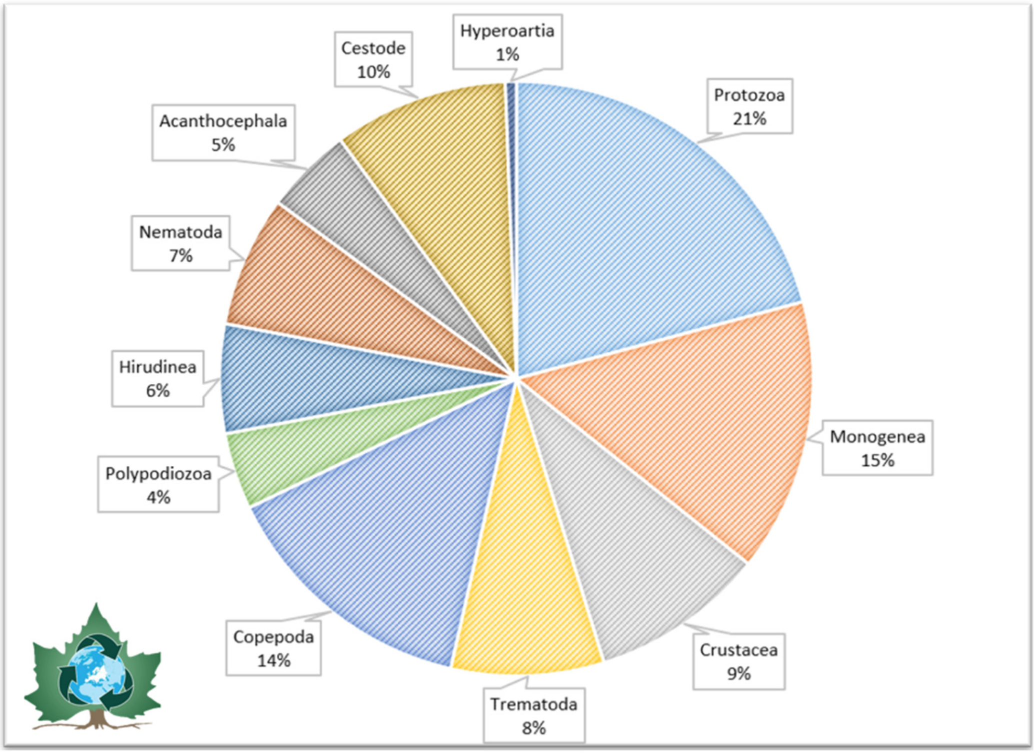

Figure 2. Percentage of parasite taxonomic group identification in sturgeon species, based on the reviewed scientific literature.

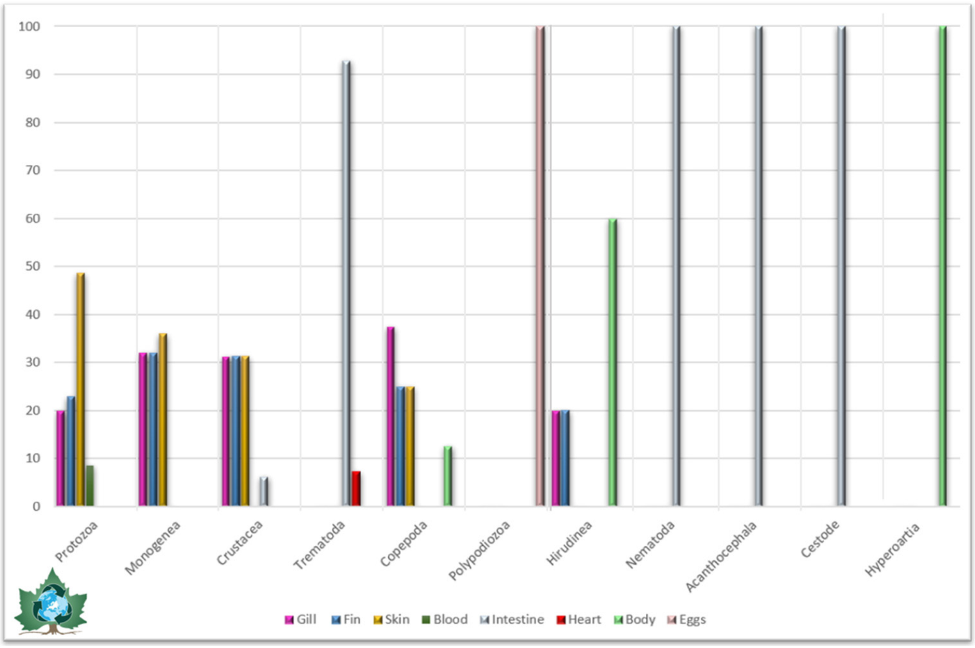

Figure 3. Percentage of infestation of each parasite taxonomic group on different organs.

Polypodiozoa species were only identified and documented in the eggs of sturgeons.

Hirudinea species were mostly documented to affect the body as a whole (60%), while 20% of studies identify these parasites in either the gills or fins of sturgeons.

Nematoda species were only identified in the intestines of sturgeon species.

Acanthocephala species were only documented in the intestines of sturgeons.

Cestoda species were only identified in the intestines of sturgeons.

Hyperoartia species were only documented in the body of sturgeons as a whole, with no particular specifications.

4. Conclusions

According to the studies, it may be concluded that among the organs of the sturgeon, the intestines are the most prone to parasite infestation, while the blood seems to be the least affected by parasites.

Considering the scientific community's present understanding, most recorded instances of infestation are attributed to protozoa, whereas the group Hyperoartia has the least amount of evidence available.

Furthermore, according to current research, each taxonomic group of parasites exhibits selectivity in terms of the sturgeon organs they target. Nevertheless, the provided statistics are based on the existing level of knowledge, and further research is necessary to gain a more thorough understanding of the impact of each parasite group on sturgeons, which are currently in a critical conservation status globally.

Despite the incomplete understanding of the diversity of parasite species that affect sturgeons, there is less research regarding their ecology, distribution, and prevalence. It is striking that there is currently a lack of scientific focus on understanding the biology and ecology of potentially harmful parasites. Despite a few comprehensive studies on the topic, which have relied solely on the enthusiasm and research efforts of individual scientists, there has been minimal motivation to structure these studies in a more systematic manner.

It is recommended that national and international organizations facilitate more structured research programs regarding fish parasites, especially regarding endangered fish species. These should be designed to allow trend analysis of changes in the parasitic fauna of fishes, such as sturgeons, in the face of environmental changes.

Furthermore, in aquaculture, diseases will continue to play an important role in the economic performance of the industry. Therefore, it is highly recommended that studies be supported and systematically organized to assist in preventing the loss of cultured stock while also preventing aquaculture from becoming a potential reservoir for parasites and disease agents affecting natural stocks.

Time and resources are required to better address the study of parasites that influence sturgeon species from the standpoints of biodiversity monitoring and reducing the risk of disease transmission in natural habitats and aquaculture farms.

Author Contributions: Conceptualization, G.D. and A.J.; methodology, A.J. and E.H.; software, I.S.; validation, G.D.; formal analysis, G.D. and I.S.; investigation, A.J.; resources, G.D.; data curation, G.D.; writing—original draft preparation, A.J.; writing—review and editing, A.J. and E.H.; visualization, G.D.; supervision, G.D.; project administration, G.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are openly available and can be found online by searching all the scientific articles cited.

Acknowledgments: The authors would like to thank Daniela VASILE, Furhan T. Mhaisen, Atheer H. Ali and Cristian-Emilian Pop. for their support and considerations.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gardiner, B.G. Sturgeons as Living Fossils. In *Living Fossils*; Springer: New York, NY, USA, 1984; pp. 148–152. [CrossRef]
2. Bemis, W.E.; Kynard, B. Sturgeon rivers: An introduction to acipenseriform biogeography and life history. *Environ. Biol. Fishes* **1997**, *48*, 167–183. [CrossRef]
3. Schmutz, S.; Moog, O. Dams: Ecological impacts and management. In *Riverine Ecosystem Management: Science for Governing towards a Sustainable Future*; University of Amsterdam: Amsterdam, The Netherlands, 2018; pp. 111–127.

4. Birstein, V.J.; Bemis, W.E. How many species are there within the genus Acipenser? *Environ. Biol. Fishes* **1997**, *48*, 157–163. [CrossRef]
5. Raischi, M.; Deák, H.G.; Oprea, L.; Raischi, N.; Dănălache, T.; Matei, S. The impact of anthropogenic pressures on sturgeon migration in the Lower Danube. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2020; p. 012030.
6. Raischi, M.C.; Deak, G.; Oprea, L. Research on the Monitoring of Sturgeon Populations by Telemetry Techniques in the Lower Danube Sector of Braila-Călărasi. Ph.D Thesis, Dunarea de Jos University of Galati, Galați, Romania, 2019.
7. Williot, P. *Reproduction de L'esturgeon Sibérien (Acipenser baeri Brandt) en Élevage: Gestion des Génitrices, Compétence à la Maturation In Vitro de Follicules Ovariens et Caractéristiques Plasmatiques Durant L'induction de la Ponte*; Université Bordeaux I: Bordeaux, Franch, 1997; pp. 1–227.
8. Birstein, V.J.; Bemis, W.E.; Waldman, J.R. The threatened status of acipenseriform species: A summary. *Sturgeon Biodivers. Conserv.* **1997**, *48*, 427–435. [CrossRef]
9. KayiŞ, Ş.; SoykÖSe, G.; İPek, Z.Z.; Er, A. Türkiye'nin Doğu Karadeniz Bölgesinde Bulunan Bazı Alabalık Çiftliklerinin Kuluçkahanelerinde Bakteri Kontaminasyonu ve Bakterilerin Antibiyotik Direncinin Belirlenmesi. *J. Limnol. Freshw. Fish. Res.* **2021**, *7*, 101–107. [CrossRef]
10. Radosavljević, V.; Milićević, V.; Maksimović-Zorić, J.; Veljović, L.; Nešić, K.; Pavlović, M.; Ljubojević Pelić, D.; Marković, Z. Sturgeon diseases in aquaculture. *Arch. Vet. Med.* **2019**, *12*, 5–20. [CrossRef]
11. Cakić, P.; Đikanović, V.; Kulišić, Z.; Paunović, M.; Jakovčev-Todorović, D.; Milošević, S. The fauna of endoparasites in Acipenser ruthenus Linnaeus, 1758 from the Serbian part of the Danube River. *Arch. Biol. Sci.* **2008**, *60*, 103–107. [CrossRef]
12. Bazari Moghaddam, S.; Mokhayer, B.; Masoumian, M.; Shenavar Masouleh, A.; Jalilpour, J.; Masoumzadeh, M.; Alizadeh, M. Parasitic infection among larvae and fingerlings of the Persian sturgeon (*Acipenser persicus*) in Vniro tanks and earthen ponds. *Iran. J. Fish. Sci.* **2010**, *9*, 342–351.
13. Abdulhusein, G.; Ramteke, P. Investigations on parasitic diseases in fish of river Yamuna during the summer season. *European Academic Research* **2014**, *2*, 10057–10097.
14. Rogin, R.E. Conservation and sustainable use of wild sturgeon populations of the NW Black Sea and Lower Danube River in Romania. Master's Thesis, Institutt for Biologi, Trondheim, Norway, 2011; pp. 1–57.
15. Savickiy, J.; Alishova, Z. Infectious and parasitic diseases of sturgeon fish. In Proceedings of the Теория и практика современной аграрной науки, Novosibirsk, Russia, 28 February 2022; pp. 1264–1267.
16. Kuperman, B. Fish parasites as bioindicators of the pollution of bodies of water. *Parazitologiia* **1992**, *26*, 479–482.
17. Palm, H.W.; Kleinertz, S.; Rueckert, S. Parasite diversity as an indicator of environmental change? An example from tropical grouper (*Epinephelus fuscoguttatus*) mariculture in Indonesia. *Parasitology* **2011**, *138*, 1793–1803. [CrossRef]
18. Barber, I. Parasites, behaviour and welfare in fish. *Appl. Anim. Behav. Sci.* **2007**, *104*, 251–264. [CrossRef]
19. Chebanov, M.S.; Galich, E.V. Sturgeon hatchery manual. *FAO Fish. Aquac. Tech. Pap.* **2011**, *558*, 1–17.
20. Vasile, D. Evidence of ichthyophthiriasis in cultured Acipenser stellatus (Pallas 1771). *Acad. Rom. Sci. Ann.-Ser. Biol. Sci.* **2019**, *8*, 17–23.
21. Popielarczyk, R.; Kolman, R. Preliminary analysis of ectoparasites of the sturgeon Acipenser oxyrinchus oxyrinchus (Mitchill, 1815) originating from different water habitats. *Ann. Parasitol.* **2013**, *59*, 139–141. [PubMed]
22. Pazooki, J.; Masoumian, M. Cryptobia acipenseris and Haemogregarina acipenseris infections in Acipenser guldenstadti and A. persicus in the Southern part of the Caspian Sea. *J. Agric. Sci. Technol.* **2018**, *6*, 95–101.
23. Mohler, J.W.; King, M.K.; Farrell, P.R. Growth and survival of first-feeding and fingerling Atlantic sturgeon under culture conditions. *N. Am. J. Aquac.* **2000**, *62*, 174–183. [CrossRef]
24. Kayiş, Ş.; Er, A.; Kangel, P.; Kurtoğlu, İ. Bacterial pathogens and health problems of Acipenser gueldenstaedtii and Acipenser baerii sturgeons reared in the eastern Black Sea region of Turkey. *Iran. J. Vet. Res.* **2017**, *18*, 18. [PubMed]
25. Adel, M.; Safari, R.; Yaghoubzadeh, Z.; Fazli, H.; Khalili, E. Parasitic infection in various stages life of cultured Acipenser persicus. In *Veterinary Research Forum*; Faculty of Veterinary Medicine, Urmia University: Urmia, Iran, 2016; p. 73.
26. Moghaddam, S.B. Study on internal helminthes parasites in Persian sturgeon (Acipenser persicus) spawners in southwest coasts of the Caspian Sea (2009–2011). *Life Sci. J.* **2013**, *10*, 12–16.
27. Matsche, M.A.; Flowers, J.R.; Markin, E.L.; Stence, C.P. Observations and Treatment of Nitzschia sturionis on Atlantic Sturgeon from Chesapeake Bay. *J. Aquat. Anim. Health* **2010**, *22*, 174–181. [CrossRef] [PubMed]
28. Baska, F. The pathology of parasitic infections in mature sterlets (*Acipenser ruthenus*) and their importance in propagation. *J. Appl. Ichthyol.* **1999**, *15*, 287. [CrossRef]
29. Barzegar, M.; Raissy, M.; Shamsi, S. Protozoan Parasites of Iranian Freshwater Fishes: Review, Composition, Classification, and Modeling Distribution. *Pathogens* **2023**, *12*, 651. [CrossRef]
30. Liberman, E.; Voropaeva, E. The parasitofauna of the Siberian sterlet Acipenser ruthenus marsiglii of the Lower Irtysh. *Regul. Mech. Biosyst.* **2018**, *9*, 329–334. [CrossRef]
31. Choudhury, A. A New Deropristiid Species (Trematoda: Deropristiidae) from the Lake Sturgeon Acipenser fulvescens in Wisconsin, and Its Biogeographical Implications. *J. Parasitol.* **2009**, *95*, 1159–1164. [CrossRef]

32. Warren, M.B.; Roberts, J.R.; Arias, C.R.; Koenigs, R.P.; Bullard, S.A. Acipensericola glacialis n. sp.(Digenea: Aporocotylidae) from heart of lake sturgeon Acipenser fulvescens Rafinesque (Acipenseriformes: Acipenseridae) in the Great Lakes basin, Lake Winnebago system, USA. *Syst. Parasitol.* **2017**, *94*, 875–889. [CrossRef]
33. Sattari, M.; Mokhayer, B.; Shafii, S. Parasitic worms of Persian sturgeon (Acipenser persicus Borodin, 1897) from the southwest of the Caspian Sea. *Bull.-Eur. Assoc. Fish Pathol.* **2006**, *26*, 131.
34. Lenhardt, M.; Jaric, I.; Cakic, P.; Cvijanovic, G.; Gacic, Z.; Kolarevic, J. Seasonal changes in condition, hepatosomatic index and parasitism in sterlet (*Acipenser ruthenus* L.). *Turk. J. Vet. Anim. Sci.* **2009**, *33*, 209–214. [CrossRef]
35. Atopkin, D.M.; Shedko, M.B. Genetic characterization of far eastern species of the genus Crepidostomum (Trematoda: Allocreadiidae) by means of 28S ribosomal DNA sequences. *Adv. Biosci. Biotechnol.* **2014**, *5*, 209–215. [CrossRef]
36. Choudhury, A. Systematics of the Deropristiidae Cable & Hunninen, 1942 (Trematoda) and biogeographical associations with sturgeons (Osteichthyes: Acipenseridae). *Syst. Parasitol.* **1998**, *41*, 21–39.
37. Sokolov, S.; Voropaeva, E.; Atopkin, D. A new species of deropristid trematode from the sterlet Acipenser ruthenus (Actinopterygii: Acipenseridae) and revision of superfamily affiliation of the family Deropristidae. *Zool. J. Linn. Soc.* **2020**, *190*, 448–459. [CrossRef]
38. Noei, M. Parasitic worms of Acipenser stellatus, A. gueldenstaedtii, A. nudiventris and Huso huso (Chondrostei: Acipenseridae) from the southwest shores of the Caspian Sea. *Casp. J. Environ. Sci.* **2011**, *9*, 257–266.
39. NOEI, M.R.; IBRAHIMOV, S.; SATTARI, M. Parasitic worms of the Persian sturgeon, Acipenser persicus Borodin, 1897 from the southwestern shores of the Caspian Sea. *Iran. J. Ichthyol.* **2015**, *2*, 287–295.
40. Fast, M.D.; Sokolowski, M.S.; Dunton, K.J.; Bowser, P.R. Dichelesthium oblongum (Copepoda: Dichelesthiidae) infestation in wild-caught Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus. *ICES J. Mar. Sci.* **2009**, *66*, 2141–2147. [CrossRef]
41. Gradil, A.M.; Wright, G.M.; Speare, D.J.; Wadowska, D.W.; Purcell, S.; Fast, M.D. The effects of temperature and body size on immunological development and responsiveness in juvenile shortnose sturgeon (*Acipenser brevirostrum*). *Fish Shellfish. Immunol.* **2014**, *40*, 545–555. [CrossRef]
42. Vasilean, I.; Cristea, V.; Dediu, L. Researches regarding the argulosis treatment to Huso huso juveniles with NaCl. *Lucr. Științifice-Univ. De Științe Agric. Și Med. Vet. Ser. Zooteh.* **2012**, *58*, 203–207.
43. Andres, M.J.; Higgs, J.M.; Grammer, P.O.; Peterson, M.S. Argulus from the Pascagoula River, MS, USA, with an emphasis on those of the threatened Gulf Sturgeon, Acipenser oxyrinchus desotoi. *Diversity* **2019**, *11*, 232. [CrossRef]
44. Sokolowski, M.; Allam, B.; Dunton, K.; Clark, M.; Kurtz, E.; Fast, M. Immunophysiology of Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus (Mitchill), and the relationship to parasitic copepod, Dichelesthium oblongum (Abilgaard) infection. *J. Fish Dis.* **2012**, *35*, 649–660. [CrossRef] [PubMed]
45. Matvienko, N.; Levchenko, A.; Danchuk, O.; Kvach, Y. Assessment of the occurrence of microorganisms and other fish parasites in the freshwater aquaculture of Ukraine in relation to the ambient temperature. *Acta Ichthyol. Et Piscat.* **2020**, *50*, 333–348. [CrossRef]
46. Piasecki, W. Redescription of Tracheliastes gigas Richiardi, 1881 from the type-specimens, and its relegation to synonymy with Pseudotracheliastes stellatus (Mayor, 1824) (Copepoda: Siphonostomatoida: Lernaeopodidae). *Syst. Parasitol.* **1993**, *25*, 153–157. [CrossRef]
47. Bauman, J.M.; Moerke, A.; Greil, R.; Gerig, B.; Baker, E.; Chiotti, J. Population status and demographics of lake sturgeon (Acipenser fulvescens) in the St. Marys River, from 2000 to 2007. *J. Great Lakes Res.* **2011**, *37*, 47–53. [CrossRef]
48. Brown, A. Life Cycle and Population Dynamics of the marine ectoparasite Dichelesthium oblongum (Copepoda: Dichelesthiidae) on Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus). Ph.D. Thesis, State University of New York at Stony Brook, New York, NY, USA, 2010.
49. Munroe, S.E.M.; Avery, T.S.; Shutler, D.; Dadswell, M.J. Spatial Attachment-Site Preferences of Macroectoparasites on Atlantic Sturgeons Acipenser oxyrinchus in Minas Basin, Bay of Fundy, Canada. *J. Parasitol.* **2011**, *97*, 377–383. [CrossRef]
50. Raikova, E.V. Polypodium hydriforme infection in the eggs of acipenseriform fishes. *J. Appl. Ichthyol.* **2002**, *18*, 405–415. [CrossRef]
51. Raikova, E.V.; Suppes, V.C.; Hoffman, G.L. The Parasitic Coelenterate, Polypodium hydriforme Ussov, from the Eggs of the American Acipenseriform Polyodon spathula. *J. Parasitol.* **1979**, *65*, 804. [CrossRef]
52. Matishov, G.; Kazarnikova, A. Analysis of the possible influence of fish parasites from the Tumnin River on fry of the Sakhalin sturgeon (Acipenser mikadoi, Hildendorf, 1892). In *Doklady Biological Sciences*; Springer: New York, NY, USA, 2009; p. 290.
53. Hoffman, G.L.; Raikova, E.; Yoder, W. Polypodium sp. (Coelenterata) found in North American sturgeon. *J. Parasitol.* **1974**, *60*, 548–550. [CrossRef]
54. Okamura, B.; Hartigan, A.; Long, P.F.; Ruggeri, P.; Smith-Easter, K.; Schooley, J.D. Epidemiology of *Polypodium hydriforme* in American Paddlefish. *J. Fish Dis.* **2020**, *43*, 979–989. [CrossRef]
55. Dick, T.A.; Holloway, H.L.; Choudhury, A. *Polypodium* sp. (Coelenterata) from Lake Sturgeon (Acipenser fulvescens Rafinesque) in the Prairie Region of Canada. *J. Parasitol.* **1991**, *77*, 483–484. [CrossRef]
56. Judd, T.M.; Tripp, S.J.; Herzog, D.P. Cause of increased size of *acipenseriform* eggs infected with *Polypodium hydriforme*. *J. Fish Biol.* **2022**, *100*, 1187–1194. [CrossRef]
57. Koshelev, V.N.; Ruban, G.; Shmigirilov, A. Spawning migrations and reproductive parameters of the kaluga sturgeon, H uso dauricus (Georgi, 1775), and A mur sturgeon, A cipenser schrenckii (B randt, 1869). *J. Appl. Ichthyol.* **2014**, *30*, 1125–1132. [CrossRef]

58. Mikodina, E.V.; Ruban, G.I. Current Data on Sakhalin Sturgeon Acipenser mikadoi (Acipenseridae, Acipenseriformes) Biology (Review). *Inland Water Biol.* **2021**, *14*, 722–731. [CrossRef]
59. Sepúlveda, M.S.; Stefanavage, T.; Goforth, R. First Record of a *Polypodium* sp. Parasitizing Eggs of Shovelnose Sturgeon from the Wabash River, Indiana. *J. Aquat. Anim. Health* **2010**, *22*, 36–38. [CrossRef]
60. Bolotov, I.N.; Maryinsky, V.V.; Palatov, D.M.; Kondakov, A.V.; Eliseeva, T.A.; Konopleva, E.S.; Gofarov, M.Y.; Vikhrev, I.V.; Bespalaya, Y.V. Host Range and Phylogenetic Position of Acipenserobdella volgensis (Zykoff, 1904) (Hirudinea: Piscicolidae) with a Global Checklist of Bivalve-Associated Fish Leeches. *Water* **2022**, *14*, 4010. [CrossRef]
61. Bielecki, A.; Kapusta, A.; Cichocka, J. Atlantic sturgeon, Acipenser oxyrinchus Mitchill, infected by the parasitic leech, Caspiobdella fadejewi (Epshtein) (Hirudinea; Piscicolidae), in the Drwęca River. *Arch. Pol. Fish.* **2011**, *19*, 87–93. [CrossRef]
62. Smith, D.; Taubert, B. New records of leeches (Annelida: Hirudinea) from the shortnose sturgeon (*Acipenser brevirostrum*) in the Connecticut River. *Proc. Helminthol. Soc. Wash.* **1980**, *47*, 147–148.
63. Appy, R.G.; Dadswell, M.J. Marine and estuarine piscicolid leeches (Hirudinea) of the Bay of Fundy and adjacent waters with a key to species. *Can. J. Zool.* **1981**, *59*, 183–192. [CrossRef]
64. Skóra, M.E.; Bogacka-Kapusta, E.; Morzuch, J.; Kulikowski, M.; Rolbiecki, L.; Kozłowski, K.; Kapusta, A. Exotic sturgeons in the Vistula Lagoon in 2011, their occurrence, diet and parasites, with notes on the fishery background. *J. Appl. Ichthyol.* **2018**, *34*, 33–38. [CrossRef]
65. Nasirov, A.; Bunyatova, K. Some peculiarities of the relationships between sturgeon of the Caspian Sea and their parasites. *J. Entomol. Zool. Stud.* **2017**, *5*, 395–399.
66. Skrjabina, E. *Helminths of Sturgeons*; Publishing house 'Nauka' M: Moscow, Russia, 1974; pp. 1–168.
67. Mikailov, T.; Buniatova, K.; Nasirov, A. The finding of the eggs of the nematode Eustrongylides excisus in true sturgeons of the Caspian Sea. *Parazitologiia* **1992**, *26*, 440–442.
68. Choudhury, A.; Nadler, S.A. Phylogenetic relationships of spiruromorph nematodes (Spirurina: Spiruromorpha) in North American freshwater fishes. *J. Parasitol.* **2018**, *104*, 496–504. [CrossRef]
69. Rajabpour, M.; Malek, M.; MacKenzie, K.; Aghlmandi, F. Helminth parasites of stellate sturgeon Acipenser stellatus Pallas, 1771 and Persian sturgeon Acipenser persicus Borodin, 1897 (Pisces: Acipenseridae) from the South–East Caspian Sea. *Parasitol. Res.* **2008**, *102*, 1089–1091. [CrossRef]
70. McCabe, G.T., Jr. Communications: Prevalence of the Parasite *Cystoopsis acipenseri* Nematoda) in Juvenile White Sturgeons in the Lower Columbia River. *J. Aquat. Anim. Health* **1993**, *5*, 313–316. [CrossRef]
71. Choudhury, A. Parasites of the Lake Sturgeon, *Acipenser fulvescens*: Systematics and Biogeography. Ph.D. Thesis, University of Manitoba, Winnipeg, MB, Canada, 1997.
72. Khajepour, F.; Paighambari, S.Y. Investigation of infected gill to Monogenea in Sturgeon at the Southern Part of the Caspian Sea. *Global Vet* **2013**, *10*, 285–287.
73. Rahmati Holasoo, H.; Marandi, A.; Ebrahimzadeh Mousavi, H.; Azizi, A. Study of the losses of Siberian sturgeon (Acipenser baerii) due to gill infection with Diclybothrium armatum in sturgeon farms of Qom and Mazandaran provinces. *J. Anim. Environ.* **2021**, *13*, 193–200.
74. Dobson, A.P.; May, R.M. The effects of parasites on fish populations—Theoretical aspects. *Int. J. Parasitol.* **1987**, *17*, 363–370. [CrossRef]
75. Amin, O.M.; Heckmann, R.A.; Halajian, A.; El-Naggar, A.M.; Tavakol, S. The description and histopathology of Leptorhynchoides polycristatus n. sp.(Acanthocephala: Rhadinorhynchidae) from sturgeons, Acipenser spp.(Actinopterygii: Acipenseridae) in the Caspian Sea, Iran, with emendation of the generic diagnosis. *Parasitol. Res.* **2013**, *112*, 3873–3882. [CrossRef]
76. Foata, J.P.; Dezfuli, B.S.; Pinelli, B.; Marchand, B. Ultrastructure of spermiogenesis and spermatozoon of Leptorhynchoides plagicephalus (Acanthocephala, Palaeacanthocephala), a parasite of the sturgeon Acipenser naccarii (Osteichthyes, Acipenseriformes). *Parasitol. Res.* **2004**, *93*, 56–63. [CrossRef]
77. Kuchta, R.; Pearson, R.; Scholz, T.; Ditrich, O.; Olson, P.D. Spathebothriidea: Survey of species, scolex and egg morphology, and interrelationships of a non-segmented, relictual tapeworm group (Platyhelminthes: Cestoda). *Folia Parasitol.* **2014**, *61*, 331–346. [CrossRef]
78. Brunanská, M.; Poddubnaya, L.G.; Xylander, W.E. A reinvestigation of spermiogenesis in Amphilina foliacea (Platyhelminthes: Amphilinidea). *Folia Parasitol.* **2013**, *60*, 43. [CrossRef]
79. Biserova, N.; Dudicheva, V.; Terenina, N.; Reuter, M.; Halton, D.; Maule, A.; Gustafsson, M. The nervous system of Amphilina foliacea (Platyhelminthes, Amphilinidea). An immunocytochemical, ultrastructural and spectrofluorometrical study. *Parasitology* **2000**, *121*, 441–453. [CrossRef]
80. Ibrahimov, S.; Mamedova, S. Ecological analysis of the fish cestode fauna of the mouth of Kura River. *J. V.N.Karazin Kharkiv Natl. Univ. Ser. Biol.* **2021**, *36*, 48–57. [CrossRef]
81. Briggs, A.S.; Chiotti, J.A.; Boase, J.C.; Hessenauer, J.M.; Wills, T.C. Incidence of lamprey marks on Lake Sturgeon (Acipenser fulvescens Rafinesque, 1817) in the St. Clair–Detroit River System: Implications for Sea Lamprey (Petromyzon marinus Linnaeus, 1758) effects. *J. Appl. Ichthyol.* **2021**, *37*, 677–686. [CrossRef]
82. Patrick, H.K.; Sutton, T.M.; Swink, W.D. Lethality of sea lamprey parasitism on lake sturgeon. *Trans. Am. Fish. Soc.* **2009**, *138*, 1065–1075. [CrossRef]

83. Sepúlveda, M.S.; Patrick, H.K.; Sutton, T.M. A single sea lamprey attack causes acute anemia and mortality in lake sturgeon. *J. Aquat. Anim. Health* **2012**, *24*, 91–99. [CrossRef]
84. Dobiesz, N.E.; Bence, J.R.; Sutton, T.; Ebener, M.; Pratt, T.C.; O'Connor, L.M.; Steeves, T.B. Evaluation of sea lamprey-associated mortality sources on a generalized lake sturgeon population in the Great Lakes. *J. Great Lakes Res.* **2018**, *44*, 319–329. [CrossRef]
85. McCabe, G.T., Jr. Frequency of Occurence of the Parasite Cystoopsis acipenseri in Juvenile White Sturgeon Acipenser transmontanus in the Lower Co1 mbia River. In *Status and Habitat Requirements of the White Sturgeon Populations in the Columbia River Downstream from Mcnary Dam*; International Atomic Energy Agency: Vienna, Austria, 1992; p. 365.
86. Margolis, L.; McDonald, T. Parasites of white sturgeon, Acipenser transmontanus, from the Fraser River, British Columbia. *J. Parasitol.* **1986**, *72*, 794–796. [CrossRef]
87. Choudhury, A.; Dick, T.A. Sturgeons (Chondrostei: Acipenseridae) and their metazoan parasites: Patterns and processes in historical biogeography. *J. Biogeogr.* **2001**, *28*, 1411–1439. [CrossRef]
88. MacMillan, J.R. Biological factors impinging upon control of external protozoan fish parasites. *Annu. Rev. Fish Dis.* **1991**, *1*, 119–131. [CrossRef]
89. Noga, E.J. Skin ulcers in fish: Pfiesteria and other etiologies. *Toxicol. Pathol.* **2000**, *28*, 807–823. [CrossRef]
90. Buchmann, K. Impact and control of protozoan parasites in maricultured fishes. *Parasitology* **2015**, *142*, 168–177. [CrossRef]
91. David Sibley, L. Invasion and intracellular survival by protozoan parasites. *Immunol. Rev.* **2011**, *240*, 72–91. [CrossRef]
92. Zargar, A.; Rahimi Afzal, Z.; Taheri Mirghaed, A.; Soltani, M.; Ebrahimzadeh Mousavi, H.A.; Mollaeian, H. Study of ectoparasite contamination of rainbow trout Oncorhynchus mykiss (Walbaum, 1792) in Aquatic Animal Health Research Center's farm, Faculty of Veterinary, University of Tehran. *J. Appl. Ichthyol. Res.* **2017**, *5*, 153–166.
93. Zilberg, D. Amoebic gill disease of marine fish caused by Neoparamoeba pemaquidensis. *Acta Zool. Sin.* **2005**, *51*, 554–556.
94. Dickerson, H.W. Ichthyophthirius multifiliis and Cryptocaryon irritans (phylum Ciliophora). *Fish Dis. Disorders. Vol. 1 Protozoan Metazoan Infect.* **2006**, *1*, 116–153.
95. Zhang, Q.; Xu, D.-H.; Klesius, P.H. Evaluation of an antiparasitic compound extracted from Galla chinensis against fish parasite Ichthyophthirius multifiliis. *Vet. Parasitol.* **2013**, *198*, 45–53. [CrossRef]
96. Matthews, R. Ichthyophthirius multifiliis Fouquet and ichthyophthiriosis in freshwater teleosts. *Adv. Parasitol.* **2005**, *59*, 159–241.
97. Hoffman, G.L. *Parasites of North American Freshwater Fishes*; Cornell University Press: Ithaca, NY, USA, 2019.
98. Molnár, K.; Székely, C.; Láng, M. *Field Guide to Warmwater Fish Diseases in Central and Eastern Europe, the Caucasus and Central Asia*; Food & Agriculture Org: Quebec, QC, Canada, 2019; pp. 1–128.
99. Modak, B.K.; Banerjee, P.; Basu, S. Studies on Identification, Prevalence and Intensity of Infestation of Trichodinid Ciliophorans (Protozoa: Ciliophora) in the Freshwater Edible Fishes of Purulia District, West Bengal. *Environ. Ecol.* **2021**, *39*, 38–41.
100. Li, M.; Wang, J.; Zhu, D.; Gu, Z.; Zhang, J.; Gong, X. Study of Apiosoma piscicola (Blanchard 1885) occurring on fry of freshwater fishes in Hongze, China with consideration of the genus Apiosoma. *Parasitol. Res.* **2008**, *102*, 931–937. [CrossRef]
101. Hansen, H.; Cojocaru, C.-D.; Mo, T.A. Infections with Gyrodactylus spp. (Monogenea) in Romanian fish farms: Gyrodactylus salaris Malmberg, 1957 extends its range. *Parasit Vectors* **2016**, *9*, 444. [CrossRef]
102. Matejusová, I.; Gelnar, M.; Verneau, O.; Cunningham, C.O.; Littlewood, D. Molecular phylogenetic analysis of the genus Gyrodactylus (Platyhelminthes: Monogenea) inferred from rDNA ITS region: Subgenera versus species groups. *Parasitology* **2003**, *127*, 603–611. [CrossRef]
103. Bakke, T.A.; Harris, P.D.; Cable, J. Host specificity dynamics: Observations on gyrodactylid monogeneans. *Int. J. Parasitol.* **2002**, *32*, 281–308. [CrossRef]
104. Hogans, W.E. Northern range extension record for Ergasilus labracis (Copepoda, Ergasilidae) parasitic on the striped bass (*Morone saxatilis*). *Crustaceana* **1985**, *49*, 97–98. [CrossRef]
105. Bari, I.P.M.; Gaikwad, J. Pathogenic cryptobia cataractae (redescribed) of fresh water fishes from masooli reser-voir, parbhani (M.S.). *Rev. Res.* **2019**, *1*, 11–14.
106. Becker, C. Haematozoa of fishes, with emphasis on north american. In *A Symposium on Diseases of Fishes and Shellfishes*; American Fisheries Society: Bethesda, MA, USA, 1970; p. 82.
107. Athanassopoulou, F.; Billinis, C.; Prapas, T. Important disease conditions of newly cultured species in intensive freshwater farms in Greece: First incidence of nodavirus infection in *Acipenser* sp. *Dis. Aquat. Org.* **2004**, *60*, 247–252. [CrossRef]
108. Heckmann, R. Eye fluke (*Diplostomum spathaceum*) of fishes from the upper Salmon River near Obsidian, Idaho. *Great Basin Nat.* **1983**, *43*, 675–683.
109. Palmieri, J.R.; Heckmann, R.A.; Evans, R.S. Life cycle and incidence of Diplostomum spathaceum Rudolphi (1819) (Trematoda: Diplostomatidae) in Utah. *Great Basin Nat.* **1976**, *36*, 6.
110. Pylkkö, P.; Suomalainen, L.R.; Tiirola, M.; Valtonen, E.T. Evidence of enhanced bacterial invasion during Diplostomum spathaceum infection in European grayling, *Thymallus thymallus* (L.). *J. Fish Dis.* **2006**, *29*, 79–86. [CrossRef]
111. Cable, R. On the systematic position of the genus Deropristis, of Dihemistephanus sturionis Little, 1930, and of a new digenetic trematode from a sturgeon. *Parasitology* **1952**, *42*, 85–91. [CrossRef]
112. Aibinu, I.E.; Smooker, P.M.; Lopata, A.L. Anisakis nematodes in fish and shellfish-from infection to allergies. *Int. J. Parasitol. Parasites Wildl.* **2019**, *9*, 384–393. [CrossRef]
113. Rahanandeh, M.; Rahanandeh, M.; Hallajian, A.; Avakh Keysami, M. Study of pathology of Diclobothrium armatum parasite in the gills of farmed Huso huso in Guilan. *J. Anim. Environ.* **2019**, *11*, 413–418.

114. Aghaee Moghadam, A.; Haghparast, S.; Pazooki, J.; Pouramini, M.; Darvish Bastami, K. Prevalence of helminth and nematode parasites in digestive tract, skin surface and blood of Sturgeon broodstocks from southeast of the Caspian Sea. *J. Anim. Res. Iran. J. Biol.* **2014**, *27*, 1–12.
115. Sattari, M. Parasites of stellate sturgeon (*Acipenser stellatus*) from south-west of Caspian Sea. *Casp. J. Environ. Sci.* **2003**, *1*, 53–60.
116. Suárez-Morales, E.; Kim, I.-H.; Castellanos, I. A new geographic and host record for Argulus flavescens Wilson, 1916 (Crustacea, Arguloida), from southeastern Mexico. *Bull. Mar. Sci.* **1998**, *62*, 293–296.
117. Bauer, O.; Pugachev, O.; Voronin, V. Study of parasites and diseases of sturgeons in Russia: A review. *J. Appl. Ichthyol.* **2002**, *18*, 420–429. [CrossRef]
118. Bozorgnia, A.; Sharifi, N.; Youssefi, M. Acipenser stellatus as a new host record for Lernaea cyprinacea linnaeus, 1758 (crustacea; copepoda), a parasites of freshwater fishes in Iran. *J Aquac Mar Biol* **2018**, *7*, 123–125.
119. Bielecki, A. Fish leeches of Poland in relation to the Palaearctic piscicolines [Hirudinea: Piscicolidae: Piscicolinae]. *Genus. Int. J. Invertebr. Taxon.* **1997**, *8*, 223–375.
120. Nesemann, H.; Neubert, E. *6/2: Annelida, Clitellata: Branchiobdellida, Acanthobdellea, Hirudinea*; Spektrum: Heidelberg, Germany, 1999; p. 187.
121. Raikova, E. The nervous system of parasitic cnidarian Polypodium hydriforme. *Cell and Tissue Biol.* **2013**, *7*, 458–464. [CrossRef]
122. Chang, E.S. Transcriptomic Evidence That Enigmatic Parasites Polypodium Hydriforme and Myxozoa are Cnidarians. Ph.D. Thesis, University of Kansas, Lawrence, KS, USA, 2013.
123. Habil, G.D.; Holban, E.; Jawdhari, A.; Sadîca, I. Review on Polypodium Hydriforme Infestation of Sturgeon Eggs and Its Implications in Species Conservation. In *E3S Web of Conferences*; EDP Sciences: Les Ulis, France, 2023; p. 02007.
124. Almeida, P.R.; Mateus, C.S.; Alexandre, C.M.; Pedro, S.; Boavida-Portugal, J.; Belo, A.F.; Pereira, E.; Silva, S.; Oliveira, I.; Quintella, B.R. The decline of the ecosystem services generated by anadromous fish in the Iberian Peninsula. *Hydrobiologia* **2023**, *850*, 2927–2961. [CrossRef]
125. Ionescu, R.A.; Mitrovic, D.; Wilkie, M.P. Disturbances to energy metabolism in juvenile lake sturgeon (Acipenser fulvescens) following exposure to niclosamide. *Ecotoxicol. Environ. Saf.* **2022**, *229*, 112969. [CrossRef]