Versión en español

CLASS BRANCHIURA

Order Arguloida

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1. Brief characterization of the group and main diagnostic characters

The (sub)class Branchiura is a group of primarily freshwater parasitic crustaceans. They are obligate parasites and utilize many different fish hosts from a wide range of families, e.g. carps, sticklebacks, perch, roach, and even predators such as pike. The only genus found in Europe is *Argulus* with a maximum of three species. in the Ibero-macronesian area the most likely species to encounter are *A. foliaceus* and *A. japonicus* (Note: there is a slight possibility of encountering a third species; *A. coregoni* which is significantly larger; the species is considered boreal by some authors, but the southern range limit of this species has not been 100% determined: This species is significantly bigger, and can be recognized by sharply pointed abdominal lobes vs. rounded in the two other species, Fig. 1). Member of the two relevant species *A. foliaceus* and *A. japonicus* species range from 2 to ca. 12 mm in length as adults, are dorso-ventrally flattened, equipped with four pairs of thoracopods for swimming and a set of specialized first maxillae (termed “suction discs”) for adhesion to the host surface (Fig. 3A,E, 4A,C). The colour can vary but typically they are transparent with a greenish tint. Presence of paired compound eyes always sets Branchiurans apart from any freshwater parasitic Copepoda, which makes the identification of the genus easy under field conditions (general body shape, four pairs of thoracopods, suction discs, paired compound eyes). However, to separate *A. foliaceus* from the invasive *A. japonicus* the aid of at least a dissection microscope is needed. There are only two main characteristics, usable for both sexes of both species: the shape and setulation of the abdomen, and the depth of the abdominal incision (Fig. 1). One or two keys suggest using the posterior extension of the carapace in a dorsal view as a way of separating the two species; in *A. foliaceus* the caparace normally does not cover the fourth pair of thoracopods, whereas in *A. japonicus* it covers all four. However, this character is not always usable when analyzing fixed material due to shrinkage of the carapace lobes, leading to misidentification. Gender specific characteristics are more obvious, the male “claspers” differ significantly between the species, but adult females can be very difficult to separate (Fig. 2).

1.1. Morphology (Fig. 3 and 4)

Ca. 2-12 mm long, dorso-ventrally flattened, transparent to greenish-tint, four pairs of thoracopods typically extending beyond the ovoid bi-lobed carapace, unsegmented two-lobed abdomen carrying small furcal rami close to the anal opening. Paired compound eyes present, first and second antennae small and situated closely together, equipped with hooks, first maxillae developed into stalked “suction discs” clearly visible, second maxillae more appendage like, with distal hooks. Mouth situated on a proboscis (or mouth cone) which fully includes the mandibles. Pre-oral spine (non-feeding) situated in front of the mouth cone, between then suction discs. Sexes mostly alike, females recognizable by presence of bright yellow eggs in the ovaries at maturity. Males recognizable (at maturity) by visible testes extending into the abdominal lobes. Members of both species hatch as metanauplii (swimming with the A2 and Md. Palps), but after the first moult, these structures are lost / reduced (Fig. 3D, F, G, 4D). Juveniles can only be separated under the dissection microscope.

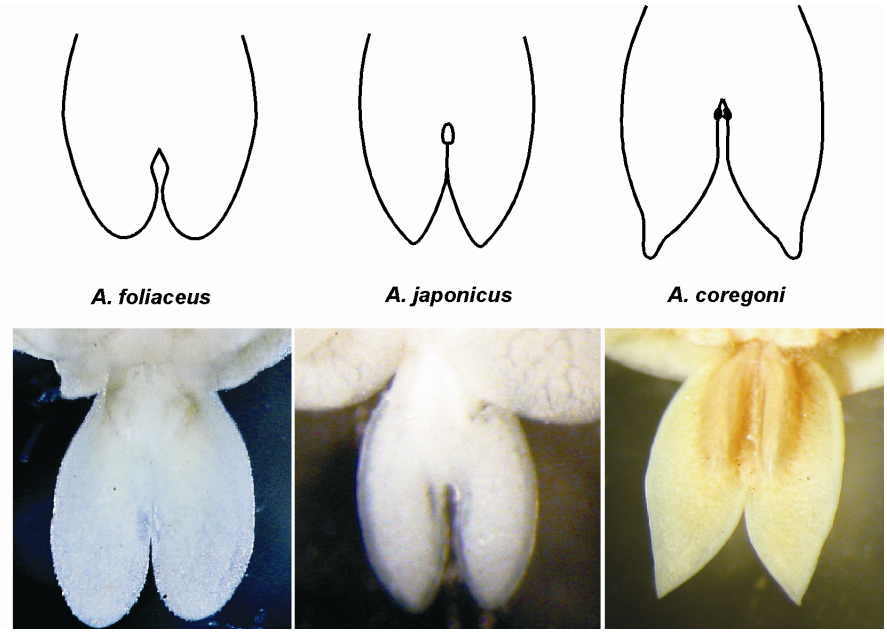

Figure 1. Abdomina from the three European species of *Argulus*. Line drawings & light microscopy. From left to right, *Argulus foliaceus*, *A. japonicus*, *A. coregoni*. Light microscopic images show fixed material / museum material stored in ethanol. Not natural colours. Partly modified from: Stressemann, E: Exkursionsfauna, Wirbellose I, 1970, Volk und Wissen Volkseigener Verlag Berlin. Photos by the author.

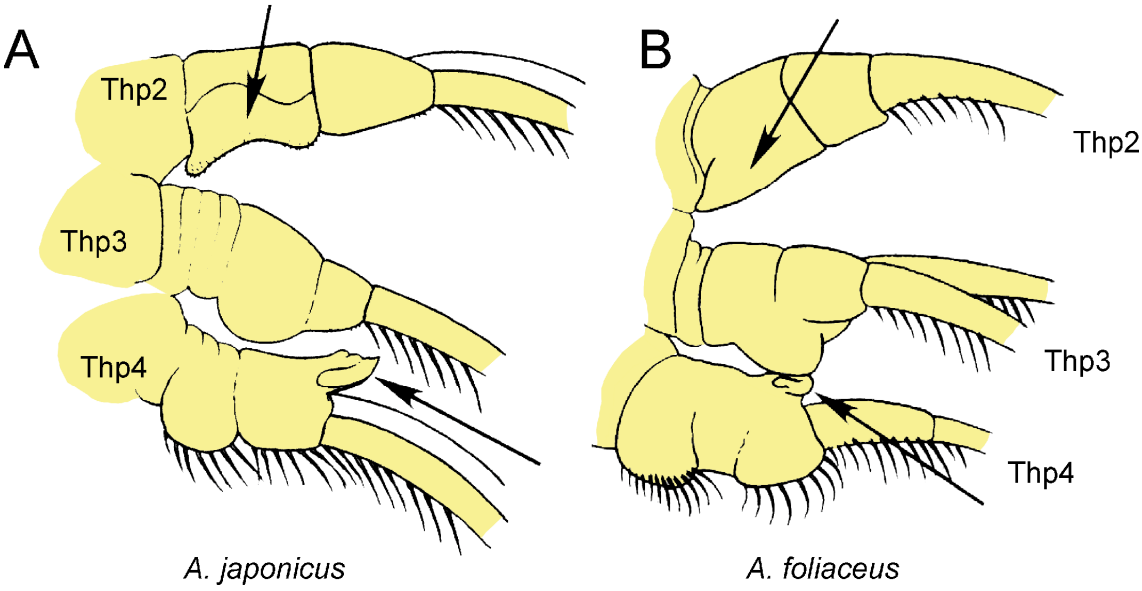

Figure 2. Line drawings. **A**: *A. japonicus*. **B**: *A. foliaceus*. Male claspers on thoracopods two and four. Arrows point to specific areas of differences to notice. Modified from Soes *et al*. (2010), with permission of the publisher E. Mauch (*Lauterbornia*).

1.2. Natural History

Branchiurans in general are not particularly host specific. They are primarily found in standing fresh water, typically lakes and wetlands, but a few (< five) species are marine. Argulids can sometimes also be encountered immediately downstream of lakes, but the life cycle is not completed in running waters. The ibero-macronesian species *A. foliaceus* and *A. japonicus* are primarily fresh water animals, but they can survive brakish waters as well (known examples from the Baltic Sea). After the copulation (taking place mostly on the host), the female leaves the host and deposits the eggs (probably fertilizing them as they leave, but this is not 100% known) on flat surfaces in the lake, e.g. rocks, submerged leaves etc. (Fig. 3B, C, 4B). Each female can lay as many as 200 eggs, and the protein covering quickly turns the egg strands darkish yellow / brownish, and they are very robust with strong adhesion to the substrate. The larvae hatch

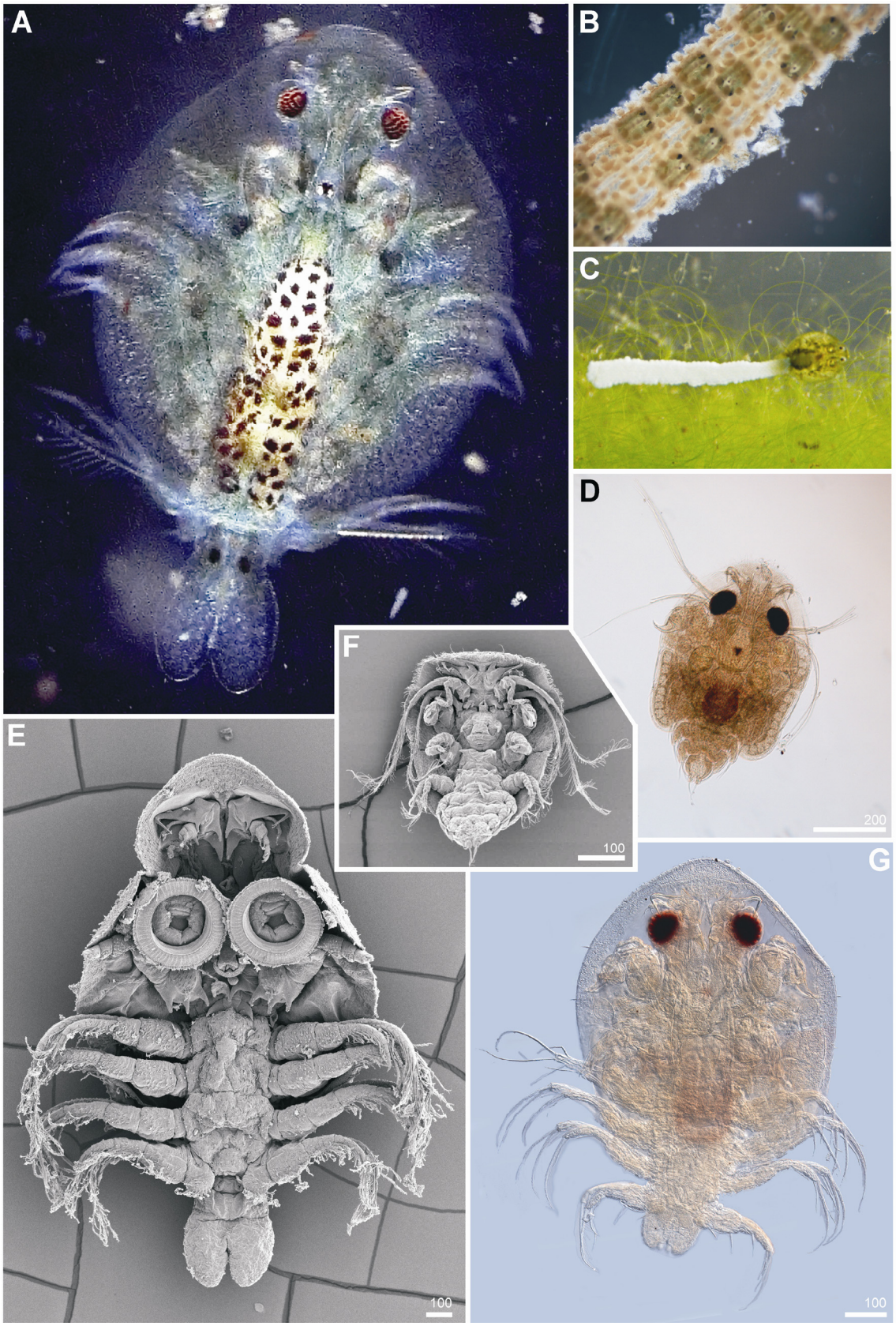

Figure 3. *Argulus foliaceus*. light microscopy & Scanning Electron Micrographs. **A**: Adult female, habitus, dorsal view. **B**: String of eggs with developing metanauplii, note the developed pigments in the compound eyes. **C**: A female during the process of egg-deposition. Taken on the viewing glass in a public aquarium. **D**: Stage I larva, metauplius, habitus. **E**: Young adult / late juvenile female, ventral view, SEM. **F**: Stage I larva, metanauplius, SEM. **G**: Stage II larva, stitched from multiple exposures, LM.

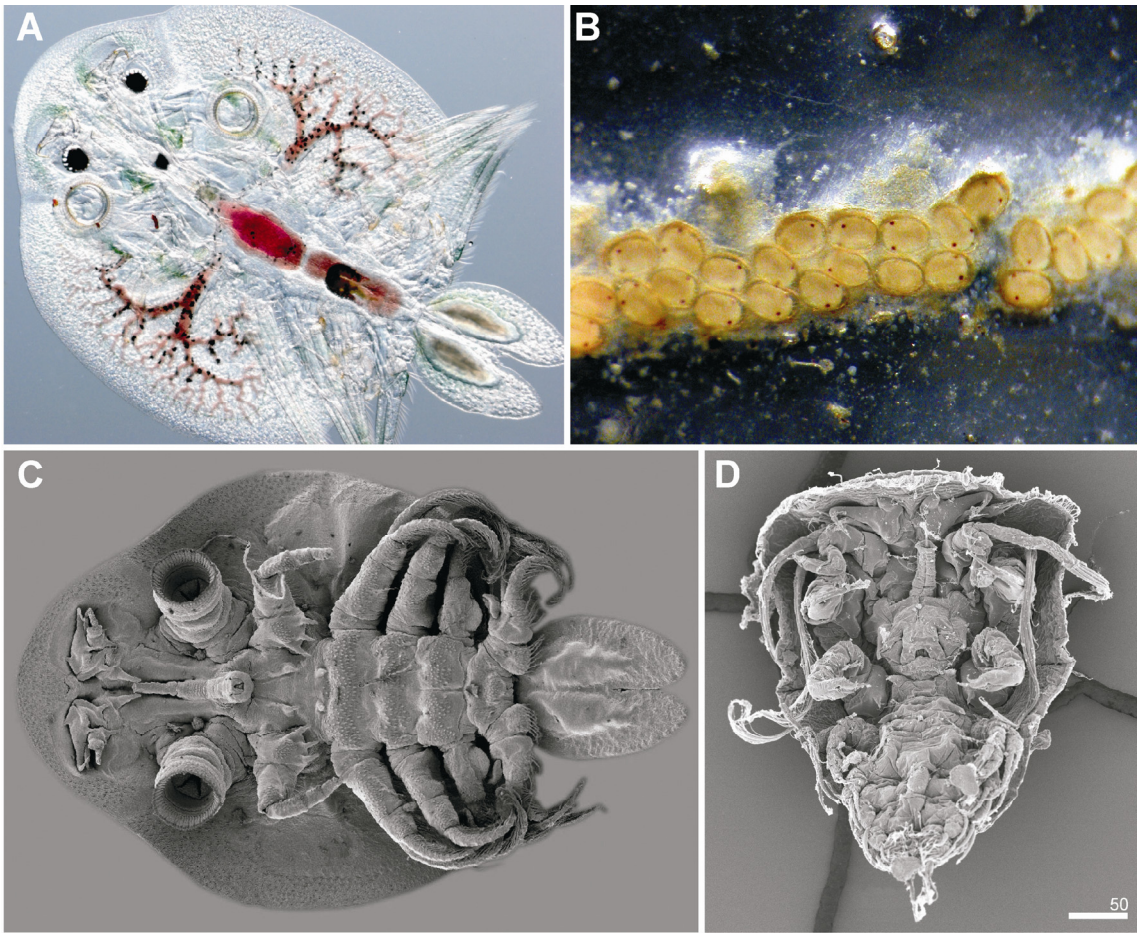

Figure 4. *Argulus japonicus*, light microscopy & Scanning Electron Micrographs. **A**: Adult male, habitus, ventral view. **B**: String of eggs with developing metauplii. **C**: Male, dorsal view, SEM. **D**: Stage I larva, metanauplius, ventral view, SEM. A and C, modified from Soes *et al*. (2010), with permission of the publisher E. Mauch (*Lauterbornia*). Photos B and D by the author.

21 days later at 22-25 degrees C, but the time to hatch is strongly dependent on temperature. Decreasing temperature lengthens the development time, and overwintering eggs have been observed in *A. foliaceus*. In both European species, the larvae hatch as metanauplii, but quickly moult (within the first one to two days) to a juvenile, which is morphologically fully equipped for the parasitic life style. The suction discs develop from the two proximal segments of the first maxillae during the following two to three moults. The precise time to maturity is not known, but the females can lay many batches of eggs during the season. The host specificity is generally very low in these two species, and they have been described from almost all commonly known freshwater fish families, even on eels. The Branchiura are obligatory parasitic animals, living from mucus, epithelial cells and blood meals from their fish hosts. The mouth opening is situated at the tip of a muscular mouth cone / oral cone, which incorporates the mandibles, situating the gnathal processes at the very tip. These processes are everted during feeding to bite into the fish epidermis, creating a wound from which the liquids are then ingested along with small pieces of skin.

The distribution on the Iberian penninsula has not been documented in any detail, but the reproductive potential in both species is very high, and thus they are probably found in most lakes. The world-wide distribution of the ca. 220-230 species of Branchiura is interesting, as the genus *Argulus* is found worldwide, the genus *Chonopeltis* only in sub-saharan Africa, while *Dolops* occurs with a single species in southern Africa, one on Tasmania and the remaining group in South America. The main species diversity of *Argulus* is found in North and South America, with Africa coming in with ca. 30 species. In Europe, we find only few but widespread species (*A. foliaceus, A. coregoni* in the North and the introduced *A. japonicus*), and the situation in Asia seems to resemble it, with *A. japonicus* being widely distributed. The center of species diversity in *Dolops* is South America, with ca. 10 species. The rarest genus *Dipteropeltis* is only found in S. America and only contains two recognized species at present. This could indicate an underlying Gondwanian distribution of the Branchiura, but the lacking radiation of *Dolops* in Africa points towards a more recent re-introduction to the continent or some other limiting factor.

As all known Branchiurans, also the two species of Argulids found on the Iberian penninsula are parasitic, and can cause damage to smaller fish. The feeding is not comparable to that of e.g. the Caligid Copepoda (e.g. marine salmon lice), but the Argulids can cause enough damage to the skin to allow fungi and other pathogens to enter the fish. *Argulus foliaceus* is also known for being a vector of a dreaded disease in commercial carp production; Spring Carp Viremia. The very high reproductive rate of *A. foliaceus* and *A. japonicus* coupled with the very resilient and tough egg-strings makes it a problem in quite many lakes, especially in the put-and-take recreational fishing business.

2. Systematics of the group

Clase/ Subclase: **B r a n c h i u r a**

Order: **Arguloida** (single)

Family: Argulidae (single)

Genera: *Argulus, Chonopeltis, Dipteropeltis, Dolops* (Only *Argulus* relevant for Europe)

Argulus foliaceus L.
(= *A. viridis* Nettowich)

Argulus japonicus Thiele
(= *A. pellucidus* Wagler)

Only the genus *Argulus* is relevant for Ibero-macronesia region. Two species are commonly found: *A. foliaceus* and *A. japonicus*. The third European species *A. coregoni* is considered boreal in its distribution, but it has previously been recorded from S. Germany and considering the potential for spreading with freshwater fish, it cannot be completely excluded as a possible species for the Ibero-Macronesian region, although it has not be recorded in the literature.

There might be cryptic species within Europe also, as no population genetic studies have been undertaken for *Argulus* yet. In other parts of the world, there is bound to be still new species from this group on not-well studied species of freshwater fish. A major void in the knowledge about the Branchiura in Europe, concerns the marine species (or semi-marine as they probably are). Very little work has been done on these species (also some found in N. America), despite them being extremely interesting both taxonomically as well as from an evolutionary morphology point of view.

Typically, only little work has been done on the details of the reproductive biology of the Branchiura. The fecundity and reproductive potential still need to be further investigated, especially for the European species. The parasitic impact on the host fish is also not fully clear as argulids can transfer viral diseases to their hosts. Many aspects of the morphology of e.g. the nervous system and the early ontogeny also still needs much more research to be fully understood.

3. Diversity of the group

The species diversity of the Branchiura is relatively low, and especially so in the European area in general. As mentioned above, only three species from one genus are found in Europe. Two more species from *Argulus* have been described from France (W. coast) and the Algerian coast of the Mediterranean *Argulus arcassonensis* Cuenot, 1912, and *A. vittatus* (Raffinesque-Schmalz), but these are seemingly very rare, and the available knowledge about them thus also limited. But as the description suggests, these were both taken from marine fish, which is very rare for Branchiura. There is no detailed knowledge of how much of the life cycle these branchiurans spend in the marine environment, but it is almost certain that they cannot complete it there.

With only ca. 220-230 species worldwide, the Branchiura is among the smaller groups of Crustacea, but the morphological disparity between the four genera is often overlooked. Three genera (*Argulus, Chonopeltis, Dipteropeltis*) are all equipped with “suction discs”, derived from the proximal segments of the first maxillae. The primarily south American genus *Dolops* (which, as mentioned above, is also found with a single species in S. Africa and one on Tasmania), does not have such “discs”, but retain a distal hook on the appendage, resembling the juvenile condition in the genera *Argulus* and *Chonopeltis* (the juveniles of *Dipteropeltis* are not known). *Chonopeltis*, on the other hand, shows a very peculiar and rare derived feature by having completely reduced their first antennae and also a strong reduction of their second antennae. The strictly South American genus *Dipteropeltis* exhibits a highly derived morphology of the carapace and abdomen, as both structures are drawn out into elongated lobes. In addition, this genus shares the presence of a pre-oral spine with *Argulus*; a structure lacking in both *Dolops* and *Chonopeltis*. So, when considered globally, the branchiuran diversity is not lacking, but here in Europe it is.

4. Current state of the knowledge of the group

In general, only two species of *Argulus* can be considered relevant for the inland waters of the Ibero-macronesian region: *A. foliaceus* and *A. japonicus*. The two species are well-known in most respects, but as it is the case with several smaller parasitic groups, many details are still lacking. The genus *Argulus* in Europe is well defined and currently, there are no recognized taxonomic problems in this region. As mentioned above, the potential for unrecognized cryptic species is definitely present in both species, but no studies have approached this problem yet. Also, there is a lack of large scale distribution data collection for these species. But it seems to be a general rule (rather than an exception) that wherever a larger population of freshwater fish is present in a lake, there will also be argluids present. It is both time consuming and costly to investigate 100s of lakes to determine the precise distribution of these species, and the detrimental impact of these parasites is not large enough to attract the attention of the industry.

5. Main available sources of information

The literature on branchiurans stretches back to some of the earliest works on Crustacea in general, and thus also includes numerous works in French, German and Spanish. Much work has been done in English also, but quite a lot of the knowledge on Branchiura needs to be extracted from general works on freshwater copepod. This is due to an unfortunate misidentification of the group as belonging to the Copepoda, which persisted until the 1930s (even later in some authors, see (Møller, 2009)). The amount of literature directly concerned with the European species is fairly limited, and the interested scholar must not be afraid of older texts. The amount of taxonomic keys available is very low, but as described above, the European species can be separated relatively easily. Here is a selection of some of the more relevant texts for the Branchiura.

● Møller, 2009.
Provides an extensive review of the Branchiura literature (both the older systematic papers and others) and an introduction to all four genera based on original data.

● Møller *et al*., 2007, 2008; Møller & Olesen, 2010.
Three papers by the current author on interesting aspects of branchiuran morphology and evolution. Contains many SEM also of *A. foliaceus* and the other three genera, including the extremely rare *Dipteropeltis* from S. America.

The following papers are sorted alphabetically:

● Ahne, 1985.
Describes how argulids can transfer a viral disease which is a serious threat to carp production

● Bandilla *et al*., 2005, 2007; Hakalahti *et al*., 2004, 2005.
Some interesting work done on the boreal species *A. coregoni* by a group of finnish researchers.

● Clark, 1902.
An old paper on *A. foliaceus* in the classic “narrative style”. Illustrations of varying quality, but some interesting observations.

● Fryer, 1959, 1964, 1961b, 1977, 1965a, 1960, 1965b, 1956, 1961a, 1968.
G. Fryer provided a long series of papers on branchiurans from his long career as a researcher in Africa. These are classical papers in their own right and contain many valuable information on the three genera of branchiurans found in Africa. However, the modern readers should be aware, that G. Fryer neither believed in a monophyletic Arthropoda (he did not believe in Hennigian methods aka. phylogenetic systematics), nor in the plate tectonic theory as we consider a fact today (introduced by A. Wegener). Thus his explanations and deliberations on the distributional patterns should be read “caveat emptor”.

● Gresty *et al*., 1993.
An excellent paper on the complex mouth cone and feeding structures in *A. japonicus*.

● Gurney, 1948.
Provides good line drawings of the three european species also described here; *A. coregoni, A. foliaceus,* and *A. japonicus* (though it is describes as “*A. pellucidus”* which has been shown to be a synonym). Very relevant for the Ibero-macronesian region.

● Meehan, 1940.
This paper must be considered as one of the classic works. It is very comprehensive, especially with respect to *Argulus* and also includes one of the rare keys published. However, the modern reader should be wary of synonymizations carried out since then.

● Menezes *et a*l., 1990.
An example of how *Argulus foliaceus* infections can have a serious impact a small lake.

● Poly, 2008.
A short paper on the global biodiversity of the Branchiura. Not very comprehensive in the literature section.

● Rushton-Mellor, 1992.
Provides the first description of *A. japonicus* for the UK.

● Rushton-Mellor, 1994.
Provides one of the rare keys to *Argulus*, but is concentrated on the african species.

● Rushton-Mellor & Boxshall, 1994.
Excellent paper with detailed drawings of the complete larval development of *Argulus foliaceus.*

● Soes *et a*l., 2010.
Providing the first description of *A. japonicus* for the Netherlands, as well as a usefull key. Figures from this paper are used in the present publication.

● Stammer, 1959.
(In german). Provides a fairly comprehensive overview of the three european species of *Argulus*.

● Tokioka, 1936.
One of the older original papers on *A. japonicus*. Includes a good description of the larval stages.

● Wilson, 1902.
One of the most comprehensive older reviews of the family; includes most historical references also.

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