
Communications

**Changes in levels
of infection with
Schistocephalus solidus
(Müller 1776) of the
three-spined stickleback
Gasterosteus aculeatus
(Actinopterygii:
Gasterosteidae) from the
Gdynia Marina**

OCEANOLOGIA, 53 (1), 2011.
pp. 181–187.

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Oceanology PAS.

KEYWORDS

Parasite
Schistocephalus solidus
Three-spined stickleback
Gdynia Marina,
Gulf of Gdańsk

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Received 19 April 2010, revised 17 December 2010, accepted 11 January 2011.

Abstract

This paper analyses the changes in the level of infection with the freshwater parasite *Schistocephalus solidus* of the three-spined stickleback from the Gdynia Marina. Environmental factors such as salinity, pollution and eutrophication or the presence of other species affect the transmission of parasites. Infection indices have been increasing since the 1990s. Differences in the infection level of morphological forms were also found: this may be due to their environmental preferences.

1. Introduction

Schistocephalus solidus is a specialist freshwater species parasitizing the three-spined stickleback *Gasterosteus aculeatus* Linnaeus, 1758. The first observations on sticklebacks with plerocercoids *S. solidus* from the Polish Baltic Coast were made at the end of the 19th century by Girdwoyń (1883). The three-spined stickleback is a common fish in the Baltic littoral zone,

The complete text of the paper is available at <http://www.iopan.gda.pl/oceanologia/>

occurring in three main lateral plate morphs: *trachurus*, *semiarmatus* and *leiurus*. The distributions and frequencies of all forms of this species in the coastal zone of the Baltic Sea are different. The dominant morph in the Gulf of Gdańsk is *trachurus*, *semiarmatus* is less frequent and *leiurus* is the rarest (Bańbura & Przybylski 1987, Bańbura 1994).

Its topography and the strong human pressure it is subject to make the Baltic Sea vulnerable to environmental changes. The large-scale inflow of nutrients and subsequent eutrophication are the most serious threats to the health and prospects of the Baltic Sea ecosystem. The Gulf of Gdańsk, an open bay in the southern Baltic Sea, is thus a highly eutrophic area with high concentrations of nutrients (Andrulewicz & Witek 2002, Lundberg 2005).

Environmental conditions, e.g. eutrophication, nutrient concentrations, oxygen deficiency, salinity and pollutants, and their changes, affect the compositions and abundances of species in a community, and also the susceptibility of these species to infection with parasites. The occurrence of parasites in a fish population depends on the behaviour of the fish and the human pressure exerted on the habitat (Rokicki & Strömberg 1995). Factors like eutrophication increase the diversity of invertebrate species and have an indirect positive influence on parasites with a complex life cycle, like cestodes.

This study is an attempt to compare changes in the level of infection with *S. solidus* of the three-spined stickleback from the Gdynia Marina (Gulf of Gdańsk) in the last 15 years. Differences in the infection of the various morphological forms of the fish will also be compared. This research is based on data from 1994 and 2008.

2. Material and methods

The three-spined sticklebacks were caught with a hand-net in the Gdynia Marina (54°31'0"N, 18°33'12"E) in 1994 and again in 2008. In both years, samples were collected in late autumn (December). Infection with many species of parasites, also tapeworms, increased in summer, reaching peak values in autumn. This is a period when copepods, the first intermediate hosts of *S. solidus*, are an important food item of the stickleback, and the high water temperatures ensure that rates of consumption are also high. It is a favourable time for the transmission and accumulation of parasites.

Three morphotypes of sticklebacks – *trachurus*, *semiarmatus* and *leiurus* – have been identified: *trachurus* is a fully plated form, *semiarmatus* is plated on the pectoral and caudal parts of the body, whereas *leiurus* possesses few lateral plates, if any. The third larval stage (plerocercoid) of *S. solidus* lives and grows freely in the body cavity of the stickleback.

Plerocercoids were removed from the body cavity of fish and counted. Species identification was based on taxonomic keys (Pojmańska 1991).

Parasitological indices (prevalence, mean and range intensity) were calculated according to Bush et al. (1997). Prevalence (expressed as a percentage) is the number of hosts infected with a particular parasite species divided by the number of hosts examined. Mean intensity is the total number of individuals of a particular parasite species found in a sample divided by the number of hosts infected with that parasite. Range intensity is the highest and lowest number of individuals of a particular parasite species found in a single infected host in a sample. The parasitological indices were calculated for all morphotypes and the entire stickleback sample.

3. Results

Differences in the parasitological indices of infection with plerocercoids of *Schistocephalus solidus* were found. Generally speaking, cestodes infected the morphs with fewer plates ($p \leq 0.005$): prevalence was the highest in *leiurus* in 1994 and in *semiarmatus* in 2008 (Table 1). In 2008, the least armoured morph *leiurus* was not caught. The 1994 intensity of infection persisted at the same level. Most of the fish were infected with one

Table 1. Infection by *Schistocephalus solidus* of *Gasterosteus aculeatus* morphotypes

morph	<i>trachurus</i>		<i>semiarmatus</i>	
	prevalence [%]	intensity ¹ [indiv.]	prevalence [%]	intensity [indiv.]
1994	4.6	1.2 (1-2)	8.5	1.1 (1-2)
2008	91.7	1.8 (1-4)	100	3.0 (1-6)
	<i>leiurus</i>		Total ²	
	prevalence [%]	intensity ¹ [indiv.]	prevalence [%]	intensity [indiv.]
1994	10.6	1.2 (1-3)	5.0	1.2 (1-3)
2008	–	–	94.4	2.2 (1-6)

¹Mean intensity and range intensity in parentheses.

²All morphotypes of *Gasterosteus aculeatus*.

plerocercoid *S. solidus*, occasionally with two. In 2008 the level of infection was significantly higher, and most sticklebacks contained more than one plerocercoid of *S. solidus*. One stickleback harboured a maximum of six plerocercoids. The total prevalence of infection also increased significantly, from 5.0% in 1994 to 94.4% in 2008. As in the case of infection intensity, the highest values were recorded in the least armoured forms, *leiurus* and *semiarmatus*.

4. Discussion

Like many other parasites that use an intermediate host, *Schistocephalus solidus* is transmitted to the next intermediate or the final host through predation. Copepods are the most important food items of a stickleback's diet (Reimchen & Nosil 2001). Copepods with infective procercoids of *S. solidus* were more active, but did not swim so well and were easier to catch than uninfected individuals (Wedekind & Milinski 1996). In turn, sticklebacks infected with *S. solidus* swam closer to the water surface (Barber & Ruxton 1998) and were more accessible to the definitive host – fish-eating birds such as herons, cormorants or gulls. In Poland adults of *S. solidus* were found in *Podiceps nigricollis*, *Ardea purpurea*, *Ciconia ciconia*, *C. nigra*, *Anas platyrhynchos*, *Tringa totanus*, *Larus canus*, *L. ridibundus* (Czapliński et al. 1992), *Phalacrocorax carbo sinensis* (Kanarek & Rokicki 2005) and *Mergus merganser* (Kavetska et al. 2008). Rokicki & Skóra (1989) showed that sticklebacks were eaten in the Gulf of Gdańsk by *Mergus serrator*, *Uria aalge*, *Melanitta fusca* and *Podiceps cristatus*, and that each of these bird species could be a final host.

In recent years, great cormorants and gulls have been the most abundant piscivorous birds in the Gulf of Gdańsk (Kanarek et al. 2003), and their populations are constantly increasing. Analysis of the parasites present in fish as larvae, including *Schistocephalus solidus*, and maturing in fish-eating birds, showed that the bird families Laridae, Phalacrocoracidae, Podicipedidae and Anatidae play the greatest part in the circulation of parasites in the environment (Rolbiecki et al. 1999).

The infection of fish hosts with parasites and the condition of fish depend on environmental factors like salinity, temperature (Möller 1978, Marcogliese 1992) and pollution (Sures 2003, 2004), but also on the occurrence of other host species.

In the sticklebacks from the Gulf of Gdańsk, examined by Rolbiecki et al. (1999) in the 1990s, infestation with *S. solidus* was 6.3% with a mean intensity of 1.2 indiv. This is slightly more than in 1994. But in the 2000s, when there was a marked increase in infection, Zander (2007) found a maximum of 14% sticklebacks infected with *S. solidus* in the

Baltic Sea at more saline localities in Schleswig-Holstein and Mecklenburg (northern Germany). These locations closer to the Danish Straits have a higher salinity than the Gulf of Gdańsk – between 10 and 18 PSU in the former area, but only about 7 PSU in the latter (Normant et al. 2005). Freshwater species like *S. solidus* have better living conditions in less saline environments. Bergersen (1996) found from 18% to 92% infected sticklebacks in freshwater localities in Greenland, and Wootton (1976) up to 88% of such fish in United Kingdom localities.

5. Conclusion

Changes in environmental factors such as salinity, pollution and eutrophication, as well as the presence of various species of intermediate and final hosts, especially the increasing population of cormorants on the Gulf of Gdańsk, affect the transmission of parasites. Differences in the infection level of morphological forms depend on their environmental condition and preferences. *Trachurus* spawned in the shallow waters of the Baltic Sea and migrated to the open sea, *leiurus* migrated during the spawning period to freshwater, and *semiarmatus* preferred shallow waters. Because of their behavioural differences, their diets are also dissimilar, owing to the accessibility of the constituent items, and they are infected to a greater or lesser extent with freshwater or marine parasites.

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