# Alien species of fish parasites in the coastal lakes and lagoons of the southern Baltic

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**Abstract**

Alien species are now found all over the world. New fish parasites have been unintentionally introduced with infected alien fish imported for aquaculture or have sometimes spread with their intermediate invertebrate hosts transported in the ballast waters of ships. Four alien fish parasites have been recorded in Polish coastal lakes and lagoons, all parasitising eels. Three were introduced with the final host – the Japanese eel – introduced for aquaculture (*Anguillicola crassus*, *Pseudodactylogyrus anguillae* and *Pseudodactylogyrus bini*) and one (*Paratenuisentis ambiguus*) with its sole intermediate host (*Gammarus tigrinus*).

## 1. Introduction

The global scale of biological invasions associated with human activities increased in the 20th century (Leppäkoski & Olenin 2000, 2001). Humans are changing the natural environment, transferring many species every day from their natural habitats to new regions (Sapota 2004). Alien species have been intentionally introduced for aquaculture and fishing, but have also been carried accidentally in the ballast waters of ships. Sometimes they have also brought their parasites to the new habitats.

The Baltic Sea is a young sea and species are still adapting to the conditions. Over 100 alien species have been recorded in the Baltic Sea and adjacent waters (Leppäkoski & Olenin 2000, 2001, Sapota 2004, 2005), four of them parasites. They were introduced with their intermediate (1 species)

or final hosts (3 species). One of these introduced parasites is common throughout the Baltic, while the remainder live in divers habitats. All are alien species that have parasitised the European eel *Anguilla anguilla* (Linnaeus, 1758) in European waters since the 1980s. First appearing in freshwaters, these parasites then spread rapidly along European coasts; they have also been recorded in the coastal lakes and lagoons of the Baltic Sea.

This paper reviews our knowledge of invasive species parasitising fish in the Baltic Sea and adjacent waters, with particular focus on the Polish coasts. Results from the coastal lakes Bukowo, Kopań and Łebsko are compared with reports of various authors from the Polish bays and lagoons, and also the Russian part of the Vistula Lagoon.

## 2. Study area

The coastal lakes Bukowo, Kopań and Łebsko are situated on the Central Coast of Poland. Lying in the Słowiński National Park, Łebsko is the largest coastal lake in Poland. All three are shallow water bodies, bordered by reeds and sedges. They are connected to the Baltic Sea, and seawater flows back into them when winds blow from the north and northwest. As a result, fish or other organisms can migrate between the lakes and the Baltic coastal waters.

## 3. Material and methods

In 2000–07, a total of 108 European eels (length 38.5–83.0 cm, weight 108.6–1002.2 g), caught by professional fishermen in Lakes Bukowo, Kopań and Łebsko, were examined for parasites using the standard procedures of parasitological examination and parasitic identification (Bylund et al. 1980).

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.

## 4. Results

The European eels from the coastal lakes Bukowo, Kopań and Łebsko were infected with three invader species. One of them, *Anguillicola crassus* Kuwahara, Nimii et Itagaki, 1974, was noted in all three lakes. This

**Table 1.** Infection of the European eel with alien parasite species in Polish coastal lakes and lagoons, and the Russian part of the Vistula Lagoon. References: Szczecin Lagoon (Garbacik-Wesołowska et al. 1994, Rząd 1998), Pomeranian Bay (Garbacik-Wesołowska et al. 1994), Pomeranian rivers (Pilecka-Rapacz 2000, Sobecka & Pilecka-Rapacz 2003), Puck Bay (Bystydzieńska et al. 2005), Gulf of Gdańsk (Rolbiecki et al. 2000), Vistula Lagoon (Rolbiecki et al. 1996, Bystydzieńska et al. 2005, Rolbiecki & Rokicki 2006), Russian part of Vistula Lagoon (Rodiuk 2003, Rodiuk & Shelenkova 2006)

| | *Pseudodactylogyrus anguillae* | | *Pseudodactylogyrus bini* | | *Anguillicola crassus* | | *Paratenuisentis ambiguus* | |
|---|---|---|---|---|---|---|---|---|
| | P | I | P | I | P | I | P | I |
| Szczecin Lagoon | | | | | 26.4–68.4 | (1–36) | | |
| Pomeranian Bay | | | | | 30.0 | (1–10) | | |
| Pomeranian rivers | 4.0–78.0[1] | 1.8–9.3 | 4.0–78.0[1] | 0.7–3.5 | 33.3–65.6 | 1.3–2.1 (1–12) | | |
| Bukowo – coastal lake | | | | | 66.7 | 17.5 (11–24) | | |
| Kopań – coastal lake | | | | | 100 | 8.0 (5–11) | | |
| Łebsko – coastal lake | 1.1 | 3.0 (3) | | | 68.2 | 5.8 (1–27) | 6.8 | 28.2 (1–163) |
| Puck Bay | 100 | 11.0 (6–16) | | | 74.4 | 8.3 (1–62) | | |
| Gulf of Gdańsk | | | | | 41.9 | 3.0 | | |
| Vistula Lagoon | | | | | 63.3–100 | 4.2–10.0 (1–58) | | |
| Vistula Lagoon (Russian part) | 1.4 | (1–2) | | | 40.2–80.2 | (1–31) | 2.8 | (1–4) |

P – prevalence [%], I – mean intensity and range in parentheses [indiv.], [1]the combined prevelance for both monogeneans.

nematode was the most abundant species of parasite. The highest prevalence (100%) was reported in Lake Kopań, the highest mean intensity (17.5 indiv.) in Lake Bukowo (Table 1). Sometimes the wall of the swim bladder was thickened, and the swim bladder lumen contained a brownish liquid. *A. crassus* has been recorded since the year 2000.

*Pseudodactylogyrus anguillae* (Yin et Sproston, 1948) and *Paratenuisentis ambiguus* Van Cleave, 1921 were reported only from Lake Łebsko. Both species have been recorded since 2002. The level of invasion was lowest in the case of *P. anguillae* – only 1.1% of eels were infected (mean intensity 3.0 indiv.). The prevalence of *P. ambiguus* was also low, but the mean intensity of this species was the highest with a maximum of 163 parasites per fish (Table 1). This acanthocephalan is a new addition to the eel parasite fauna in Poland (Morozińska-Gogol 2008).

Table 1 compares the parasitological indices from Lakes Bukowo, Kopań and Łebsko with those calculated by other authors for Polish bays and lagoons, and also the Russian part of the Vistula Lagoon.

## 5. Discussion

### 5.1. Origin of parasites

*Pseudodactylogyrus anguillae* (Yin et Sproston, 1948) and *Pseudodactylogyrus bini* (Kikuchi, 1929) were carried to Europe by the transport from East Asia of live juvenile Japanese eels *Anguilla japonica* Temminck et Schlegel, 1864, for aquaculture (Buchmann et al. 1987).The donor region of these species is the north-west Pacific (Jensen & Knudsen 2005). In Europe, both species were first reported from an eel aquaculture in the Kalinin region of Russia in 1977 (Buchmann et al. 1987).

*Anguillicola crassus* Kuwahara, Nimii et Itagaki, 1974, is a natural parasite of the swim bladder of the Japanese eel. *A. crassus* was introduced with Japanese eels imported from Taiwan for aquaculture and was first noted in Germany in 1980 (Jensen & Knudsen 2005). A freshwater species, it dispersed from the rivers of continental Europe to those of Scandinavia via the brackish water of the Baltic Sea (Reimer et al. 1994, Zander & Reimer 2002).

*Paratenuisentis ambiguus* Van Cleave, 1921, is a specialist parasite of the American eel *Anguilla rostrata* (Lesueur, 1817) along the east coast of North America from Labrador to Florida (Samuel & Bullock 1981). The donor region is thus the north-west Atlantic. *P. ambiguus* was introduced to Europe via its sole intermediate host *Gammarus tigrinus* Sexton, 1939 (Bullock & Samuel 1975, Kennedy 2006, Taraschewski 2006). Its occurrence

in Europe was first reported in the River Weser in Germany (Taraschewski et al. 1987).

### 5.2. Dispersal and distribution in the Baltic Sea and adjacent waters

*P. anguillae* and *P. bini* have been reported on the European eel from the Baltic Sea, including the Danish Straits, since the 1980s (Buchmann et al. 1987, Buchmann 1988, Leppäkoski & Olenin 2000, Jensen & Knudsen 2005).

First recorded in Poland in freshwater habitats in 1985 (Dzika et al. 1995), these parasites were noted in the coastal lakes and lagoons of the southern Baltic a few years later. Both species were found on gills of the European eel from rivers in Western Pomerania (the Radew, Rega, Wieprza); *P. anguillae* was decidedly more abundant (Sobecka & Pilecka-Rapacz 2003). Since 2002, *P. anguillae* has also been recorded in eels from the coastal lake Łebsko, Puck Bay (Bystydzieńska et al. 2005) and the Russian part of the Vistula Lagoon (Rodiuk 2003, Rodiuk & Shelenkova 2006).

In the European eel from Baltic coasts, a second invader species *A. crassus* was recorded with a prevalence of up to 90% (Jensen & Knudsen 2005, Morozińska-Gogol 2005, Rolbiecki & Rokicki 2005). This swim bladder nematode has been recorded in eels from the Baltic Sea: the Swedish coast (Höglund & Andersson 1993), the Danish Straits (Jensen & Knudsen 2005), Germany – Wismar Bay (Reimer et al. 1994), Poland – Szczecin Lagoon (Garbacik-Wesołowska et al. 1994, Rząd 1998), the Pomeranian Bay (Garbacik-Wesołowska et al. 1994), Pomeranian rivers (Wieprza, Rega, Radew) (Pilecka-Rapacz 2000, Pilecka-Rapacz & Sobecka 2004), the coastal lakes Bukowo, Kopań and Łebsko (Morozińska-Gogol 2005), Puck Bay (Bystydzieńska et al. 2005), the Gulf of Gdańsk (Rolbiecki et al. 2000), the Vistula Lagoon (Rolbiecki et al. 1996, Bystydzieńska et al. 2005, Rolbiecki & Rokicki 2006), Russia – the Vistula Lagoon (Rodiuk 2003, Rodiuk & Shelenkova 2006), and Lithuania – the Curonian Lagoon and Lithuanian Coastal Zone (Bacevicius 2004).

The fourth alien species, the acanthocephalan *P. ambiguus*, has been recorded in Poland – Lake Łebsko (Morozińska-Gogol 2008) and Russia – the Vistula Lagoon (Rodiuk & Shelenkova 2006).

### 5.3. Biology and life cycle

*P. anguillae* and *P. bini* very often live together on the gills of a single host individual in freshwater localities; *P. anguillae* has also been recorded in various brackish water localities. Both of these monogeneans were recorded

only on the gills of eels ascending Pomeranian rivers from the Baltic Sea, with *P. anguillae* being very much more abundant (Table 1). With an upper salinity tolerance of 20 PSU, *P. anguillae* can live and reproduce in both marine and brackish water habitats (Sobecka & Pilecka-Rapacz 2003, Jensen & Knudsen 2005). *P. bini* is more sensitive to elevated salinities and thus prefers freshwater localities.

The nematode *A. crassus* is an excellent coloniser and has infected eels in Asia, Europe, Africa and America (Kirk 2003). This large, blood-sucking parasite can infect a wide range of intermediate hosts (numerous invertebrate species) and paratenic hosts (certain fish species), and can survive in larval form for many months in the wall of the swim bladder (Kennedy 2007). The nematodes can be transferred to fish by invertebrates (copepods, ostracods) or by fish (Zander & Reimer 2002). In the German coastal zone (Wismar Bay) the pipefish *Syngnathus typhle* Linnaeus, 1758, is the most frequent paratenic host (prevalence up to 9.6%). The pipefish is a component of the eel's diet in the Baltic Sea (Reimer et al. 1994). On the Baltic coast of Sweden the black goby *Gobius niger* Linnaeus, 1758, (96%) and ruffe *Gymnocephalus cernuus* (Linnaeus, 1758) (79%) are the most frequent paratenic host species of *A. crassus* (Höglund & Thomas 1992).

One of the paratenic hosts in the Polish coastal zone is itself an alien fish species, the round goby *Neogobius melanostomus* (Pallas, 1811), infected with a prevalence of up to 9.1% (Rolbiecki 2006, Kvach & Skóra 2007). Very high levels of prevalence have also been reported in the ruffe (11.8%) (Własow et al. 1998, Rolbiecki 2002), three-spined stickleback *Gasterosteus aculeatus* Linnaeus, 1758, (8.9%) and European smelt *Osmerus eperlanus* (Linnaeus, 1758) (8.6%) (Rolbiecki 2004a). $L_3$ larvae have also been occasionally found in the European perch *Perca fluviatilis* Linnaeus, 1758, zander *Sander lucioperca* (Linnaeus, 1758) (Własow et al. 1998, Rolbiecki 2002), common bream *Abramis brama* (Linnaeus, 1758), ziege *Pelecus cultratus* (Linnaeus, 1758) (Rolbiecki 2002) and dab *Limanda limanda* (Linnaeus, 1758) (Rolbiecki 2004b).

The distribution of *P. ambiguus* was correlated with that of its intermediate host (Taraschewski et al. 1987). The occurrence of the adult form of this acanthocephalan in eels from European localities was preceded by the occurrence of *G. tigrinus* (Morozińska-Gogol 2008). In brackish water habitats the distribution of this gammarid is restricted to shallow lagoons, bays and estuaries, and also coastal lakes. *G. tigrinus* has spread rapidly along the Polish Baltic coast, having been recorded from the Szczecin Lagoon (Gruszka 1995) to the Vistula Lagoon (Jażdżewski & Konopacka 2000). It has also been reported from the south-eastern Baltic (Daunys

& Zettler 2006). As in the case of the monogeneans, prevalence of infection with *P. ambiguus* was low, but parasites were observed with intensities up to 163 indiv. (Table 1).

### 5.4. Pathogenicity

Parasites from the genus *Pseudodactylogyrus* cause serious damage to the gills when present on a host in large numbers under optimal conditions (Kennedy 2007). Under natural conditions, however, infection with monogeneans does not cause any serious problems.

*A. crassus* is more pathogenic to the European eel than to the Japanese eel. Maximally 10–40% of Japanese eels were infected, whereas prevalences of up to 90% and locally 100% have been reported in the European eel (Jensen & Knudsen 2005, Morozińska-Gogol 2005, Rolbiecki & Rokicki 2005); the intensity of infection ranged between a few and several tens of nematodes (Table 1). *A. crassus* has also been recorded in elvers. Pilecka-Rapacz (2000) reported that 33–40% of elvers from Pomeranian rivers were infected. The smallest infected eel was 13.2 cm in length, and the level of infection increased with fish length. In the worst infected eels the swim bladder contained a brownish liquid and its wall was thickened. Migrating larvae cause haemorrhages. Moreover, Kennedy (2007) reported that *A. crassus* reduces the oxygen concentration in the swim bladder, reducing its ability to function as a hydrostatic organ. That author also feared that the nematodes could affect the ability of eels to migrate to the Sargasso Sea and might be causing a decline in eel populations.

*P. ambiguus* was not observed to be pathogenic. A non-perforating species, it always occupies a shallow attachment and does not enter the muscular layers of the intestinal wall of the host; the posterior part of the proboscis usually remains unattached (Taraschewski 2000). This species, like other acanthocephalans, could cause mechanical damage to the intestinal wall and blockage of the intestinal lumen if a high number of parasites is present.

## 6. Conclusion

- The European eel is more susceptible to parasite invaders than their original hosts, especially the Japanese eel. Because eel aquaculture is based on wild elvers, these potentially pathogenic parasites (especially *Anguillicola crassus*) have entered eel farms, where they have caused great economic losses (Køie 1991).
- Both monogeneans prefer freshwater localities and are rare parasites in brackish waters.

- Eels are most under threat from the nematode *A. crassus* because of its wide range of intermediate and paratenic hosts, and also its pathogenicity.
- The occurrence of the acanthocephalan *Pseudodactylogyrus ambiguus* is correlated with the distribution of its intermediate host, *Gammarus tigrinus*.

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