Vol. 32: 233–236, 1998 | DISEASES OF AQUATIC ORGANISMS Dis Aquat Org | Published April 3

NOTE

Parasitation with *Pseudoterranova decipiens* (Nematoda) influences the survival rate of the European smelt *Osmerus eperlanus* retained by a screen wall of a nuclear power plant

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ABSTRACT: A total of 354 adult European smelts *Osmerus eperlanus* (L.) were tested for their ability to survive the screen system of the cooling water inflow of a power plant. With increasing number of musculature parasitic third-stage larvae of *Pseudoterranova decipiens*, the survival rate of *O. eperlanus* decreased while the total number of externally visible injuries as well as the number of seriously injured specimens increased. The results indicate that even a single specimen of *P. decipiens* influences resistance and stamina and affects overall mortality of 7 to 20 cm long smelts. The initial effect of the parasites is to reduce swimming speed of infested fish, which leads to more frequent contact of these fish with the fine meshed screen of the cooling water inlet before they are removed by the automatic cleaning system. If the separated fishes are returned to the main stream, it becomes apparent that the cooling water inflow selectively reduces the number of living parasitised smelt in the area. Thus, the number of parasitic third-stage *P. decipiens* larvae in the local smelt population which are able to complete their life-cycle is also reduced. *P. decipiens* makes infested smelt more susceptible to negative anthropogenic influences such as cooling water intake or trawl fisheries.

KEY WORDS: Damage · Nematode · *Osmerus eperlanus* *Pseudoterranova decipiens* · Cooling water inflow · Power plant

Parasites can have a negative effect on their fish hosts, in particular when they reach epizootic proportions in a population. Effects on growth (Richards & Arme 1981), maturation (Arme 1968), mortality (Hoffman & Dunbar 1961, Threlfall 1968, Adjei et al. 1986, Molnar et al. 1993) as well as on orientation (Garnick & Margolis 1990), respiration (Lester 1971), resistance to low oxygen levels (Molnar 1994) and behaviour (Milinski 1985, Godin & Sproul 1988, Ranta 1995) have been observed. Sprengel & Lüchtenberg (1991) demonstrated that infestation with endoparasites, microsporidians and the musculature-infesting nematode *Pseudoterranova decipiens* reduces the swimming speed of the European smelt *Osmerus eperlanus* and the European eel *Anguilla anguilla*. In the case of *P. decipiens* this effect has benefits for the parasite. A reduced swimming speed makes the fish more vulnerable to predation and therefore enhances the probability of transfer of the parasite from its intermediate to its final host, the seal *Phoca vitulina*.

Osmerus eperlanus is known to harbour third-stage larvae of nematodes belonging to the genera *Hysterothylacium* and *Pseudoterranova* (see Möller & Klatt 1990). The influence of the latter on swimming speed was experimentally tested in a circular tank by Sprengel & Lüchtenberg (1991). However, data on its effects in a natural as well as in an industrially influenced environment have not yet been collected. The purpose of the present study was to demonstrate the overall effects of the parasitation of European smelt with *P. decipiens* under power plant intake conditions in order to assess this stress factor on survival capacity of parasitised smelt compared to non-parasitised specimens.

Materials and methods. The sampling site was the cooling water inflow canal and screen of the nuclear power station Brunsbüttel, which is situated in the estuary of the Elbe River (northern Germany). It has one 806 MW generating block and needs about 40 m^3 s^{-1} of cooling water. A retaining system collects debris and all fish from the fine screen at the intake (mesh opening 5 mm) every 2 h and transfers all retained material to a water-filled reservoir. From this reservoir, a total number of 354 adult European smelts with a body length between 7 and 20 cm (year classes 1 and 2

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after Kausch & Nellen 1994) were collected between April 1996 and July 1996 (a total of 12 samples). The fish were carefully transferred in buckets to a 130 l tank filled with Elbe water.

The survival of and physical damage to smelts were determined directly after a 3 h containment period. A total of 7 different externally visible injuries could be observed directly after the experiment as well as in the laboratory after 12 to 24 h of storage on ice (Table 1). Of these, 3 types were considered minor and 4 were considered serious. This classification is based on the observation that smelts with a single minor injury normally survived the containment while a fish with a single serious injury died. Specimens with 3 types of minor injury also died; thus, the effect was similar to that of a single serious injury. For better comparison between slightly and seriously injured smelts, a specific damage index (s) was calculated for each fish according to the following formula:

$$s = \sum \text{minor lesions} + (\sum \text{serious lesions} \times 3)$$

In the laboratory, the condition factor using the gutted weight (modified after Carlander 1950) was determined and all *Pseudoterranova decipiens* (Krabbe, 1878) were isolated from the fish musculature. A damage rate (percentage of fish showing any damage at all) and a mean damage index could be calculated for differently parasitised fish. Additionally, the fishes were investigated for other flesh parasites in order to exclude these as other possible factors influencing fish survival. All results were tested using a chi^2-test ($p = 0.95$). The damage indices and the condition factor were also tested by means of a t-test ($p = 0.95$).

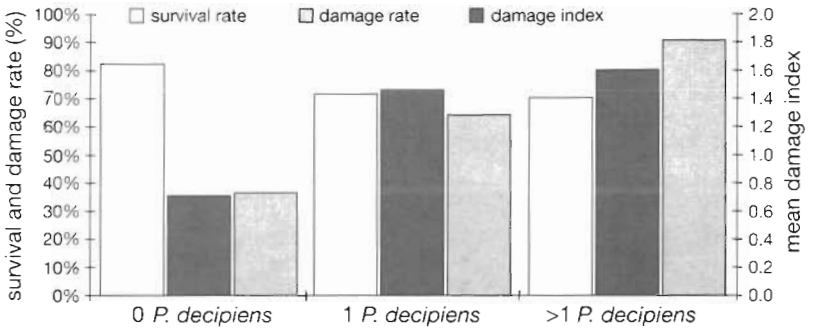

Fig. 1. *Osmerus eperlanus*. Survival rate (%), visible external damage rate (%) and mean damage index of *O. eperlanus* differently parasitised with *Pseudoterranova decipiens*. The 'damage index' is described in 'Materials and methods'; types of damage indicated in Table 1

Table 1 *Osmerus eperlanus*. Externally visible injuries observed in smelt exposed to contact with the screen mesh in an inflow cooling water canal of a power station

Minor lesions	Serious lesions
Loss of scales	Bruise on body
Fin skin damage	Loss of fin rays
Sub-skin bleeding	Bleeding in brain
	Internal bleeding

During the sample period at the Brunsbüttel Nuclear Power Station salinity ranged between 0.1 and 6.4, water temperature measured between 12 and 19°C and oxygen saturation varied between 87 and 96%. The current conditions within the cooling water inlet were the same during all samples.

Results and discussion. The survival rate of parasitised *Osmerus eperlanus* decreased significantly from 82.3 to 70% during a 3 h observation period, depending on the intensity of infestation with *Pseudoterranova decipiens* (Table 2, Fig. 1). However, no significant difference was detected between the 2 parasitised groups (71.4 and 70%) (Table 2, Fig. 1). In contrast to this, the damage rate increased significantly from 36.4% for non-parasitised to 64 and 90% for smelts infested with 1 and >1 *P. decipiens*, respectively (Table 2, Fig. 1).

The distribution of damage indices (s) changed significantly with the intensity of infestation (Table 3). About 64% of non-parasitised *Osmerus eperlanus* were uninjured ($s = 0$), while only 9.8% showed serious effects ($s > 2$). In contrast to this, only 10% of the smelts with more than a single *Pseudoterranova decipiens*

Table 2. *Osmerus eperlanus*. Survival rate, visible external damage rate and mean damage index in comparison to condition factor and mean length of smelt taken from the cooling water inlet screen of a power station. The damage index is described in 'Materials and methods'; types of injuries are listed in Table 1. n: number of fish examined

	Survival rate (%)	Damage rate (%)	Mean damage index (SD)	n	Mean length (cm) (SD)	Condition factor (SD)
Non-parasited	82.3	36.4	0.71 (1.72)	316	8.3 (1.99)	0.49 (0.06)
1 *Pseudoterranova decipiens*	71.4	64.0	1.46 (1.64)	28	10.9 (3.75)	0.49 (0.07)
>1 *Pseudoterranova decipiens*	70.0	90.0	1.6 (0.97)	10	15.8 (3.12)	0.44 (0.04)

Table 3. *Osmerus eperlanus*. Distribution of damage indices *s*, indicating the grade of damage observed in smelt with different intensities of infestation with *Pseudoterranova decipiens*

	Uninjured ($s = 0$)	Slightly injured ($s = 1$)	Injured ($s = 2$)	Seriously injured ($s > 2$)
Non-parasitised	63.6%	21.2%	5.4%	9.8%
1 *P. decipiens*	35.7%	25.0%	14.3%	25.0%
>1 *P. decipiens*	10.0%	40.0%	30.0%	20.0%

(group >1) were uninjured ($s = 0$) and 20% were seriously injured ($s > 2$). The resulting mean damage index also increased significantly from 0.71 (non-parasitised smelt) to 1.46 (1 *P. decipiens*) and significantly from 1.46 to 1.6 (>1 *P. decipiens*). Thus, the number of slightly and seriously injured specimens was related to the intensity of infestation with *P. decipiens* in the fish flesh (Fig. 2). The effect of fish size on survival was not tested during the present study. However, bigger fish had higher damage rates and damage indices and lower survival rates (Table 2, Fig. 1). The only explanation for this can be the reduction of fish condition due to the higher parasite burden even in larger fish.

The calculated mean damage index appears to be a useful indicator to evaluate the different effects of the observed externally visible injuries. Though the damage rate increased significantly from the 1 to the >1 group, the short-term survival rate was almost the same between these 2 groups of affected smelts (71.4 and 70%). This corresponds to a similar mean damage index in both groups, indicating that in the >1 group fewer specimens were seriously harmed. This can explain the similar survival rate values determined for the 2 parasitised groups.

Though the condition factors were not significantly different between the 3 differently parasitised groups (Table 2), the condition factor of non-parasitised fish and of fish hosting a single *Pseudoterranova decipiens* was slightly higher (10.2%) than the value for those fish with >1 parasite (0.49 vs 0.44) (Table 2). This is in contrast to a larger size class of the latter group, indicating a greater age (2 yr vs 1 yr) (Table 2). Möller (1988) demonstrated that the condition factor of both non-parasitised and parasitised smelt increased with age. However, there was a significantly greater increase in the condition factor of non-parasitised fish (Möller 1988). This is in contrast to our data, where the condition factor decreases with increasing fish length (10.2%). We propose that *P. decipiens* infestation contributed to the reduced condition factor of the sampled specimens. This conclusion is supported by the results of Klatt (1985), who reported that smelts older than 2 yr displayed a significant reduction in condition factor (11 to 14%) due to infestation with *P. decipiens* (see Möller & Anders 1986). Interestingly, no significant difference was found between the survival rates of the 2 parasitised groups (Table 2). The reason for this might be that larger size of more heavily infested smelts results

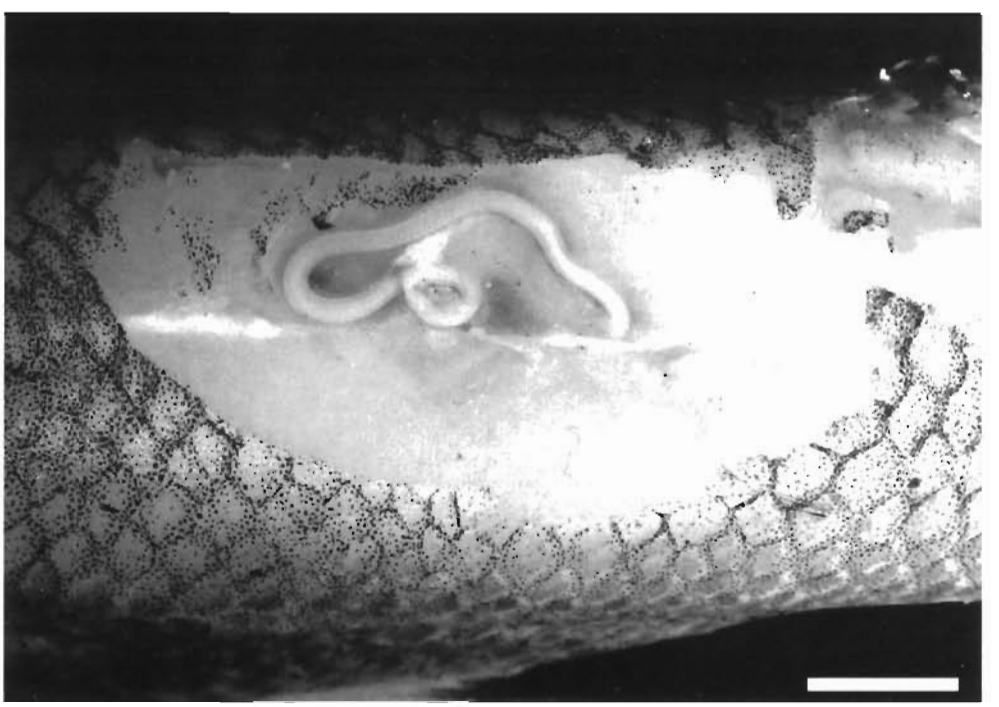

Fig. 2. *Osmerus eperlanus* infested with *Pseudoterranova decipiens* in the musculature. Scale bar = 5 mm

in a higher swimming speed and compensates for the negative effects of an increasing intensity of parasitation with *P. decipiens*.

In addition to *Pseudoterranova decipiens*, we also isolated 5 third-stage larvae of *Anisakis simplex* from the musculature of 4 smelts, and a single fish carried the muscle microsporidian *Pleistophora ladogensis*. Of these, none occurred in the smelts harbouring a single *P. decipiens*, and only 2 smelts of the group with >1 *P. decipiens* were additionally infested with these parasites. It was not possible to test the possible cumulative effect of co-parasitation on survival and seriousness of damage.

Sprengel & Lüchtenberg (1991) clearly demonstrated a reduced swimming speed for smelts (5 and 17 cm total length) depending on the intensity of infestation with *Pseudoterranova decipiens* in their muscles. Under the conditions in the cooling water intake of the power station studied, small and highly parasitised *Osmerus eperlanus* should have more difficulties in avoiding contact with the cleaning system than larger and non-parasitised fish before being removed by the screen. Our data correspond to this scenario. Highly parasitised smelts reached the reservoirs in poorer condition than those with a low parasite load or those with no parasites and were more seriously damaged than the others.

The present data indicate that parasitised fishes may experience higher mortality rates when passing through the cooling water intake fish recovery system. It is apparent that the number of surviving parasitised smelt in the area will be reduced by returning separated and surviving fish to the river from which they came. Thus, the number of parasitic third-stage larvae of *Pseudoterranova decipiens* in the local smelt population which are able to complete their life-cycle will also be reduced. Our results support the statement by Sprengel & Lüchtenberg (1991) that highly infected fish become more vulnerable to anthropogenic influences such as cooling water intakes at power stations and trawl fisheries.

Acknowledgements. We are grateful for the scientific and administrative assistance of Dr Matthias Voigt and for the technical support of Hans Lüchtenberg and Maren Dilge. Many thanks to Thorsten Walter for photographing a parasitised smelt.

LITERATURE CITED

Adjei EL, Barnes A, Lester RJG (1986) A method for estimating possible parasite-related host mortality, illustrated using data from *Callitetrarhynchus gracilis* (Cestoda: Trypanorhyncha) in lizardfish (*Saurida* spp.). Parasitology 92: 227–243

Arme C (1968) Effects of the plerocercoid larva of a pseudophyllidean cestode, *Ligula intestinalis*, on the pituitary gland and gonads of its host. Biol Bull (Woods Hole) 134: 15–25

Carlander KD (1950) Handbook of freshwater biology. Wm C Brown, Des Moines, IA

Garnick E, Margolis L (1990) Influence of four species of helminth parasites on orientation of seaward migrating sockeye salmon (*Oncorhynchus nerka*) smolts. Can J Fish Aquat Sci 47:2380–2389

Godin JGJ, Sproul CD (1988) Risk taking in parasitised sticklebacks under the threat of predation: effects of energetic need and food availability. Can J Zool 66:2360–2367

Hoffman GL, Dunbar CE (1961) Mortality of eastern brook trout caused by plerocercoids (Cestoda: Pseudophyllidea: Diphyllobothriidae) in the heart and viscera. J Parasitol 47: 399–400

Kausch H, Nellen W (1994) Wechselwirkungen zwischen abiotischen und biotischen Prozessen in der Tideelbe. In: Tätigkeitsbericht des Sonderforschungsbereiches 327, 1992–1994. Universität Hamburg, p 445–478

Klatt S (1985) Populationsdynamik des parasitischen Nematoden *Phocanema decipiens* im Stint. MSc thesis, Math-Nat Fak Kiel

Lester RJG (1971) The influence of *Schistocephalus plerocercoids* on the respiration of *Gasterosteus* and a possible resulting effect on the behavior of the fish. Can J Zool 49: 361–366

Milinski M (1985) Risk of predation of parasitised sticklebacks (*Gasterosteus aculeatus* L.) under competition for food. Behaviour 93:203–216

Molnar K (1994) Effect of decreased oxygen content on common carp fry with *Dactylogurus vastator* (Monogenea) infection of varying severity. Dis Aquat Org 20:153–157

Molnar K, Baska F, Csaba G, Glavits R, Szekely C (1993) Pathological and histopathological studies of the swimbladder of eels *Anguilla anguilla* infected by *Anguillicola crassus* (Nematoda: Dracunculoidea). Dis Aquat Org 15: 41–50

Möller H (1988) Fischbestände und Fischkrankheiten in der Unterelbe 1984–1986. Verlag H Möller, Kiel

Möller H, Anders K (1986) Diseases and parasites of marine fishes. Verlag H Möller, Kiel

Möller H, Klatt S (1990) Smelt as host of the sealworm *Pseudoterranova decipiens* in the Elbe estuary. Can Bull Fish Aquat Sci 222:129–138

Ranta E (1995) *Schistocephalus* infestation improves prey-size selection by three-spined sticklebacks, *Gasterosteus aculeatus*. J Fish Biol 46:156–158

Richards KS, Arme C (1981) The effects of the plerocercoid larva of the pseudophyllidean cestode *Ligula intestinalis* on the musculature of bream (*Abramis brama*). Z Parasitenkd 65:207–215

Sprengel G, Lüchtenberg H (1991) Infection by endoparasites reduces maximum swimming speed of European smelt *Osmerus eperlanus* and European eel *Anguilla anguilla*. Dis Aquat Org 11:31–35

Threlfall W (1968) A mass die-off of three-spined sticklebacks (*Gasterosteus aculeatus* L.) caused by parasites. Can J Zool 46:105–106

Editorial responsibility: Wolfgang Körting, Hannover, Germany

Submitted: September 29, 1997; Accepted: January 28, 1998
Proofs received from author(s): February 24, 1998