THE SPREADING OF *ANGUILLICOLA CRASSUS* IN FRESHWATER LAKES IN SWEDEN.

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ABSTRACT

The first record of *Anguillicola crassus* in Sweden was made in 1987. Nine years later, the swimbladder parasite was well established not only in thermal discharge areas but in other brackish waters along the coasts as well as in some freshwater lakes. In comparison with certain localities affected by thermal discharges, the infection rate has been much slower in two inland eel stocks and in one coastal stock monitored in this study. There are strong indications that the parasite was introduced into several freshwater lakes as a consequence of active stocking measures using yellow eels caught at the Swedish west coast.

LA PROPAGATION D'*ANGUILLICOLA CRASSUS* DANS LES LACS DULÇAQUICOLES DE SUÈDE.

RÉSUMÉ

Le premier cas d'*Anguillicola crassus* a été enregistré en Suède en 1987. Neuf ans après, ce parasite de la vessie gazeuse était bien implanté non seulement dans des zones réchauffées par des eaux thermales, mais aussi dans les eaux côtières saumâtres et dans certains lacs dulçaquicoles. Comparativement à ces zones réchauffées par les eaux thermales, l'infestation a été beaucoup plus lente dans deux populations continentales et une population côtière suivies dans le cadre de cette étude. Des indices montrent que ce parasite a probablement été introduit dans de nombreux lacs dulçaquicoles par les programmes d'alevinage réalisés à partir d'anguilles jaunes capturées dans les eaux côtières.

INTRODUCTION

The swimbladder parasite *Anguillicola crassus* was first recorded in Sweden in 1987. The first findings were made in two transit consignments of Polish silver eels and later the same year *A. crassus* was also found in an indigenous eel (HELLSTRÖM *et al.*, 1988). The development and spreading of *A. crassus* were studied by HÖGLUND between 1989-1993 (*e.g.* HÖGLUND *et al.*, 1992 ; HÖGLUND and ANDERSSON, 1993). During this period, *A. crassus* was mainly found in eels from coastal sites affected by thermal discharges but in 1989 *A. crassus* was found also in medium-sized yellow eels from the west coast of Sweden (HÖGLUND *et al.*, 1992). Such eels were, and still are, often used as stocking material for the eel stock enhancement programmes in freshwater lakes and

Article available at http://www.kmae-journal.org or http://dx.doi.org/10.1051/kmae:1998046

along the Baltic coast. Consequently, there was a risk for the spreading of the parasite through stocking programmes. Therefore, from 1987 and onwards, screening of *A. crassus* in all eels dissected at the Institute of Freshwater Research, Drottningholm, was implemented in the routine. In this long time study, we report on the colonization and rate of infection in three localities where eels were stocked for several years. The study was commenced in 1990.

MATERIAL AND METHODS

Study area

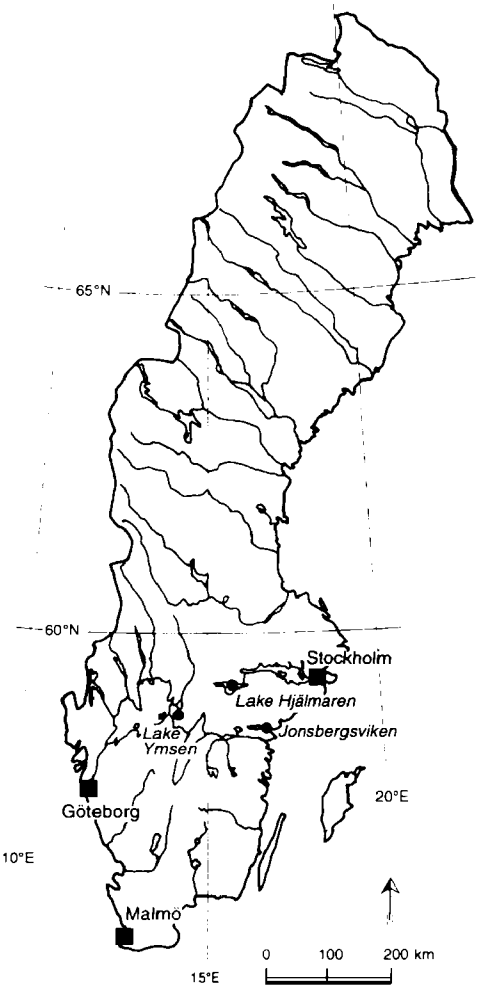

Figure 1
Map of Sweden with sampling sites indicated (1).

Figure 1
Carte de Suède indiquant les sites d'échantillonnage (1).

Two freshwater lakes and one sheltered cove of the Baltic were chosen for the study. Lake Hjälmaren and Lake Ymsen are in the central part of southern Sweden whereas the cove Jonsbergsviken is situated along the Swedish east coast in the same part of the country (Table I and Figure 1). The conductivity in Jonsbergsviken was in September 1991, 838 $mS.m^{-1}$, corresponding to a salinity of about 4.6 ‰. All three water-bodies have been stocked with yellow eels from the Swedish west coast for more than ten years, Lake Ymsen excepted, because the use of yellow eels was restricted in most

freshwater bodies from 1994. Since then, Lake Ymsen has been stocked with imported and quarantinized elvers. The yellow eels for restocking were normally between 300 and 500 mm with a mean length of 395 mm (HOLMGREN and WICKSTRÖM, 1988). Such eels were mainly caught from the near-shore sea along the Swedish west coast in the counties of Malmöhus, Halland and Bohus.

Table I

Morphometrical and physico-chemical data from the three studied water-bodies (data from various official sources).

Tableau I

Données morphométriques et physico-chimiques des trois réseaux hydrographiques étudiés (données de sources officielles diverses).

Lake	Location	Area (km^2)	Max. depth (m)	Secchi disc depth (m)	Conductivity ($mS.m^{-1}$)	pH	Tot-P ($\mu g.L^{-1}$)	Tot-N ($\mu g.L^{-1}$)
Ymsen	58 39'N 13 56'E	13.4	4.1	1.8	16.0	7.5	65	1.136
Hjälmaren	59 19'N 16 25'E	484.0	20.0	2.2	19.0	7.5	44	710
Jonsbergsviken	58 14'N 16 50'E	0.4	5.0	-	838.0	7.6	24	528

Sampling

The examined eels were mainly caught with small fyke-nets by local fishermen. The requested sample size was 100 eels from the first catch, *i.e.* normally from May to August. The eels were deep-frozen and then transported to the laboratory at Drottningholm where they were measured, weighed, sexed and classified as yellow or silver after thawing. The swimbladders were dissected and searched for parasites with the naked eye. This implies that only preadults and adults were detected. The parasites were counted and then preserved in 80 % ethylalcohol for identification. In addition to this sampling schedule, all other dissected eels at the institute were also examined. Since 1987 more than 4,200 additional eels from several localities, mostly freshwater lakes but also coastal areas, were examined for swimbladder parasites. Most of these eels came from the full-scale stocking experiments described by WICKSTRÖM (1986). In 1994, additional samples from Lake Vombsjön and Lake Ringsjön situated in the southern part of Sweden were also collected and examined.

Some additional results from studies made by two other Swedish institutes are also presented. The National Veterinary Institute has been screening eels caught along the west coast for stocking purposes, with respect to *A. crassus* and viral diseases. Yearly samples of 30-619 eels were analysed in 1987-1995, (1988 excepted), all together 2,569 eels. The Institute of Coastal Research has also screened all sampled eels from their research areas for *A. crassus* since 1988. They have searched for the parasite in samples from 15 coastal localities spread from the Norwegian border to about 60°30'N in the Baltic and in one river.

Statistical treatment of data

The occurrence of *A. crassus* is expressed as the percentage of examined eels that were infected, *i.e.* the prevalence as well as the mean numbers of parasites per swimbladder in infected eels, *i.e.* the mean intensity. All statistical tests were performed with SPSS for Windows, Release 6.1. Differences in prevalences between years were tested with χ^2-test and Fisher's exact test. The Mann-Whitney and Kruskall-Wallis tests were performed when testing for differences in intensity between years, while changes in the condition factor (according to BERG (1986)) were tested with T-test and with an ANOVA combined with a multiple range-test. To compare the length distributions of infected and non-infected eels, χ^2-tests (2*r contingency tables) were performed.

RESULTS

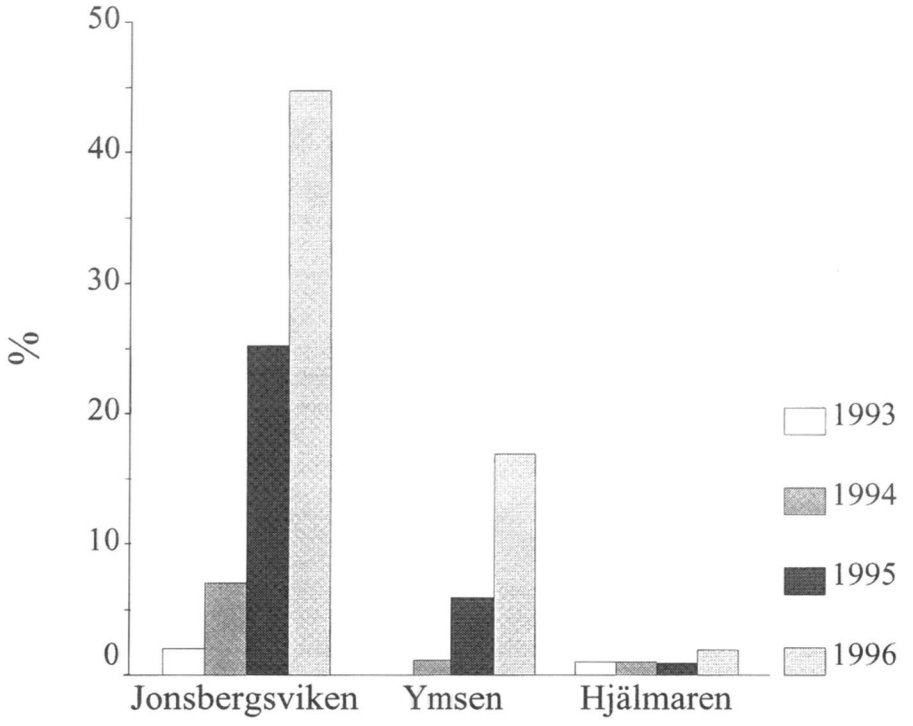

Figure 2
Prevalence of *A. crassus* in 1993-1996.

Figure 2
Prévalence d'*A. crassus* de 1993 à 1996.

The 2,098 examined eels were between 218 and 897 mm in length. The first records of *A. crassus* in this investigation were from Lake Hjälmaren and the cove Jonsbergsviken in 1993. Already the previous year one infected eel had been discovered in a sample of silver eels from Lake Hjälmaren. In 1994 all of the eel stocks were infected (Figure 2). In Lake Hjälmaren the prevalence and intensity of *A. crassus* remained very low during the whole study period. In both Ymsen and Jonsbergsviken the prevalence increased significantly ($p<0.05$) between 1995 and 1996 and in Jonsbergsviken a significant increase of *A. crassus* was also noted between 1994 and 1995. Intensities were generally low with a maximum of ten parasites. Still, the number of parasites significantly increased from 1.7 in 1995 to 3.0 in 1996 ($p<0.05$) in eels only from Jonsbergsviken (Table II). In Hjälmaren and Ymsen the differences in intensity between the years were not significant (Figure 3). When the condition between infected and non-infected eels in 1995 and 1996 were compared, a significant difference was found only in Jonsbergsviken 1996. The condition factor (see BERG, 1986) was higher in the infected eels (t-test, $p<0.05$). The length distribution of infected eels from Jonsbergsviken in 1995 was not different from the non-infected ones (χ^2, $p>0.83$).

Table II

Records of *Anguillicola* in 1990-1996. Figures within brackets include findings outside normal samples. Statistical tests of change are made from one consecutive year to another. S = significant difference ; NS = no significant difference, level of significance = 0.05 ; CI = confidence interval ; SD = standard deviation.

Tableau II

Observations d'*Anguillicola* de 1990 à 1996. Les chiffres entre parenthèses comprennent les résultats en dehors des échantillons normaux. Les tests statistiques des variations sont réalisés consécutivement d'une année à l'autre. S = différence significative ; NS = pas de différence significative, niveau de signification = 0,05 ; CI = intervalle de confiance ; SD = déviation standard.

		Sample size	Records	Prevalance		Intensity (no. of parasites / infected eel)			
		n	n	%	S / NS	mean intensity +/- 95 % CI	SD	max. intensity	S / NS
Jonsbergsviken	1990	59	0	0					
	1991	102	0	0					
	1992	99	0	0					
	1993	100	2	2.0	NS	1.0	0	1	-
	1994	100 (102)	7 (8)	7.0 (7.8)	NS	1.0 (2.1 +/- 2.7)	0 (3.2)	1 (10)	-
	1995	107	27	25.2	S	1.7 +/- 0.5	1.4	6	NS
	1996	103	46	44.7	S	3.0 +/- 0.7	2.2	10	S
Ymsen	1990	104	0	0					
	1991	111	0	0					
	1992	127	0	0					
	1993	104	0	0					
	1994	93	1	1.1	NS	2.0	-	2	-
	1995	102	6	5.9	NS	1.0	0	1	-
	1996	58	10	16.9	S	1.8 +/- 1.1	1.5	6	NS
Hjälmaren	1990	100	0	0					
	1991	114	0	0					
	1992	100 (194)	0 (1)	0 (0.5)	NS	0 (1.0)	- (-)	0 (1)	
	1993	102	1	1.0	NS	1.0	-	1	-
	1994	98	1	1.0	NS	1.0	-	1	-
	1995	106	1	0.9	NS	1.0	-	1	-
	1996	108	2	1.9	NS	1.0	0	1	-

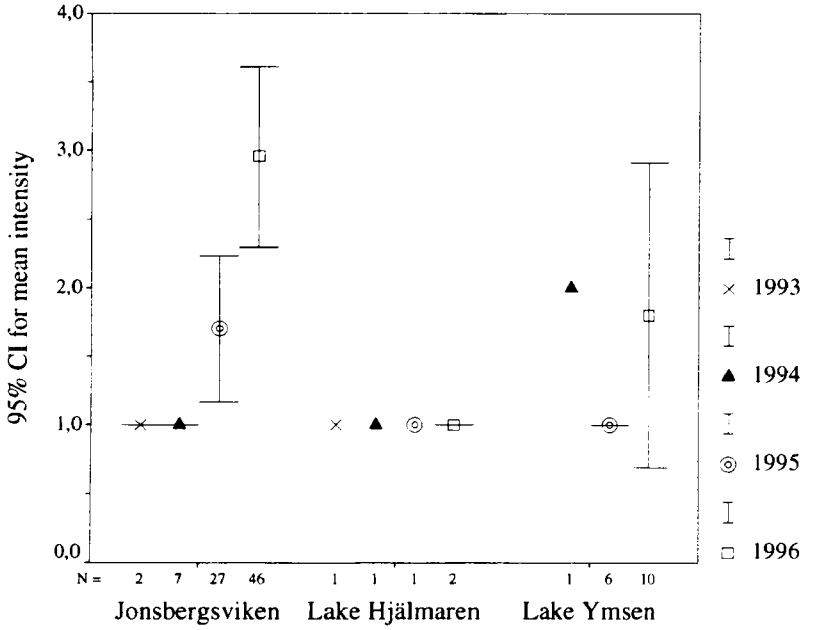

Figure 3

Intensity of *A. crassus* in 1993-1996.

Figure 3

Intensité d'*A. crassus* de 1993 à 1996.

Among the additional eels examined, *A. crassus* was found in eels from Lake Hjälmaren (1992, as above-mentioned), Lake Vombsjön (1994), Lake Ringsjön (1994) and from Lake Ången (1995). In Lake Vombsjön and Lake Ringsjön the prevalence was 22 and 35 %, respectively and the intensity 1.9 and 1.5, respectively. From coastal areas there were two records from silver males caught in 1991 and 1992 at Aspöja close to Jonsbergsviken (M. REIZENSTEIN, pers. comm.).

From the studies made by the National Veterinary Institute on west coast eels for stocking purposes, the first two findings were made in 1989 close to the River Göta älv estuary (which is close to Gothenburg). In 1991 there were also some findings from coastal sites farther to the north, followed by occasional findings in 1993 and 1994. The prevalence was low, never exceeding 8 %. Some sites were free from *A. crassus* during the whole period despite the proximity to infected areas. Beside these findings, infected ascending eels were found from River Göta älv in 1995 (35 % prevalence) (A. HELLSTRÖM, pers. comm.). The screening for *A. crassus* in all eels sampled by the Institute of Coastal Research since 1988 shows that 13 out of 15 coastal localities were infected with the parasite. Prevalence was high primarily in areas with thermal discharge (nuclear power plants) although there was an undisturbed archipelago in the Baltic Sea with very high prevalence of *A. crassus*. Only the isolated archipelago of Kosteröarna in Skagerrak is in recent samples free of *A. crassus*. Both intensity and maximum number of parasites per swimbladder were generally higher compared with eels in our own study (H. SVEDÄNG, pers. comm.).

DISCUSSION - CONCLUSION

The three freshwater localities in our study were all infected three to five years after the first record of *A. crassus* was made from a sample of stocking eels caught in the Skagerrak. Since two of the three water-bodies concerned are situated quite far upstream from the Baltic where natural ascending eels nowadays are rare, we suggest that *A. crassus* was introduced via the stocking material. The same is probably true for Lake Vombsjön and Lake Ringsjön. How the parasite was introduced to eels in the cove Jonsbergsviken, which is connected with the Baltic, is an open question. There have been some earlier records (in 1988, 1991 and 1992) of infected eels from sites in the vicinity of Jonsbergsviken. At the same time, this small cove has been stocked with yellow eels from the Swedish west coast at several occasions. Lake Vombsjön and Lake Ringsjön in southern Sweden probably were infected some years before the time of sampling in 1994 as the prevalence and intensity were already quite high. Lake Vombsjön for example was known to be infected already in 1993 (J. HÖGLUND, pers. comm.). These lakes have also been stocked annually with large numbers of yellow eels from the west coast. The single record from Lake Ången in 1995, which is situated to the north of Jonsbergsviken, was from an ascending eel trying to pass an eel trap for descending silver eels. Whether that eel originated from the sparse stock of natural recruits or from eels stocked in the Baltic is unknown. Likewise are the prevalence and intensity of *A. crassus* unknown in that lake.

The rate of increase in infection levels is quite low in most of the eel populations included in this study if compared with the development of the parasite in sites affected by thermal discharges close to some nuclear power plants in Sweden (HÖGLUND *et al.*, 1992), in the archipelago in the south-easternmost part of Sweden (H. SVEDÄNG, pers. comm.) and in Europe in general (*e.g.* HAENEN, 1995). The explanation for this is unknown, but might be due to comparatively sparser stocks of eels in most of the lakes and also the lower temperatures in this part of Sweden, not allowing the parasite to reproduce as efficiently as in denser eel populations living in warmer climates. The eels from the cove Jonsbergsviken exhibited a lower condition factor than eels from the other two study lakes, possibly indicating a denser population that might facilitate the spreading.

There are no direct estimates of eel densities in the three lakes. However, the catches per unit of effort when obtaining the samples indicate that Jonsbergsviken has a more dense population of eels compared to Lake Ymsen. CPUE from Lake Hjälmaren was much lower. Differences in the feeding habits of eels living in lakes might be an additional explanation. For example, eels from Lake Ymsen feed on chironomids which have not been reported as an intermediate host for *A. crassus*.

Although the infection rate was low in many sites receiving stocking material in Sweden, we have reasons to believe that *A. crassus* are established in most lakes receiving yellow eels as a stocking material. *A. crassus* will probably also spread to most eel stocks with an open access for natural recruits ascending from the Baltic. Although there are very few case-reports of direct mortalities in wild eels due to *A. crassus* (*e.g.* HAENEN, 1995), an already threatened species like the European eel would at least not gain on hosting a blood sucking nematode in its swimbladder.

ACKNOWLEDGEMENTS

The authors are grateful to our colleagues K. HOLMGREN and M. REIZENSTEIN who did some of the dissection work and to H. SVEDÄNG at the Institute of Coastal Research along with A. HELLSTRÖM at the National Veterinary Institute allowing us to use their unpublished results from the coastal sites.

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