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Short communication

Old timers from the Baltic Sea: Revisiting the population structure and maximum recorded age of ide *Leuciscus idus*

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ABSTRACT

Population age structure of ide *Leuciscus idus* in the eastern Baltic Sea was investigated using samples from three sites in the Väinameri Sea. Using the otolith thin sections for the first time on ide otoliths, a new maximum age of 29 years was observed. It is suggested that otolith thin sections should be preferred to scales if clear-cut and accurate age determinations of ide are desired. The results demonstrated that ide population in the Baltic Sea may consist of individuals with more variable age range than previously reported. There was a significant difference in adult age structure among study sites (spawning stocks), which was also reflected in the overall abundance of ide in the particular site. Higher growth rates were recorded compared to historical datasets collected from the same region. A strong positive relationship between age and otolith weight was observed. Potential factors behind the differences in age structure and abundance among study sites are discussed.

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1. Introduction

Ide, *Leuciscus idus*, is a large-bodied cyprinid that lives naturally in Europe and Asia. Generally ide is considered a freshwater species that inhabits large lowland rivers and nutrient-rich lakes (Kuliskova et al., 2009; Winter and Fredrich, 2003). However, in the brackish Baltic Sea where salinities are mostly below 10 psu, ide spawns in freshwater but otherwise lives in the sea, therefore displaying anadromous behavior (Müller and Berg, 1982). The sea offers more favorable feeding and living conditions, resulting in higher growth rate and body size compared to freshwaters (Järvalt et al., 2003). This allows to maximize fitness in terms of higher fecundity (McDowall, 1988; Müller and Berg, 1982). High growth rate in the sea makes ide an attractive target for small-scale commercial and especially recreational fisheries, although the overall landings are currently low. In Estonia ide is relatively abundant only around Hiiumaa Island; the historically important mainland (Matsalu and Saunja Bay) and Saaremaa Island (Nasva River) spawning stocks are in the lows (Järvalt et al., 2003; Eschbaum et al., 2014).

Age data is vital when estimations on growth rate, mortality rate and productivity are desired. The only peer-reviewed study on ide age used scales and was conducted with female fish that originated from a Polish freshwater lake (Targońska et al., 2012). Unfortunately, the growth rate was not in the scope of their study as only pre-spawn total weights of fish were provided. However, few scale-based studies on age and growth rate of Baltic Sea ide are published as grey literature (Cala, 1975; Järvalt et al., 2003). According to Fishbase (accessed in January of 2015) the maximum recorded age of ide is 18 years. However, a 28-year old specimen was reportedly caught near Vaasa, Finland (Segerstråle, 1950). Although Segerstråle does not specify the methods used in age determination process, it can be assumed that scales were used as this was the common practice at that time. A more recent publication from Finland states that the maximum reported age of ide in Finland is 23–24 years based on scale readings (Raitaniemi et al., 2000).

Otoliths are generally preferred to scales in aging a fish because they grow continuously and are metabolically inert (Campana and Thorrold, 2001). Scales are usually harder to read and they may also contain incomplete growth history due to loss of scales, leading to under- or overestimation of age (Campana, 2001; Howland et al., 2004; Raitaniemi et al., 2000). In cyprinids, the largest otolith is lapillus and it is therefore preferred over sagitta, which is usually used in aging a fish. As cyprinid lapillus is oddly shaped, thin section should be the best option to choose when accurate age estimates are desired (Raitaniemi et al., 2000). However, otoliths have the disadvantage that they require sacrificing the fish, which may be a serious problem when dealing with endangered species or

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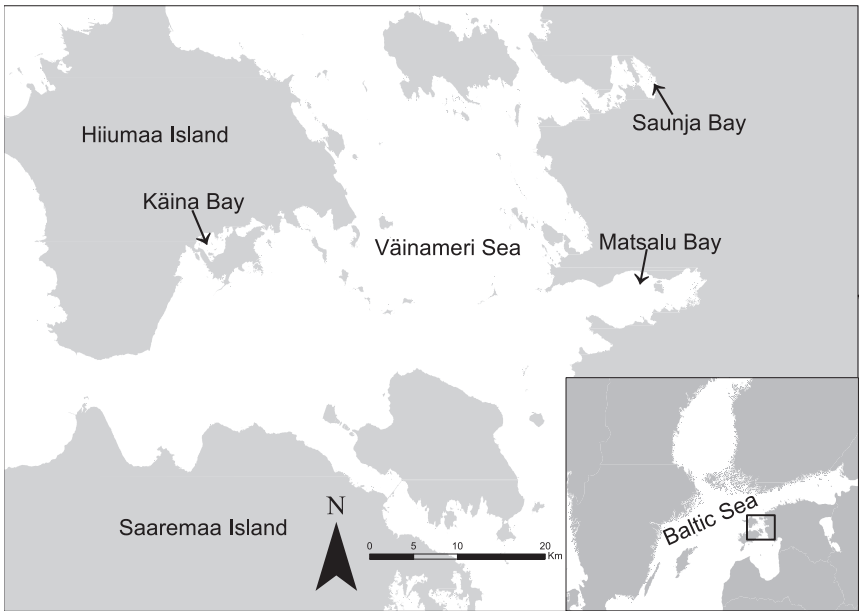

Fig. 1. Ide sampling sites from the Väinameri Sea, Baltic Sea (indicated with arrows).

population. Therefore, non-lethal collection of scales, and especially fin rays may be the best options in some cases (Howland et al., 2004; Zymonas and McMahon, 2009).

The aim of this study was to investigate the age structure of ide population sampled from three sites in western Estonia, Baltic Sea. Length at age estimates obtained in this study using otolith this sections were compared to similar scale-based data from the past. Also, the relationships between age, otolith weight and total length were investigated.

2. Materials and methods

2.1. Sample collection

A total of 141 ide were collected from three sites around Väinameri Sea (Fig. 1, Table 1). Käina Bay (KB) adult sample was obtained with gillnets as a part of another project in 2010, so extra sampling was not necessary. Matsalu Bay (MB) samples were purchased from a local fisherman in 2010–2013. Saunja Bay (SB) samples were collected in 2012–2013 with gillnets. A limited sample size was used in MB and SB because the numbers of ide are low at those sites (Eschbaum et al., 2014). All the sampled individuals were post-spawners or juveniles. For most of the individuals, total length (TL, 1 mm), total weight (TW, 0.1 g) and sex were recorded and otoliths (lapillus) removed immediately after capture. Some individuals were frozen by the fisherman and later thawed for analysis. Otoliths were cleaned and stored dry in micro-tubes.

2.2. Otolith preparation

Before processing, both otoliths were weighted to the nearest 0.1 mg. There were no differences between the weight of left and right otolith (paired *t*-test, $P = 0.1$); therefore, one otolith was chosen randomly for further preparation. As the cyprinid lapillus is oddly shaped and thick, it cannot be viewed directly for age determination. Raitaniemi et al. (2000) used otolith thin sections to age cyprinids like bream (*Abramis brama*) and white bream (*Blicca bjoerkna*). This method was also tested on ide in the present study and it turned out that frontal thin section is the best way to section ide otoliths. Therefore, otoliths were embedded into epoxy resin and subsequently a frontal thin section was obtained by grinding both sides of the block with silicon carbide sandpapers until the core was visible from one side. To improve the clarity of the thin sections, they were stained for 15 min in a solution of neutral red (1%) and acetic acid (0.5%) in distilled water. This resulted in clear-cut thin sections for most of the otoliths (Fig. 2).

2.3. Age and growth

Ages were determined by one experienced reader by counting the narrow winter zones on stained otoliths. This was done twice without any reference to fish TL and catch date. To estimate the precision of these readings, index of average percent error was calculated (IAPE) (Beamish and Fournier, 1981):

$$\mathrm{IAPE} = 100\sum_{j=1}^{N_A}\left(R^{-1}\sum_{i=1}^{R}\left|X_{ij}-X_j\right|X_j^{-1}\right)N_A^{-1},$$

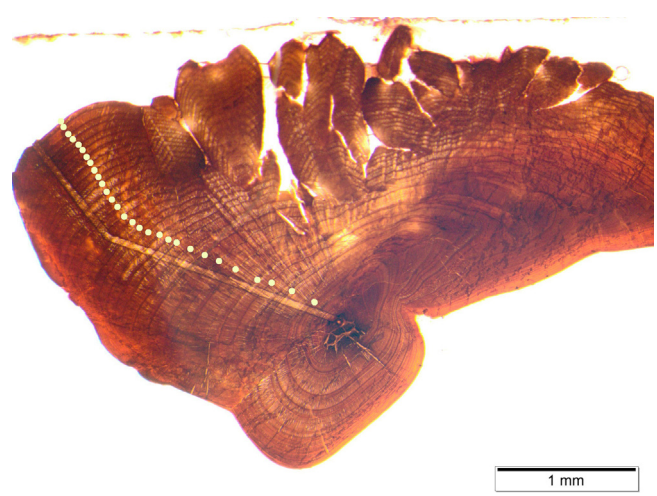

Fig. 2. Neutral red stained otolith thin section of a 29 year old ide caught from Saunja Bay. The light line on the otolith is the resultant crater from microchemical analysis (M.Rohtla, unpublished data). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Recorded biological parameters from the sampled locations expressed as mean ± SD and range. F:M denotes females to males sex ratio.

Site	Coordinates	*n*	TL (mm)	F:M	Otolith weight (mg)	Age (years)
Käina	58°48′33.6954″N	89	384 ± 139	38:33*	17.8 ± 10.8	6.5 ± 4
Bay	22°47′ 37.068″E		68–521		0.6–57.3	1–24
Matsalu	58°45′32.256″N	25	454 ± 77	11:14	32.2 ± 20.8	10.9 ± 7.5
Bay	23°38′56.9394″E		222–568		4.4–82.4	3–27
Saunja	58°58′44.508″N	27	522 ± 69	10:17	43.6 ± 20.4	16.2 ± 8.5
Bay	23°38′13.7034″E		207–587		4.4–83.5	3–29

* Seventeen individuals were juveniles and one could not be sexed.

where N_A is the number of aged fish, R the number of times each fish was aged, X_{ij} the ith reading of the jth fish and Xj the mean age of the jth fish. If the two counts of the same individual were different, final ages were determined by a third reading (i.e. by consulting with previous readings).

As with other fish species (Campana, 2001), the most difficult part in aging ide using otoliths is to determine the first annulus, because this period is usually crowded with various pseudo-annuli. Therefore, extra care was taken in assuring that this was done correctly. This included sampling additional 1+ and 2+ fish from KB in 2013 to learn about the placement of annuli (i.e. radius measurements of the age determination axis and inspection of marginal increment; Campana, 2001). Absolute age of ide is not validated nor has the periodicity of increment formation never been validated. Age validation methods like marginal increment analysis or edge analysis can be used for confirming annual formation of annuli if samples are collected throughout the year (Campana, 2001). Unfortunately, these methods could not be used in the present study because almost all the samples were collected during spring when ide concentrates to the spawning grounds and is therefore easier to catch. As the numbers of ide are relatively low and there is no ide targeted sea-fishery in Estonia, it is hard to collect them during other months. However, some samples were collected in autumn and these did suggest that annuli is formed on an annual basis in ide. Annuli formation is completed in the beginning of May.

Obtained length at age data was compared to similar scale-based data from the past (Cala, 1975; Järvalt et al., 2003). The fish from the first Estonian historical dataset (n = 500) were sampled in the 1980s from Kasari River which is the major tributary of MB. The fish from the second Estonian historical dataset were sampled in the 1980s from Nasva River (n = 504) that is located in southern Saaremaa Island. Nasva River together with the inland lakes supported the largest runs of anadromous ide in the past (Järvalt et al., 2003). The fish from the historical Swedish dataset (n = 432) were sampled from an anadromous population in the 1960s from Kävlingeån River that drains into Øresund Strait (Cala, 1975). Those fish spend their marine life stage in salinities of 10–20 psu, which is also the known salinity maximum for ide. Data from the Swedish dataset was not included to statistical tests, and it is presented just for comparative purposes. To our best knowledge, these are the only published studies on ide growth rates.

All the statistics were performed in Statistica. Nonparametric Kruskal–Wallis ANOVA was used to see if the determined ages for adult fish collected in the present study differed among sites. All the juveniles were excluded from this test as KB sample contained 17 juveniles and it was reasoned that this would bias the overall differences as only one juvenile per site was sampled in MB and SB. Standard t-test was used in other cases.

3. Results

3.1. Age and growth

High age range was observed in all three sites although the age structure was more skewed towards older individuals in MB and SB

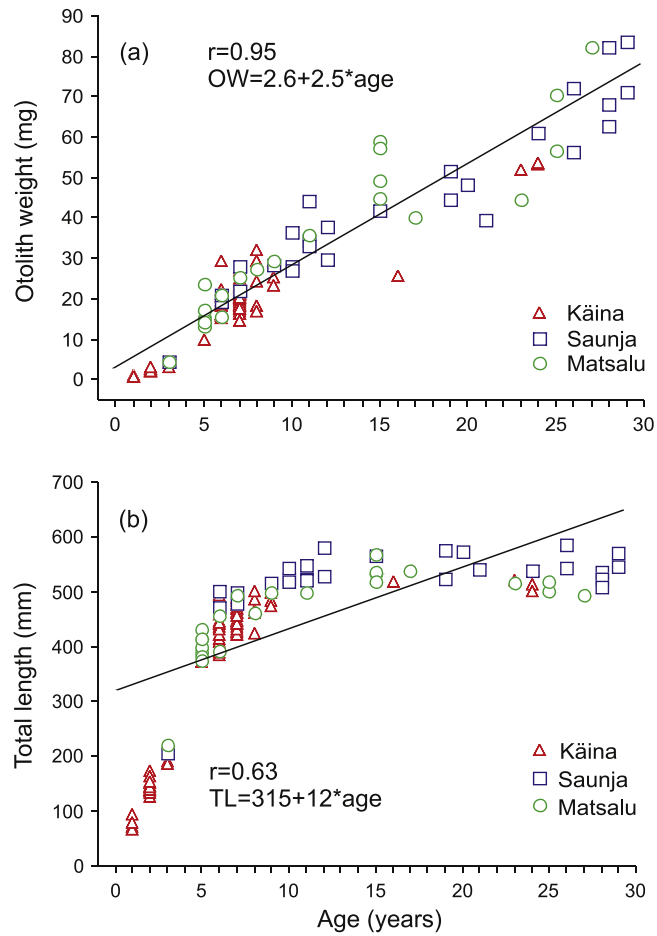

Fig. 3. Observed relationship between (a) age and otolith weight, and (b) age and total length of ide.

(Table 1, Fig. 3). The data for males and females was pooled because there was no evident difference between them and the sample sizes were relatively small. Furthermore, it is known that male and female ide from the Baltic Sea grow at the same rate (Järvalt et al., 2003). There was a significant difference in mean adult age among sites (K–W, P < 0.001). A new reported maximum age of ide was recorded in two individuals, being 29 years at the time of capture. A total of 19 fish were 19+ years old with 10 of them being 25+ years old suggesting that the oldest individuals were born in the 1980s when the historical Estonian datasets were collected.

Ide growth was relatively fast during first seven years after that it slowed down and reached a plateau at about 10 years of age (Fig. 3b). Although the detailed data for the Estonian historical datasets were not available, attempts were made to statistically compare the historical mean length at age estimates to the results obtained in present study. As there was no difference between Kasari and Nasva River mean length at age estimates (paired t-test, P = 0.76), these datasets were combined. The data from the

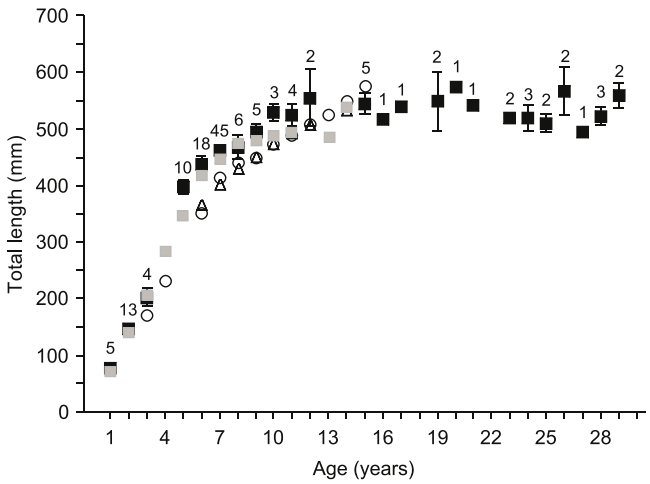

Fig. 4. Available length at age data for ide from the northern range. Black squares: this study; data given as mean ± 2SE. Open circles: Kasari River; data given as means (Järvalt et al., 2003). Open triangles: Nasva River; data given as means (Järvalt et al., 2003). Grey squares: Kavlingeån River; data given as means (Cala, 1975). The number above each plot indicates sample size for the present study. Note that there are several age groups missing in all datasets.

present study was also combined to increase the sample size per age group. This resulted in nine matching age groups and significant difference between the modern and historical datasets (paired *t*-test, $P = 0.003$). Ide sampled in present study grew faster than ide from the historical Estonian datasets, at least during fast growth phase (Fig. 4). The growth rate data from Cala (1975) was more similar to the data from present study (Fig. 4).

3.2. Precision of aging

The precision of aging fish was high (IAPE = 1%). Of the 141 aged otolith thin sections, only nine resulted in discrepancy between the two readings. Seven of them differed by one year and two of them by two years. This aging inconsistency was mostly related to staining failures (i.e. neutral red did not bind with the otolith surface), but also to false annuli which were identified as incomplete and vague annuli.

3.3. Age, otolith weight and total length relationships

There was a strong positive correlation between age and otolith weight ($R = 0.95$; $P < 0.001$) (Fig. 3a), although there was a considerable overlap in otolith weight among age groups. The correlation between age and TL was also positive, but considerably weaker ($R = 0.63$; $P < 0.001$) (Fig. 3b). The relationship between age and otolith weight (OW, the predictor) was best described by a polynomial function: $\text{age} = 0.0009 \times \text{OW}^2 + 0.2924 \times \text{OW} + 0.7826$ ($R^2 = 0.9$; $P < 0.001$).

4. Discussion

Present study showed that ide population in the eastern Baltic Sea may consist of individuals with a wider age range than previously reported. This might have both positive and negative impacts on population viability. For example, presence of really old individuals within otherwise healthy spawning stock (e.g. Käina Bay) may show that part of the spawning stock has a life history that minimizes mortality and as such, allows them to reproduce for many years. This may include fast spawning migrations to freshwater (i.e. spawning just after ice break up or even earlier and returning immediately to the sea) and sea-life further away from the coast where fishing pressure is lower. However, older ide may produce eggs with lower biological quality or not reproduce at all (Targońska et al., 2012) and therefore may have limited positive influence on spawning stock viability, especially when they dominate (e.g. Saunja and Matsalu Bay). Targońska et al. (2012) studied freshwater resident ide and showed that the oldest age group in their study (9+) had the highest percentage of dead embryos during incubation and also the highest percentage of morphological abnormalities in hatched larvae.

Käina Bay (KB) spawning stock had the youngest age structure as evidenced by prevalence of 5–7 year old adults. This was to be expected as KB spawning stock is abundant and reproduction seems to be successful on a yearly basis as the numbers of juvenile fish have recently increased in the region (Eschbaum et al., 2014). The current situation is quite the opposite in Matsalu Bay (MB) and Saunja Bay (SB), where spawning stock biomasses are low and juvenile fish are rare. This is also reflected in the age structure of these spawning stocks as older individuals dominate. All these suggest that, for some unknown reason, reproduction of MB and SB ide is disturbed on a yearly basis. It can be hypothesized that the quality of spawners is low due to skewed age structure (Targońska et al., 2012) which leads to minimal recruitment. Alternatively, it may have something to do with unfavorable environmental conditions and/or inter-species competition. Ide competes for food and/or nursery grounds with other cyprinids such as roach (*Rutilus rutilus*), white bream, rudd (*Scardinius erythrophthalmus*) and gibel carp (*Carassius gibelio*), all of which are abundant in MB and SB, but nowadays practically absent around Hiiumaa Island. These hypothesis deserve further investigation in the future.

Differences in age structure and overall ide abundance among study sites suggests that subpopulations (stocks) may occur in the Väinameri Sea. First, it seems that ide from the large islands (including KB) do not mix with ide from mainland (MB and SB), although ide is capable of performing long migrations (Kuliskova et al., 2009; Winter and Fredrich, 2003). If they did mix, then it would increase the abundance of low-numbered mainland ide. However, this has not happened (Eschbaum et al., 2014). Furthermore, Winter and Fredrich (2003) reported natal homing for ide and this could be the main factor responsible for population structuring in ide. Unfortunately, there are no genetic, morphological or ecological studies that can support the proposed subpopulation hypothesis and it should be therefore investigated in the future.

Two 29 year old and multiple 20+ ide were recorded in this study. To our best knowledge this is the new maximum reported age for ide. Segerstråle (1950) reports a maximum age of 28 years in Finland, but a recent source from the same country reports a maximum age of 23–24 years (Raitaniemi et al., 2000). It must be stressed that all of those previously reported readings are from scales. Scale readings often result in age underestimation, especially when working with scales from long-lived species in which fewer annuli are discernable as fish age (Francis et al., 1992; Yule et al., 2008). However, the same can happen with otoliths (Campana et al., 1990). Furthermore, one could also overestimate the age (Andrews et al., 2011; Lessa et al., 2008). This is highly possible when working with ide scales as we have observed numerous pseudo-annuli throughout the scale. Regarding the otolith thin section readings conducted in this study, we did not observe that annuli were crowded even in the otolith edges of the oldest individuals. For the most part, annuli were clear and discernable. The only source of error may come from identification of the first annulus, but this will bias the age only by one year. Therefore, we are relatively confident in our readings. Interestingly, previous studies from Estonia did not record such high ages from the scales (Järvalt et al., 2003). This could mean that they underestimated the ages. Alternatively, this may be the result of changed population dynamics due to modifications in environmental conditions and/or fishing pressure. The latter is also supported by faster growth rates

observed in the present study compared to the historical datasets from the same region, although this too depends on accuracy of age estimates.

A strong positive relationship between fish age and otolith weight was recorded in this study. The oldest individuals also had the heaviest otoliths, while TL and TW of those fish were often similar to fish that were 2–3 times younger. Several authors have reported a close relationship between otolith weight and fish age and have used this to estimate age using only otolith weight (Boehlert, 1985; Cardinale and Arrhenius, 2004). However, this can be done accurately only with species with fast growth rates, low longevity and discrete age groups. For example, Britton and Blackburn (2014) studied three flatfish species and reported that otolith weight and total length were highly age group specific which allowed them to estimate ages with relatively high accuracy. This is not the case in the present study, regardless of the strong positive relationship between otolith weight and age. Otolith weight overlap among age groups was too extensive to accurately estimate ide age. However, rough age estimates can be made using otolith weight, especially if the aim is to obtain fast population age structure estimations.

In conclusion, this study demonstrated that ide population in the Baltic Sea may consist of individuals with high age range. Spawning stock with the lowest average age was also the most abundant and vice versa. This draws attention to serious recruitment problems in some of the investigated areas and calls for looking into these issues in the future. A new maximum age of 29 was reported. It is suggested that frontal thin sections of lapillus should be used in ide age determination.

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