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Estimation of vendace year-class strength with different methods in the subarctic lake Inari

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Vendace (*Coregonus albula*) is a new introduced species in the Paatsjoki river system and lake Inari; it has only got a 30- to 40-year history in the area. The strong vendace year-classes of the 1980s were followed by weak ones until 2000, when a stronger year-class emerged. Data on the vendace catch-at-age were collected from 1987 to 2001 and the year-class strengths (YCS) were estimated by the virtual population analysis (VPA). The YCS was estimated directly by survey trawling conducted annually in early fall aimed at 0+ fish and by seine netting in the following winter. Direct estimates were compared with VPA estimates. The trawl survey and winter seine data show that the YCS of vendace is discernible during the first year of their lifespan. As a practical application in fisheries management, these data can be used in adjusting of e.g. stocking of predatory salmonids.

Introduction

Coregonid fish, especially vendace (*Coregonus albula*) often show large variation in their year-class strength (YCS) and hence, in their entire populations. Vendace stocks have shown to be extremely variable in many Finnish lakes (e.g. Viljanen 1986, Helminen *et al*. 1993, Valkeajärvi & Marjomäki 2004). In subarctic lake Inari, vendace is a new introduced Coregonid species among many indigenous polymorphous European whitefishes, such as the dwarf whitefish, called reeska (*Coregonus lavaretus*). At present, vendace and reeska are the most important prey species for predatory salmonids. Vendace in lake Inari is north of its natural distribution area and the history of vendace is short, only about 30–40 years in the lake. It was introduced into the whole watershed for the first time in 1956 and then between 1964 and 1966. Vendace was first observed in lake Inari in 1973 (Sergejeff 1985) and registered in the catch statistics since 1983 (Mutenia & Salonen 1992). Vendace has also invaded downstream from lake Inari, to the Paatsjoki river system and was observed for the first time in Norway in 1989 (Amundsen *et al*. 1999, Bøhn & Amundsen 2001).

According to earlier studies, factors such as density dependence, spawning stock size, biomass and fecundity, spring weather conditions, predation and fishing can play a role in the determination of YCS of vendace (Auvinen 1995, Karjalainen *et al*. 2000). In lake Inari, the water temperature, the size of the spawning stock, fisheries and the predation of salmonids have all been suggested as factors in the varia-

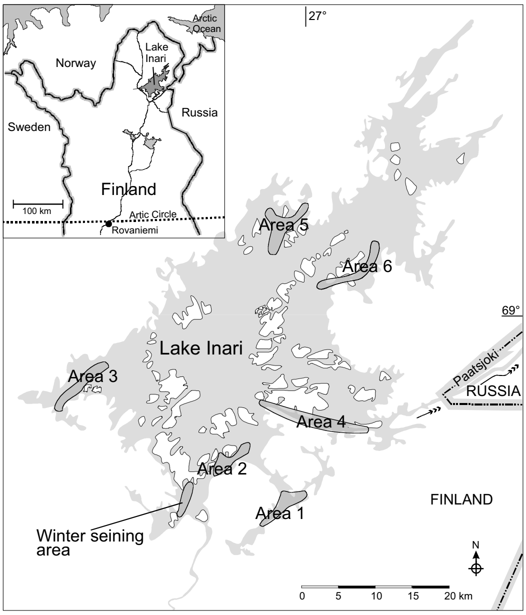

Fig. 1. The location of lake Inari and the sampling areas of survey trawling (numbered 1–6) and the winter seining area.

tions of stocks (Salonen 1998). Large variations in vendace YCS have created a growing need to detect these variations as early as possible, through the regular monitoring. In this study, my aim was to examine and compare data on vendace YCS gathered with different methods: (1) catch-at-age data/virtual population analysis (VPA); (2) catch per unit of effort (CPUE) in survey trawling aimed at the 0+, young-of-the-year (YOY) fish, in early autumn; and (3) CPUE in winter seining during the following winter aimed at the same year-class.

Study area

Lake Inari (69°N, 28°E) is a central lake of the Paatsjoki river system, flowing into the Arctic Ocean. It has been regulated since the 1940s. It is a subarctic large lake (1100 km^2), covered by ice six to eighth months of the year (Fig. 1). It is a deep (max. 95 m) and oligotrophic lake, with excellent water quality. The Sechi disc transparency is of about 4 m in the southern areas and even 10 m in the northern areas. Total phosphorous content is from 3 μg (northern area) to 6 to 7 μg l^{-1} (southern area) (Marttunen *et al*. 1997). Lake Inari is today inhabited by 10 native fish species, of which the whitefish includes several forms. The lake also has three introduced fish species; vendace, lake trout (*Salvelinus namaycush)* and land-locked salmon (*Salmo salar m. sebago*) of which only the vendace has so far developed into a naturally reproducing population.

Material and methods

The vendace catch and fishing effort data have been collected annually since 1987 both by mail inquiries and bookkeeping (compulsory for trawls and trap nets). The vendace samples have been collected regularly from all lake areas since 1987 from the catches taken by different gear, mostly from commercial fisheries, for an analysis of length, weight, sex, maturity and age (Table 1). Age of fish was determined from the scales. Age distribution and mean weight were determined by each gear. The realised yield of year-classes since 1983 was calculated based on yearly catch statistics, age distribution and the average weight of age groups by the gear used. VPA was used to assess the size of year-classes (Pope 1972). The natural mortality of 0.3 was applied for all age groups and years (Auvinen & Jurvelius 1994, Salonen 1998). The number

Table 1. The number of sampled and aged vendace in lake Inari in 1987–2001.

Year	Trawl	Trapnet	Winter seine	Gillnets	Total
1987	1682	78	0	0	1760
1988	1541	1073	1720	161	4495
1989	5852	1148	1423	200	8623
1990	995	1230	2108	156	4489
1991	1882	636	1497	397	4412
1992	925	162	1119	105	2311
1993	298	13	534	279	1124
1994	460	67	316	838	1681
1995	485	13	289	687	1474
1996	493	269	521	545	1828
1997	506	64	329	296	1195
1998	243	155	484	202	1084
1999	233	44	100	192	569
2000	189	33	200	166	588
2001	122	29	132	103	386

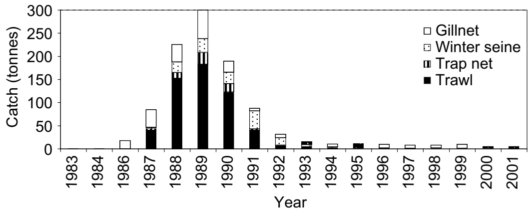

Fig. 2. Vendace catch by different gear in lake Inari until 2001. Data for 1985 not available.

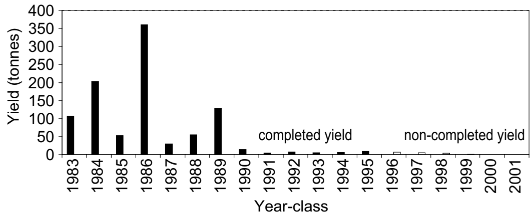

Fig. 3. Realised vendace yield (kg) by year-class from 1983 to 2000 during the years 1987–2001.

of one-year-old fish given by VPA was used to indicate vendace YCS.

The survey trawling, aimed at obtaining an index of the abundance of the YOY fish for both vendace and reeska (data on reeska excluded in this paper), was done at the beginning of September from 1993 to 2001. Trawling in 1993–1994 was carried out with an 8-meter-deep, and since 1995 with a 12-meter-deep pelagial trawl, which was dragged below the surface by two trawlers. The mesh size of the trawl cod end was 8 mm and the width of the trawl mouth in the normal towing situation was around 30 m. Our survey trawl was the same size as the average size commercial trawls in lake Inari, and hence, much bigger than a few survey trawls used elsewhere in smaller inland waters (e.g. Müller *et al.* 2002, Sutela *et al.* 2004). Annually 15 to 22 tows, each usually lasting 50 min., were made at twilight. Since 1994 the same trawling areas have been used (Fig. 1). Results of the first years (1993–1994), were altered by the change from the 8- to the 12-meter-deep trawl, assuming that there was an even distribution of fish around that layer. The number of YOY vendace (total length averaged 7–8 cm) caught in each tow were counted per trawling hour. The YOY by areas were counted by arithmetical means usually taken from three tows. These annual mean values of YOY, which are primarily to be taken as relative density estimates, were compared with corresponding YCS estimates from VPA, utilizing the Spearman correlation analysis.

The professional winter seining targeting on vendace (Mutenia & Salonen 1992) has focused on the southern part of the lake. In recent years, it has been performed by only one team. They have dragged a winter seine (height 16 m, seine bag 8 mm) in one or two towing places, about 10 km from the survey trawling area number 2 (Fig. 1). Annual samples of winter seine fishing, between January and April have been taken since 1996, between two to four seinetows. The number of one-year-old vendace (total length averaged 8–9 cm) per tow was estimated, usually from subsamples. Their abundance was compared with corresponding year-classes YOY (1995–2001) caught during the previous autumn by the survey trawl, and with YCS estimates by VPA.

Results

The vendace catch dropped from over 300 tonnes in 1989 to only 5 tonnes in 2000 and 2001 (Fig. 2). The realised yield by year-classes varied dramatically. According to 15-year catch-at-age data, the year-classes of vendace in lake Inari were seldom strong. After strong year-classes in the 1980s, the last in 1989, only weak year-classes emerged. Every year-class in the 1990s has produced a poor yield although the yield is still incomplete and lacking the year-classes 1996 and younger (Fig. 3). The number of YOY vendace by the survey trawl were low between 1993 and 1999, in all areas, but increased in 2000 to around a hundredfold in some trawling areas. In the southern survey trawl area (number 2) we caught so huge a number of YOY vendace that the estimate for abundance is quite rough because of technical problems in lifting up the trawl cod end weighing a couple of hundred kilos (Fig. 4). The average number of YOY vendace by the survey trawl and the following number of one-year-olds by winter seine in the southern study area show that year-classes 1995, 1996 and 1999 were weak. Both methods show that year-class 2000 was good (Fig. 5). The average number of YOY by trawling (all areas) cor-

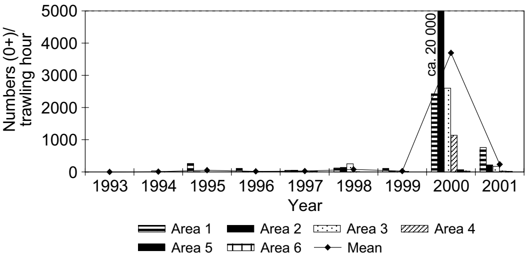

Fig. 4. Numbers of 0+ vendace per trawling hour by survey trawling (area 1–6 and the mean value of all areas) in lake Inari in 1993–2001.

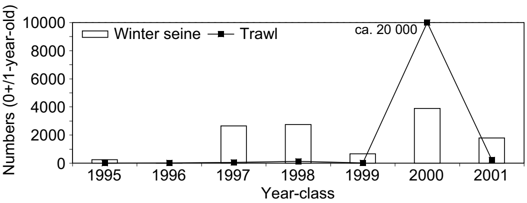

Fig. 5. Numbers of 0+ vendace per trawling hour and corresponding one-year-olds per winter seine drag by year-class 1995–2001 in the southern study area (survey trawl area number 2/winter seine area) in lake Inari.

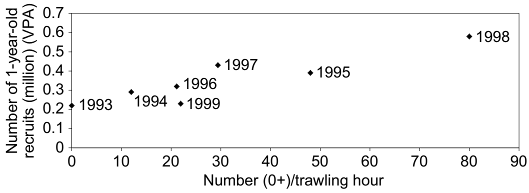

Fig. 6. Relationship between the numbers of 0+ vendace by survey trawling and one-year-old recruits gained by VPA.

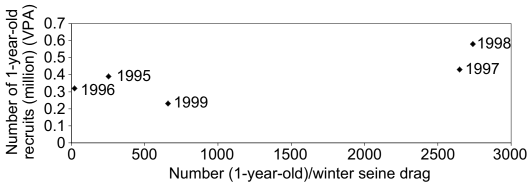

Fig. 7. Relationship between the numbers of one-year-old vendace by winter seining and one-year-old recruits gained by VPA.

related positively with the resulting YCS, gained by VPA (Fig. 6) (Spearman $r = 0.857$, $p = 0.0137$, $n = 7$). Winter seining results (one-year-old) and corresponding YCS by VPA included only five years of data, which is still short for correlation analysis. However, their trend seemed parallel with certain exceptions, year-classes 1997 and 1998 appeared much stronger in winter seining than trawling (Fig. 7).

Discussion

A major finding in this study was that the number of YOY vendace in early autumn, caught by survey trawling, could serve as a predictor of forthcoming YCS. Numbers of one-year-olds in the winter seining results gave support for this view, at least in the southernmost area of the lake.

On the contrary to many other lakes in Finland, the vendace in lake Inari are recruited to the fishery quite late, mainly as two-year olds, whereas for instance in Pyhäjärvi (south-western Finland) they are recruited to the fishery during their first winter (Helminen & Sarvala 1994).

In the subarctic lake Inari, vendace grow slowly and remain quite small after their first growing season, but during the following growing seasons they grow faster. In the vendace fishery, today mostly gillnetting, the vendace are recruited to the fishery at 2+, but they can live even beyond age 10. There have regularly been individuals up to ages 6 to 7 (length around 25 cm, weight 100–150 g) in the catch samples (Salonen 1998). In lake Inari, the vendace catch is composed of older age groups than in many other lakes elsewhere in Finland (e.g. Viljanen 1986, Salonen 1998, Viljanen *et al.* 2004). Because of the relative late recruitment and the old age structure of lake Inari vendace, there is fairly good time to make possible management decisions.

The year-class 2000 seem to be good. In 2001, a major part of the catch in the trawl survey was composed of 1+ year olds. In recent years commercial trawling has ceased in practise, but some trial hauls, with two trawl pairs, have given the signs of a slightly rising CPUE of vendace in 2002 (Salonen & Mutenia 2004). But regardless, based on my preliminary estimation, YCS 2000 is still much weaker than the strong YCS's in the 1980s. Unfortunately, the direct estimation methods for recruitment had not yet been taken into use during the rapid fluctuations of the vendace stock and fisheries in the early stage in lake Inari (Salonen 1998).

Survey trawling results include various uncertainties, e.g. large variations between different areas and tows. The numbers of YOY were, however, much greater in southern parts of the lake than in central and notably in northern parts. Moreover, the catches of 1+ and older vendace have been greater in southern parts, caught both by the trawl survey and by the vendace fishery with other gear. The vendace population, and hence also the fisheries and catches, have decreased and concentrated on these obviously the most favourable southern areas for vendace. The southernmost study areas, especially the winter seining area, belong to the most favourable area of the lake, and variation in the vendace YCS can be more even than elsewhere in the barren lake Inari. Thereby, it is important that we can find and concentrate surveys to the certain, right areas in a big lake as lake Inari. Many factors, like clustered distribution of coregonids, can cause high variation by trawling and winter seining results (Sutela *et al*. 2004).

Survey trawling elsewhere in inland waters is rarely used for the prediction of the recruitment of coregonids. In the Finnish reservoirs, Lokka and Porttipahta, a small, light trawl has been used, and with the pelagial peled whitefish (*Coregonus peled*), the results were also impressively good ($r = 0.96$ in Lokka, $r = 0.91$ in Porttipahta) (Sutela *et al*. 2004). In Lake Hallwil in Switzerland, a small survey trawl was also successfully used for forecasting year-class strength and yield for whitefish (Müller *et al*. 2002). As with many other studies concerned with predicting recruitment from early life (larval) stages (Auvinen 1995, Karjalainen *et al*. 2000), the case of the vendace recruitment in large, subarctic lake Inari also includes many uncertainties and even mystery, as named by Valkeajärvi and Marjomäki (2004). When concentrating on the later YOY stage, it would be possible to reduce this uncertainty. The additional methods, like winter seining in lake Inari, can verify the survey trawling results because the one-year-old fish have safely survived the most hazardous phases in their lifespan (e.g. Karjalainen *et al*. 2000).

The results counted by VPA, despite good catch-at-age data, can be very sensitive to natural and fishing mortality estimates. Decreasing fishing effort is one factor which can create uncertainty in VPA during recent years in lake Inari.

The role of vendace, together with reeska, is important as prey (mainly age groups 0+ to 2) for predatory fish, especially salmonids. Brown trout (*Salmo trutta m. lacustris*) and other salmonids have been yearly stocked in the lake according to the obligatory regular monitoring program. To some extent, the preliminary results of the survey trawlings have already been used in the management: the number of salmonids stocked was reduced due to the low abundance of food in the mid 1990s and trawl licenses have been reduced. Foreknowledge gained by these direct estimation methods can be used further for fisheries management, today especially for the sustainable adjustment of salmonid stocking numbers and areas.

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