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Gonadosomatic Index (GSI) of Female Whitefish (*Coregonus lavaretus*) in Lake Constance*

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With 3 Figures

Key words: Whitefish, gonadosomatic index, spawning, Lake Constance

Abstract

From 1991 to 1997 the gonadosomatic index (GSI) of pelagic spawning female whitefish (*Coregonus lavaretus,* local name "Blaufelchen") in Lake Constance-Obersee was determined. Average GSI increased from low values in summer to a maximum of about 24% immediately before spawning (end of November/beginning of December). The coefficient of variation of GSI ranged from 14–35% of the mean in summer and autumn and decreased to values between 9 and 16% immediately before spawning. The seasonal increase in GSI was similar for all years investigated, except in 1995, when after an exceptionally mild autumn spawning took place at a water temperature of about 9.4 °C. In this year, the post-August development of GSI was retarded compared to the other years of the investigation, but immediately before spawning GSI was at a value of about 24% body weight, i. e. in the same range as in the other years of the study. Despite continuing re-oligotrophication of Lake Constance no decrease in GSI was found during the study period.

Introduction

Lake Constance originally was an oligotrophic lake. Lake trophic state changed as total phosphorus concentration increased attaining values up to 90 µg l^{-1} in 1979, yet since then phosphorus has undergone a continuous decline (MÜLLER 1993). During the period of the present study (1991–1997) total phosphorus concentration decreased from 34 µg l^{-1} in 1991 to 18 µg l^{-1} in 1997 (ROßKNECHT 1998). As the lake's nutrient levels increased, growth of whitefish increased and whitefish yield comprised a smaller amount of the total commercial yield of Lake Constance fishes (NÜMANN 1972). It is unknown how whitefish populations will respond to nutrient changes as the lake returns to an oligotrophic state (KIRCHHOFER 1995; MÜLLER & BIA 1998). Possible reactions to a decreasing nutrient level are growth retardation and changes in fecundity (MILLS et al. 1998). Early data on gonadosomatic index (GSI) and fertility of Lake Constance whitefish were given by ELSTER (1944), NÜMANN (1963), and VON KRAFT et al. (1964). HARTMANN & QUOSS (1992) suggest a correlation of whitefish fecundity and phosphorus concentration of Lake Constance for the years 1964–1991. In recent years the commercial yield composition of Lake Constance is returning back to the pre-eutrophication state with whitefish comprising up to 80% of total yield, yet with a much higher total annual yield than occurred when the lake was oligotrophic (ECKMANN & RÖSCH 1998).

This paper presents data on the seasonal changes in the gonadosomatic index (GSI) of pelagic spawning female whitefish in Lake Constance for the years 1991–1997.

Material and Methods

As part of a routine monitoring program for pelagic spawning whitefish (local name "Blaufelchen") in Lake Constance, pelagic drifting gill nets were set once or twice a month in the open lake using nets with mesh sizes (knot to knot) of 20, 26, 32, 38, 40 and 44 mm. Nets were 7 m high, yarn diameter was 0,12 mm and the length of a single net varied between 30 and 120 m. 44 mm nets were set at each sampling, whereas smaller mesh sizes were used from 1991 to 1995 for the whole year, and during the late autumn of 1996 and 1997. From summer until spawning from a minimum of five females of each mesh size total body length (accuracy 1 cm), total body wet weight (accuracy 5 g), and gonad wet weight (accuracy 0.1 g) were determined. This resulted in a sample size of 8 to 45 fish per day. Scales were taken for age determination. Females sampled for gonad weight excluded immature females, and those females with freely

* This paper is dedicated to Prof. Dr. HARTMUT KAUSCH on the occasion of his 60th birthday.

flowing eggs were excluded to avoid biasing GSI values by using fish with partly depleted ovaries. The number of seasonal samples for gonad weight varied from 4 in 1997 to 17 in 1995. For each fish GSI (%) was calculated as gonad wet weight expressed as a percentage of body wet weight (total weight). For each sampling date a mean ± standard-deviation of GSI was calculated. Also the coefficient of variation of GSI was calculated as the standard deviation expressed as a percentage of the mean.

Results

GSI on any single sampling varied widely. As an example, GSI values determined on 14 September 1995 are given in Fig. 1. For this particular date, GSI varied between 2.8 and 11% body weight, independently of the total body weight of the fish ($p > 0.05$). A test for correlation between GSI and

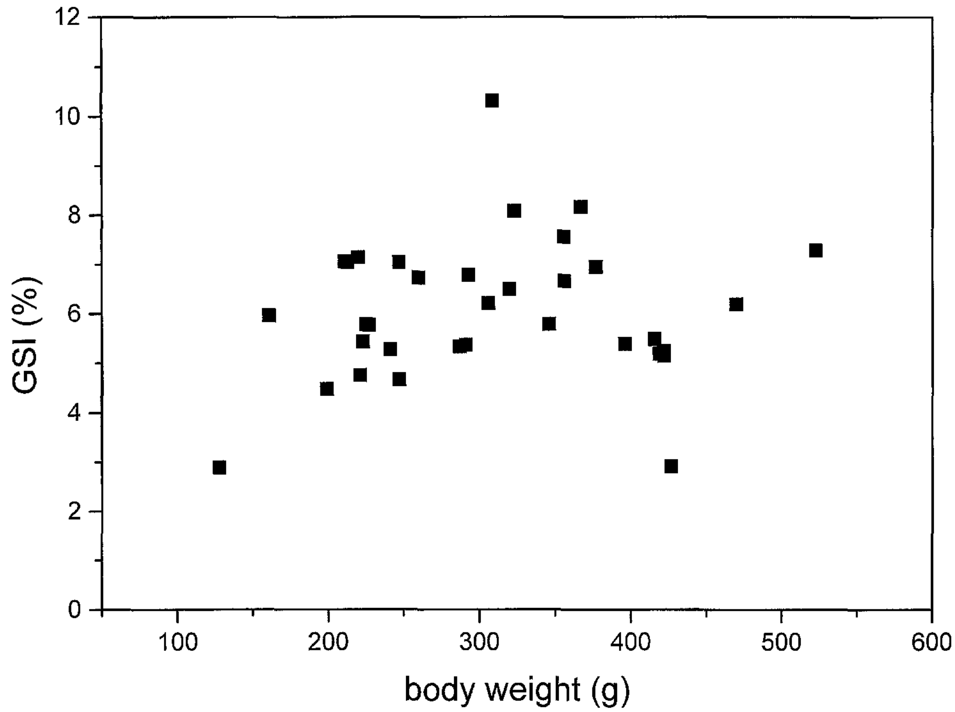

Fig. 1. Gonadosomatic index (GSI) in relation to total body weight for the sampling date 14 September, 1995.

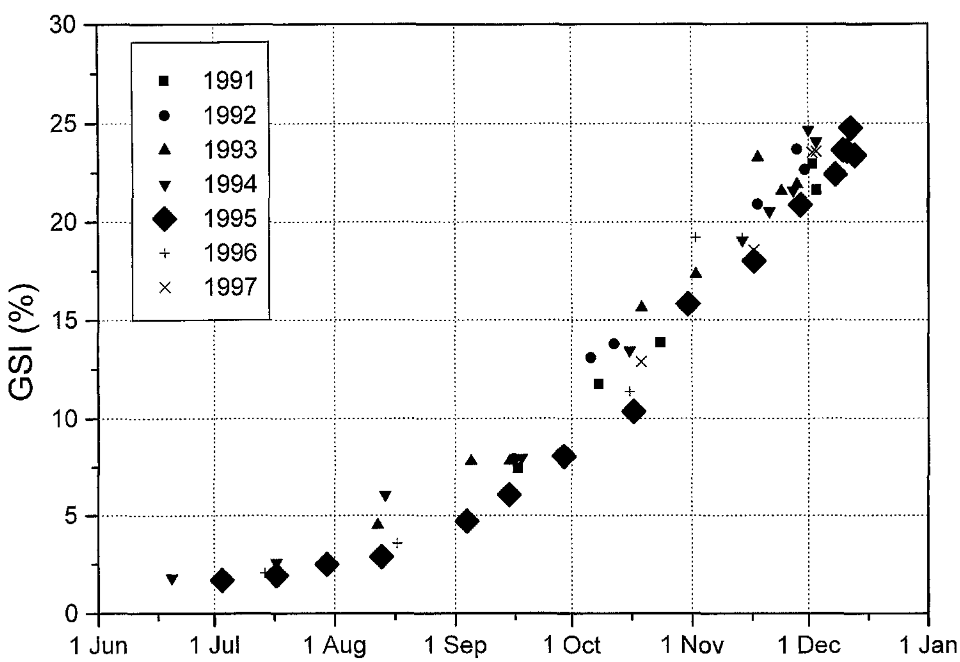

Fig. 2. Mean GSI (% total body weight) in relation to time of year.

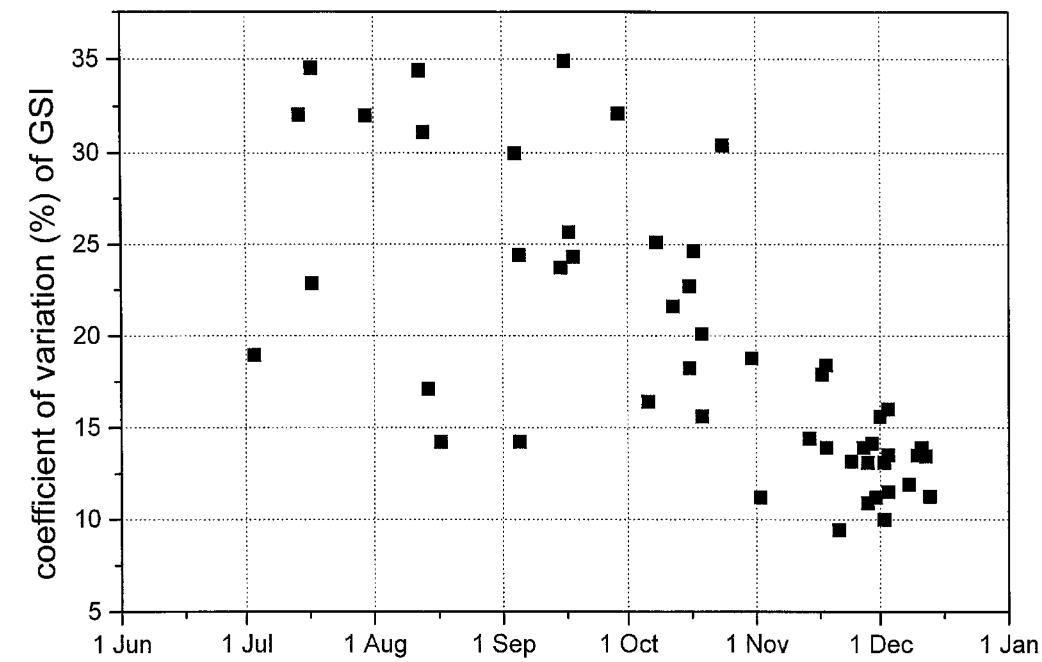

Fig. 3. Coefficient of variation of GSI in relation to time of year, combined for all seven years of the investigation (1991–1997).

total body weight was made for each sampling date according to SACHS (1984). No significant correlations ($p > 0.05$) between GSI and total body weight were found. This finding precluded the need for use of analysis of covariance (TRIPPEL & HUBERT 1990). Therefore, a mean GSI was calculated to represent all fish sized on a given sampling date. During the course of the year mean GSI increased from low values in summer to a maximum of about 24% body weight immediately before or at the beginning of the spawning season (Fig. 2). In 1995, after September the GSI was lower than during the same period in the other years of the study. In this particular year spawning started at a surface water temperature of 9.4 °C, whereas in all other years spawning took place at a surface temperature of 8 °C or lower. The maximum value of GSI immediately before spawning did not differ among the seven years. The coefficient of variation of GSI was highest in summer and early autumn with values of 14 to 35% of the mean, but before and during spawning the coefficient of variation of GSI was between 9 and 16% (Fig. 3).

Discussion

The GSI of pelagic spawning female whitefish in Lake Constance increased from low values during summer to about 24% body weight just before spawning in December (Fig. 2). In 1986, ELPERS (1988) found similar GSI values for Blaufelchen and slightly lower values for Gangfisch, a nearshore spawning whitefish in Lake Constance. In contrast to the present investigation ELPERS (1988) found a higher GSI for 4 year old Blaufelchen compared to 2 year old ones. This discrepancy to the present investigation may be explained by the wide variation of age (age 2–6 years) and body weight (200–500 g) of the fish investigated from 1991–1997. In the 1980s, one year class often dominated the catch, whereas in recent years the whitefish catch comprised up to three year classes (ECKMANN & RÖSCH 1998). A similar seasonal cycle of gonadal development as in the present investigation was found for pollan, *Coregonus autumnalis pollan,* of Lough Neagh (WILSON & PITCHER 1983).

On each sampling date GSI varied widely. However, before spawning the coefficient of variation of GSI clearly decreased from 15–34% in summer to 10–16% just before spawning (Fig. 3). Several reasons for this finding may be discussed: During the growing season both whitefish forms Gangfisch and Blaufelchen inhabit the pelagic zone of the lake. During this time it is very difficult to differentiate both forms (LUCZYNSKI et al. 1995). A few weeks before spawning they segregate into different spawning habitats: Gangfisch spawn nearshore and Blaufelchen in the pelagic zone (ECKMANN 1995). The spawning period of Gangfish extends over a few weeks whereas Blaufelchen spawn a few days only (IBKF 1998). Unfortunately, only few data are available on GSI of nearshore spawning Gangfish (R. RÖSCH, unpubl. data). Lower variation in GSI before spawning may also result from the fact that shortly before and during spawning gill nets fishing for pelagic spawning whitefish are only set near the lake's surface. Before and during spawning gravid whitefish and those with freely flowing eggs (ripe and running) segregate into different depths, with spawning females staying mainly near the surface and gravid and already spawned fish in deeper layers (ECKMANN 1991, 1995).

GSI values during spawning of up to 27% were reported for whitefish of Lake Leman (DABROWSKI & CHAMPIG-

NEULLE 1986) and of up to 20% for pollan in Lough Neagh, Northern Irland (WILSON & PITCHER 1983). Vendace (*Coregonus albula*) from Finnish lakes have GSI values between 15 and 27% depending on the trophic state of the lake (LAHTI 1991; LAHTI & MUJE 1991). Apparently GSI values of whitefish do not exceed values of 25–27%. The fact that GSI values of Lake Constance whitefish are still at this level despite re-oligotrophication indicates that the trophic state of Lake Constance still provides good living conditions for the progression of oogenesis of whitefish. In 1962, at the beginning of eutrophication of Lake Constance, GSI of Blaufelchen did not exceed 16% total body weight (NÜMANN 1963). Unfortunately, for the following years up to the present study no data on maximum GSI values are available. The data on fertility reported by HARTMANN & QUOSS (1992) were from samples taken a few weeks before spawning, which did not include informations on maximum GSI values immediately before spawning. MÜLLER & BIA (1998) reported a reduced yield of slow-growing whitefish of Lake Lucerne, when total phosphorus concentration in the lake was below 10 $\mu g\ l^{-1}$, whereas during the same period fast-growing whitefish did not respond. During the study period total phosphorus concentration in Lake Constance was clearly above the threshold value in Lake Lucerne. Assuming a further reduction in phosphorus concentration followed by a further reduction of primary and secondary production, it may be expected that whitefish growth will slow and GSI values decline. However, taking into account the unknown influence of fisheries management and fishing intensity, any predictions of possible responses of Lake Constance whitefish to a further re-oligotrophication may remain speculative.

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