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Adaptive management for a whitefish population exclusively exploited by anglers — first results after a test period of four years

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The whitefish population of Irrsee, a typical Austrian prealpine lake, is exploited exclusively by anglers, which is an unusual situation for many lakes dominated by Coregonids. Because of a significant decrease in the whitefish harvest, fishery regulations were changed between 1996 and 2002. The object of this study was to investigate whether the changed harvest regulations influence the proportion of catchable whitefish, to test the effectiveness of the size limit in force, and to investigate whether the practice of releasing undersized and hooked whitefish affected condition factors. The results from our study show a significant effect of changed harvest regulations on the number of catchable whitefish, on the proportion of hooked whitefish with typical injuries, and on the population size structure. Until now the effect of intensive angling on a whitefish population was largely underestimated in the Austrian lakes, but more attention should be paid to these effects in the future.

Introduction

Whitefish, *Coregonus* spp., is the most important fish species of the commercial freshwater gillnet fishery in Austrian lakes. For anglers, the harvest of whitefish was hardly attractive until approximately 1980. This was because no effective angling technique existed and the harvest was forbidden in most of the Austrian lakes. Since about 1980, in Irrsee and also in some other Austrian lakes, anglers have begun to catch whitefish more and more intensively because of the knowledge of a new and effective technique, called *Hegene*. This technique was imported from Switzerland almost 25 years ago. There, the catch of coregonids by anglers using a *Hegene* angling system has a long tradition and has been described by Elster (1944), Steinmann (1950) and Müller (1980). This system is very effective because it imitates uprising chironomid pupae which are an important part of the diet of the whitefish population in Irrsee (Riedlsperger 1996). Under optimal conditions with the *Hegene* technique, a harvest of more than 40 whitefish per day by one angler is possible (Steinmann 1950, Gassner 1996). The whitefish population of Irrsee is exploited exclusively by anglers and is managed as such, an unusual situation for many lakes dominated by Coregonids.

As a consequence of the new angling technique, the amount of whitefish harvested from Irrsee by anglers increased significantly in 1986–1994. Since 1996, however, the harvest has decreased. The mean weight of harvested fish had decreased in 1991–1996 but was slightly higher in 1997–2001 (Table 1). Since 1986 annual licence numbers did not fluctuate greatly (Table 1). Furthermore, most of the anglers on Irrsee have changed their fishing practices. Since anglers started to catch whitefish very intensively, they have taken significantly fewer fish of other species. In Irrsee, the proportion of whitefish in the total annual harvest increased from 7.8% in 1986 to 81.0% in 1993 and fluctuated in the following years around 65% (data from the catch statistics of the Irrsee angler's union). Starting from 1998, anglers observed much fewer catchable whitefish and most of the whitefish caught were smaller than the minimum size limit (40 cm). Per one catchable whitefish, up to five whitefish smaller than the size limit had to be caught and released (personal communication: Irrsee anglers' union).

The fisheries management board of Irrsee changed the harvest regulations several times in the last few years (Table 2). In order to improve the proportion of catchable whitefish in the population and to avoid the extensive practice of catch-and-release of undersized whitefish, substantial changes were once again applied in the year 2000, when restrictive daily and yearly bag limits were imposed (Table 2). Parallel to the changed harvest regulations, since 1999 the whitefish population has been investigated annually.

The objective of this study was to investigate whether the changed harvest regulations influ-

Table 1. Annual whitefish harvest, mean weight and the number of annual licenses sold (data from the Irrsee angler's union, [1)] until August 2002, – = no data available).

Year	Harvest (kg)	Harvest (no. of fish)	Mean weight (kg)	Harvest (kg ha^{-1})	Number of annual licenses
1986	2795	–	–	8.1	260
1987	2632	–	–	7.6	276
1988	2410	–	–	6.9	335
1989	2667	3064	0.87	7.7	375
1990	3300	3365	0.98	9.5	347
1991	3810	3810	1.00	11.0	334
1992	4580	6538	0.70	13.2	304
1993	5766	9706	0.59	16.6	360
1994	6035	9867	0.61	17.4	369
1995	5040	8512	0.59	14.5	325
1996	5493	9636	0.57	15.8	328
1997	3473	5249	0.66	10.0	315
1998	2456	3485	0.70	7.1	303
1999	2501	3474	0.72	7.2	298
2000	1238	1719	0.72	3.6	312
2001	563	761	0.74	1.6	309
2002	2500[1)]	–	–	–	319

Table 2. Harvest regulations for anglers.

Year	< 1996	1996	1997	1998	1999	2000	2001	2002
Minimum size limit (cm)	35	37	40	40	40	40	40	40
Daily bag limit (*n*)	7	7	4	4	4	2	2	2
Yearly bag limit (*n*)	no limit	70	70	70	70	20	20	50
Maximum hook number	no limit	6	6	6	6	6	6	6

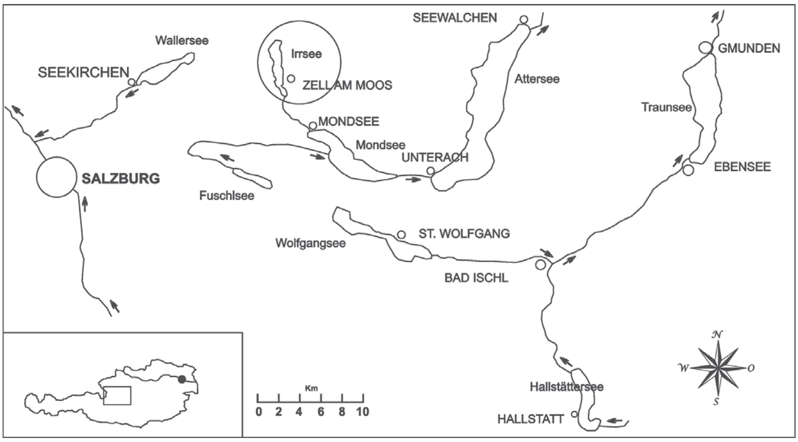

Fig. 1. Map of the Salzkammergut lake district.

enced the size and age structure of the whitefish population, particularly the proportion and relative abundance of whitefish over 40 cm in total length. Secondly, this study was used to test the effectiveness of the size limit in force by determining the proportion of mature and immature whitefish and, finally, to investigate whether the practice of catching and then releasing undersized whitefish affects their condition.

Materials and methods

Study area

Irrsee, a typical Austrian prealpine lake, is located in the northwestern part of the Salzkammergut lake district east of Salzburg (Fig. 1). During the last five decades it has undergone man-made eutrophication and recent re-oligotrophication since approximately 1990. The lake is currently classified as an oligo-mesotrophic (Table 3), with profundal oxygen depletion occurring at the end of the summer stagnation. It is inhabited by 15 fish species of which the dominant are whitefish, pike and bream. The lake was stocked with whitefish for the first time in 1968, since then annual stocking with differently sized whitefish (fry to 2+) has been carried out. Currently the whitefish population of Irrsee reproduces naturally (Gassner 1996) and is supplemented with annual stocking of fry (about 3000 per ha) originating from the local spawning stock.

Sampling procedure

The fish were caught with gillnets in the first week of October 1999, 2000, 2001 and 2002. A fleet of 8 gillnets (15-, 26-, 32-, 38-, 42-, 45-, 50- and 60-mm bar-mesh size) with a total length of 400 m and a height of 3 m was used. The nets were set randomly in the south basin of Irrsee. Each gillnet was set on the lake bottom in about 15-m deep water and was left overnight (12 hours). After lifting the nets, the whitefish were sorted and transported to the laboratory. All whitefish were measured for total length (± 0.5 cm) and total weight (± 5 g); sex and stage of maturity were also determined. For age determination, scales were removed from a standard position for whitefish, above the lateral line and at the posterior edge of the dorsal fin. In order to determine typical injuries of whitefish caught and released by anglers, the area around the mouth of each whitefish was examined for deformities and wounds.

Table 3. Limnological and morphological lake characteristics. (n = 36).

Altitude (m)	533
Surface area (ha)	347
Max. depth (m)	32
Mean depth (m)	15
Volume (m^3)	53×10^6
Retention time (years)	1.7
Secchi depth (m)*	5.3
Total phosphorus (mg m^{-3})*	6.9
Chlorophyll *a* (mg m^{-3})*	2.5

* average of monthly measurements 1998–2000.

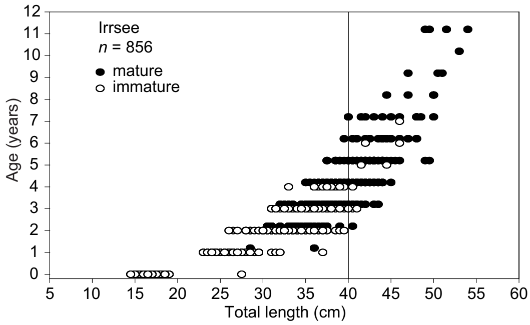

Fig. 2. Age, total length and maturity of whitefish from Lake Irrsee (vertical line = size limit).

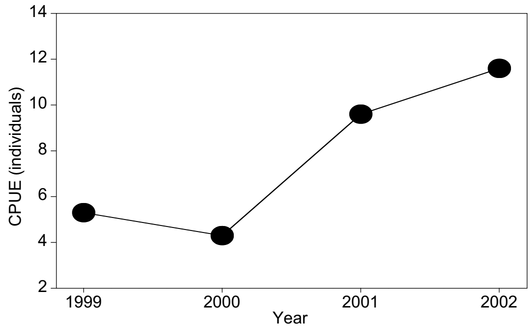

Fig. 3. CPUE of whitefish above the size limit (> 40 cm TL).

Age determination was made by counting annuli from projected slide images of dried and cleaned scales. Two independent readers, to whom information such as length or weight was not available, aged each fish three times. The most frequent age-value was used for further calculations.

Size class distributions were calculated using 2-cm size classes. The Fulton condition factor was calculated according to Anderson and Neumann (1996). Statistical analyses were accomplished with Sigma-Stat. First, the data were tested for their fit to a normal distribution, and then the means compared with Student's *t*-test or the Mann-Whitney *U*-test (Lozán 1992). For the comparison of the condition factor of hooked and unhooked whitefish, the sample was divided into two length groups: 30–40 cm and > 40 cm total length (TL).

Results

In the length class > 40 cm TL (≥ size limit), 96.1% of the whitefish caught in Irrsee were mature and 3.9% were immature (Fig. 2). From the whitefish of the length class < 40 cm, 26.3% were mature and 73.7% were immature. With the imposed size limit of 40 cm, almost all immature whitefish, with the exception of some outliers, were protected (Fig. 2).

In the data sets 1999, 2000, 2001 and 2002, the whitefish age at 50% maturity was 2.8 years, i.e. slightly less than in 1994 (3.1 years).

From the whitefish of age groups 0, 1, 2 and 3, the percentages of mature fish were 0%, 1%, 17% and 58%, respectively. Almost all whitefish were mature at age 4 (89%). Sex-specific values showed that males become mature somewhat earlier than females. In our catches, the mean age (male: 4.0 years ± 1.7 S.D.; female 4.3 years ± 1.5 S.D) and the mean total length (male: 39.5 cm ± 4.5 S.D.; female 40.4 cm ± 3.6 S.D.) of mature males were significantly smaller than those of the females (Mann-Whitney *U*-test: age $p = 0.027$; length $p = 0.022$).

The proportions of catchable whitefish (> 40 cm) were 31.3% ($n = 63$) in 1999, 25.2% in 2000, ($n = 34$), 40.3% in 2001 ($n = 77$) and 33.8% in 2002 ($n = 93$). The CPUEs (catch per unit of effort, i.e. net night) of catchable whitefish (> 40 cm) doubled from 5.2 in 1999 and 4.2 in 2000, to 9.6 in 2001, and to 11.6 in 2002 (Fig. 3).

Comparing the length frequency distributions in 1999 and 2000 with those in 2001 and 2002 (Fig. 4), a significant increase of the abundances of whitefish in the 40–42-cm length group and the 42–44-cm length group were observed. Further the abundances of the 14–16 cm and 16–18 cm were also higher in 2001 and 2002 than in 1999 and 2000.

No whitefish of age 5 were observed in 1999 and relatively few whitefish of age 5 and older could be caught in 2000. In 2001 and 2002, much higher numbers of age 0, 1, 4, 5 and 6 whitefish were observed (Fig. 5).

The proportion of caught and released whitefish with typical injuries decreased from 21.5% in 1999 to 17.0% in 2000, and further to 8.8% in 2001. It increased to 17.9% in 2002. Deformities in the area around the maxillary and premaxillary were very common, and whole parts were missing or the premaxillary was peeled off.

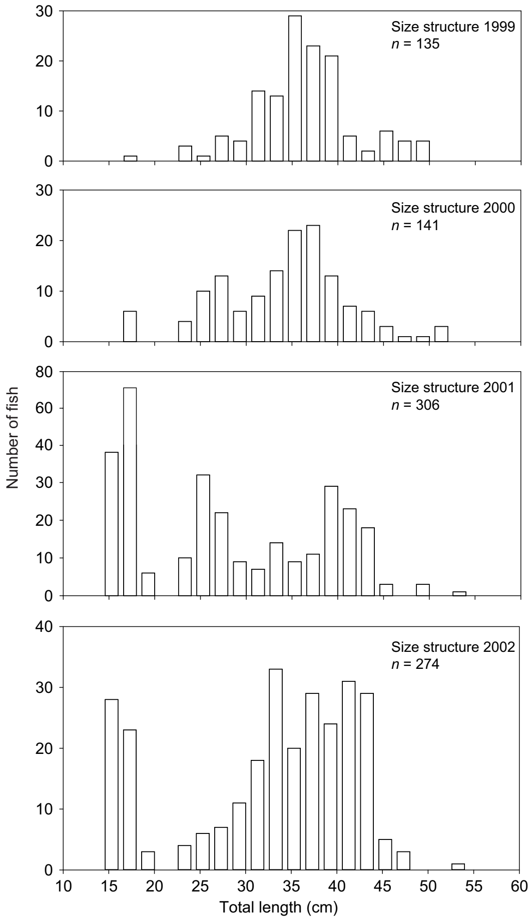

Fig. 4. Size structure of the whitefish population of Irrsee based on test fishing with gillnets.

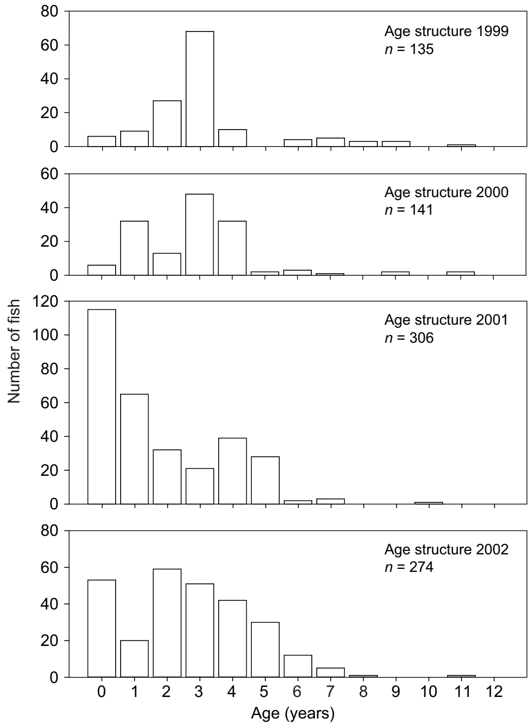

Fig. 5. Age structure of the whitefish population of Irrsee based on test fishing with gillnets.

These wounded parts were often crippled.

The percentages of injured whitefish in size groups of 5 cm (TL) were as follows: 15–19 (0.0%), 20–24 (6.7%) and 25–29 cm (0.9%). The highest proportions of injured fish were found in the size groups 30–34 (18.2%) and 35–39 cm (26.9%). These proportions were between 20% and 24% in the size classes ≥ 40 cm. A comparison, however, of the condition factor between whitefish with and without injuries showed no statistically significant differences (t-test: group 30–39 cm, $p = 0.463$; group ≥ 40 cm, $p = 0.652$).

Discussion

Whitefish populations which are exploited by commercial gillnet fisheries are often studied to determine the effects of fisheries and fisheries management on the population structure and other biological factors in Austrian (e.g. Wanzenböck & Jagsch 1998, Wanzenböck *et al.* 2002) and in other European (e.g. Müller & Bia 1998, Turunen *et al.* 1998) lakes. Contrary to the various investigations in gillnet-fished lakes, less is known about the effects of intensive angling on whitefish populations. Generally, angling is a quickly growing element of leisure activities in Austria. Therefore, its effect on fish stocks should not be underestimated. There are currently about 380 000 anglers in Austria who harvest approximately 1000 tonnes per year. This is twice the harvest of the commercial gillnet fishery in Austrian waters (Spindler 1997).

The results from our study on Irrsee showed significant changes in the whitefish population due to the changed harvest regulations. The effects of increasing the size limit and the daily and yearly bag limits in 1996 and 1999 were rather clear. In each of the following years (1997 and 2000), the total harvest decreased significantly and the mean weight of harvested whitefish increased slightly in 1997. The correlation between an increased minimum size limit and increasing mean weight of angler-harvested fish is known for other fish populations (Webb & Ott 1991, Hoff 1995).

The decrease in harvest from 1999 to 2000 might be a consequence of the strongly reduced daily and yearly bag limits. In Irrsee, the catch rate of whitefish corresponds with the proportion of chironomidae pupae in their stomachs (Riedlsperger 1996). The period with high chironomid abundance, however, is rather short: whitefish feed on chironomide pupae approximately two months in spring and one month in autumn. At other times whitefish feed mostly on zooplankton, and are caught by anglers only sporadically. The combination of a short, effective angling period, with small daily and yearly bag limits for an equal number of angler licences, results in a decrease of the yearly harvest.

Our results from the test fishing also show low numbers and CPUE values of catchable whitefish in 1999 and 2000, confirming the pattern observed in the angler's catch. Higher numbers and catches per unit effort of catchable whitefish were observed at the end of the angling season 2001. Consequently, the total whitefish harvest from January to July 2002 increased to approximately 2500 kg (personal communication: angler's union of Irrsee) (Table 1).

The whitefish of Irrsee become mature relatively late as compared with other whitefish populations in the Salzkammergut lake district (Hassan 2000, Wanzenböck *et al*. 2002). Therefore, the 40 cm minimum size limit is necessary and, as determined in the present study, quite effective. Consequently, a reduction of the present size limit to increase the proportion of catchable whitefish would not be useful. Such a reduction would marginally decrease the number of caught-and-released undersized whitefish, but its effect on the condition factor would be insignificant. In this study, the number of whitefish that die immediately when released could not be determined. The estimated mortality rate of whitefish caught using the *Hegene* technique and subsequently released was, however, approximately one percent in lakes of Switzerland (Müller 1980). In summary, the practice of hooking-and-releasing undersized whitefish might not have any substantial effect on the whitefish population of Irrsee.

The changed harvest regulations also have significant effects on the size and age structure of the whitefish population of Irrsee. The reduction of harvest in 2000 by 50% resulted in a threefold increase of age 4 fish in our survey in late 2000 as compared with our survey in late 1999. It is possible that this increase in spawning biomass may be partly responsible for the increase of age 0 fish in 2001 and 2002. The relatively low number of age 0 whitefish in our catches in the years 1999 and 2000 may be partly due to low selectivity of the used gillnets for this length range (15 mm and 26 mm mesh size). Further the decreased fishing mortality in age 4 fish in 2000 allowed more of that cohort to survive, showing up as age 5 fish in 2001 as well as age 6 fish in 2002. It appears that the effect of the bag limit reductions in combination with the size limit have been very effective.

In general, when an unexploited coregonid population receives high fishing pressure by gill netting, the older age classes are first to show a dramatic decrease (Healey 1978, Bowen *et al.* 1991). This may have occurred in Irrsee where intensive angling pressure resulted in the disappearance of the older fish first. Analysis of the population structure in 1994 showed a high proportion of older whitefish age 7 to 12 years (Gassner 1996).

For several North American non-coregonid sport-fish-species, Olson and Cunningham (1989) showed that the number of older fish, and the mean weight of the captured fish, declined under increased sport-fishing exploitation. Additionally, studies on white crappies, *Pomoxis annularis*, and brook trout, *Salvelinus fontinalis*, showed that the harvest by anglers may have significant influence on the population structure (Colvin 1991, Webb & Ott 1991, Nuhfer & Alexander 1994).

Until now, however, the effect of intensive angling on a whitefish population in Austrian lakes was largely underestimated, but as shown in the present study on Irrsee, more attention should be paid to these effects in the future. In Irrsee, high angling pressure over several years resulted in a disappearance of the older fish, and subsequently, a significant decrease of the yearly harvest.

The imposed management tools, especially the bag limit reductions in combination with the size limit have been very effective and the whitefish population of Irrsee shows a significant tendency for recovering. The age structure indicates that strong year classes have been born as a result of the management measures. The practice of hooking-and-releasing undersized whitefish might not have any substantial effect on the condition factor of the whitefish population of Irrsee. With the imposed size limit of 40 cm all immature whitefish, with the exception of some outliers, were protected. Now it remains to fine-tune the bag limits, in a careful and adaptive manner.

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