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Application of population size structure indices to Austrian whitefish (Coregonus sp.) stocks

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with 1 figure and 2 tables

Abstract: We adapted the traditional North American "proportional-stock-density" (PSD) and "relative-stock-density" (RSD) index systems to be used on whitefish (*Coregonus lavaretus* (L.)) populations of Austrian lakes. The method was tested on length-frequency data from the whitefish population of Lake Irrsee. Length frequency indices provide a numeric estimation for deviations of the population structure from a balanced population. A more precise measurement of stock size structure can be quantified using the RSD, which is based on a five cell length categorisation system.

The results showed that all the PSD values of the three study periods were within the thresholds from a balanced reference population. In contrast, the calculated RSD values indicate a balanced size structure only in 1994. RSD values were outside of the range for trophy sized fish in 1999–2000 and for both memorable and trophy sized fish in 2003–2004. These indices, which reflect the size structure of fish populations, are a useful tool for fisheries managers and can be used for the assessment of fish populations in fulfilment of the "Water Framework Directive".

Introduction

The assessment of a fish population provides fundamental information for the management of commercially and recreationally fished populations. Readily obtainable indices that reflect the size structure of fish populations and assist in making inferences about population parameters are needed by fisheries managers (CARLINE et al. 1984) and are used to assess population integrity according to the European Union "Water Framework Directive" (EU-WFD) (EU 2000).

One of the first approaches to assessing fish populations using length-frequency data was proposed by ANDERSON (1976a, b) who introduced the concept of the "proportional–stock-density" index (PSD). Stock density indices are numerical descriptors of length-frequency data and until now they have mostly been applied to North American lake fish communities (WILLIS et al. 1993). PSD is defined as the percentage of "stock-length" fish that are also longer than a specified size (ANDERSON 1976a, b). The specified size was later termed by Anderson as the "quality length".

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A more precise measurement of stock structure is the "relative-stock-density" (RSD), the percentage of fish of any designated length-group in a stock (WEGE & ANDERSON 1978).

RSD was first employed for the assessment of largemouth bass, *Micropterus salmoides* (Lacepède). Based on the world-record lengths, GABLEHOUSE (1984) developed a five cell length categorisation system ("stock", "quality", "preferred", "memorable" and "trophy") for 70 fish species (including two hybrids and one family), which were updated by WILLIS et al. (1993). "Quality-length" is the minimum size of a fish most anglers like to catch. While anglers may like to catch a fish of quality-length, most would prefer to catch something at least somewhat bigger, hence the category "preferred". "Memorable" is defined as a size most anglers remember catching and "trophy" is a size considered worthy of acknowledgement (GABLEHOUSE 1984).

Stock density indices have been applied most commonly to electrofishing catch data for largemouth bass and bluegill, *Lepomis macrochirus* Rafinesque (e.g. CARLINE et al. 1984, GABLEHOUSE 1984, GUY & WILLIS 1990). WILLIS et al. (1985) applied stock-density-indices to walleye, *Sander vitreus* (Mitchill), white bass, *Morone chrysops* (Rafinesque) and gizzard shad, *Dorosoma cepedianum* (Lesueur) which were sampled by gillnetting.

Even though PSD and RSD calculations are frequently used in North America, they are rarely employed in Europe. GODINHO & FERREIA (1996) discussed the utility of length-frequency indices to describe the status of Iberian centrarchid populations. A first attempt to apply PSD and RSD calculations to fish populations in Austrian lakes was performed on five Arctic charr populations (ZICK et al. 2006) and as a part of the assessment of fish communities for the purposes of the EU-WFD (GASSNER et al. 2003a). In this directive the recognized quality elements of the fish community in lakes are species composition, abundance, and age structure (EU 2000). Age determination is methodologically complex and very time- and cost-intensive. An alternative and easy to calculate substitute for age composition could be the PSD and RSD calculations.

In Austria, whitefish (*Coregonus lavaretus* (L.)) has a very high recreational value and is also the most important fish species in the commercial gillnet fishery. Historically whitefish populations occurred in 15 out of 43 Austrian lakes that are larger than 50 ha. Today they are found in 27 lakes due to ongoing stocking activities (GASSNER et al. 2003b). All these populations have been exploited by commercial fisheries since the middle ages and by anglers since approximately 1980 (GASSNER et al. 2003a, b). In most of these lakes the combination of commercial fisheries and angler's catches resulted in overfishing of the whitefish populations. To monitor the actual state of the whitefish populations in the Austrian lakes it would be useful to have a robust and easy to calculate numerical descriptor of the population structure.

We adapted the traditional North American PSD and RSD indices of ANDERSON (1976a, b) and GABLEHOUSE (1984) to whitefish populations from pre-alpine and alpine Austrian lakes. Because of the lack of unexploited whitefish populations in Austria the stock-density-index ranges for balanced fish populations were defined using length-frequency data of simulated unexploited whitefish populations. Furthermore we included a biological (population specific) parameter in the PSD and RSD index calculation and tested the system on length frequency data from the whitefish (*Coregonus lavaretus* (L.)) population in Lake Irrsee.

Material and Methods

Study area

Lake Irrsee is located in the northwestern part of the Salzkammergut lake district east of Salzburg and is a typical Austrian pre-alpine lake. During the last five decades Lake Irrsee has undergone man-made eutrophication before a recent re-oligotrophication initiative which started in 1990. Lake Irrsee is currently classified as an oligomesotrophic lake, with profundal oxygen depletion occurring at the end of the summer. At present Lake Irrsee is inhabited by 15 fish species. The dominant fish species are whitefish, pike (*Esox lucius* (L.)) and bream (*Abramis brama* (L.)). Whitefish were first stocked in 1968 followed by annual stocking with different sized whitefish (fry to age 2+). Currently the whitefish population of Lake Irrsee reproduces naturally (GASSNER et al. 2004) and is supplemented with a wild origin based annual stocking program of 3000 fry/ha. The whitefish population of Lake Irrsee is exploited exclusively by anglers and is managed as such, an unusual situation for Austrian lakes dominated by coregonids.

Data collection

Length - frequency data were collected during gillnet surveys on Lake Irrsee in 1994, 1999, 2000, 2003, and 2004. In 1994 multimesh gillnets (Lundgreen, monofilament survey net S-REV) were used monthly between April and October. In the years 1999 to 2004 gillnetting was performed in the first week of October using 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. To improve the whitefish sample size, the catches from the years 1999 and 2000 were pooled (1999–2000) as where the catches from 2003 and 2004 (2003–2004). The nets were set randomly in the southern basin of Lake Irrsee. Each gillnet was set on the lake bottom in about 15 m of water and was fished overnight (12 hours). After lifting the nets, the whitefish were sorted and transported to the laboratory. All whitefish caught were counted, weighed and measured (total length in cm). Sex and stage of maturity of whitefish were determined according to NIKOLSKY (in: RICKER 1970). For the estimation of the length at first maturity, a relationship between length and percentage of mature whitefish was calculated by the logistic function:

$$f(y) = a/1+e^{-(x-xo)/b}$$

(x = total length (cm), x_0 = center, a = amplitude, b = coefficient)

Gillnet selectivity was corrected using the selection model according to KURKILAHTI (1999). The relative efficiency of each gillnet mesh size was calculated for the different length classes and summed up to the pooled relative efficiency (PRE) for the series of mesh sizes used in this study (1999 to 2004). This relationship was used to correct the length frequency distribution of the catches in the years 1999–2000 and 2003–2004 by weighting the catch of each length class with the PRE of the same length class (KURKILAHTI 1999).

Data analyses

For assessing the length-frequency data (in 1 cm steps), a "proportional-stock-density-index" (PSD) and a "relative-stock-density-index" (RSD) were created for the whitefish populations. The calculations of the indices were defined as:

$$PSD = \frac{number\ of\ fish \geq specified\ length^1}{number\ of\ fish \geq minimum\ stock\ length}\ x\ 100$$

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[1]) specified lengths are the length categories "quality", "preferred", "memorable" and "trophy".

The length categories (cm) for whitefish were defined as:
1.) Minimum stock length: S = Q - ((T-Q)/3); (Irrsee: 31 cm)
2.) Minimum quality length: Q = total length, at which approximately 75% of whitefish are mature; (Irrsee: 37 cm; mean of the years 1999–2000 and 2003–2004)
3.) Minimum preferred length: P = Q + ((T-Q)/3); (Irrsee: 45 cm)
4.) Minimum memorable length: M = Q + (((T-Q)/3) · 2); (Irrsee: 50 cm)
5.) Minimum trophy length: T = 80% of observed maximum length of *Coregonus sp.* = ~70 cm; according to published maximum lengths: FROESE & PAULY (2000) (Irrsee: 56 cm).

The calculation of both stock density index results in values between 0 and 100. WILLIS et al. (1993) gave a list of generally accepted stock-density-index ranges for balanced fish populations. A balanced fish population is one that is intermediate between the extremes of a large number of small fish and a small number of large fish and is rather similar to an unexploited population. This often suggests that the rates of recruitment, growth, and mortality within the population are satisfactory (ANDERSON & WEITHMAN 1978). As no values for balanced European whitefish populations are available, we used length-frequency data from simulated unexploited whitefish populations for the definition of the stock-density-index ranges. These simulations were based on a longevity of 17 years, a seeding of 50 individuals of 3+ age class, and on the survival rates given in WINFIELD et al. (2004) (for age classes 0+ to 4 +) and MILLS et al. (2004) (for age classes > 4 +). The ranges in length within the different age classes were assumed to be 5 cm in 0+ age class, 7 cm in 1+ and 2+ age classes and 9 cm in the age classes > 3+ years according to GASSNER et al. (1998), HASSAN (2000). Based on these data length frequency histograms were simulated showing a total mortality rate between 0.25 and 0.55 as pointed out by JENSEN (1981) for unexploited or underfished whitefish populations. The resulting upper and lower thresholds for a reference population were 42 to 60 for the PSD and RSD-Q, 12 to 34 for the RSD-P, 3 to 19 for the RSD-M and 0.5 to 8.0 for the RSD-T. These values are very similar to the generally accepted stock density index ranges for unexploited fish populations given in WILLIS et al. (1993).

Results

The mean total length of whitefish caught in Lake Irrsee was 37.0 cm in 1994, 35.1 cm in the years 1999–2000 and 33.5 cm in the years 2003–2004. Maximum total length decreased from 55.6 cm in 1994 to 51.5 cm in 1999–2000, finally reaching 51.0 cm in the years 2003–2004. The most abundant length group was nearly the same during the three study periods (36 cm in 1994 and 1999–2000 and 35 cm in 2003–2004 (Fig. 1)). The maturity schedule for these fish changed marginally between 1999–2000 (90% mature at 38.9 cm) and 2003–2004 (40.2 cm). The total length at 75% maturity was found to be 36.4 cm in 1999–2000 and 37.6 cm in 2003–2004.

The calculation of the proportional-stock-density-indices (PSD) for the three gillnet surveys resulted in values between 44 and 60. All of these PSD values were within the estimated thresholds derived from the modelled reference population (Table 1). Relative stock density indices (RSD) were within the modelled thresholds only in 1994, indicating a well structured population in that year. In the years 1999–2000 RSD-Quality, -Preferred and -Memorable indices were also within the reference thresholds (Table 1) however, no RSD-Trophy length whitefish were caught (Table 2; Fig. 1). In the years 2003–2004, RSD- Preferred, -Memorable and -Trophy values were outside of the thresholds (Table 1) and only RSD-Quality length values were within the reference thresholds. RSD and PSD values based on gillnet selectivity corrected data differed only slightly when compared to the uncorrected data (Table 1).

Discussion

During the three study periods all calculated PSD values for the whitefish population of Lake Irrsee were within the range of a modelled balanced population. In contrast, the RSD values indicated a balanced situation only in 1994, they were out of the range for trophy sized fish in 1999–2000 and for memorable and trophy sized fish in 2003–2004. This corresponds to the

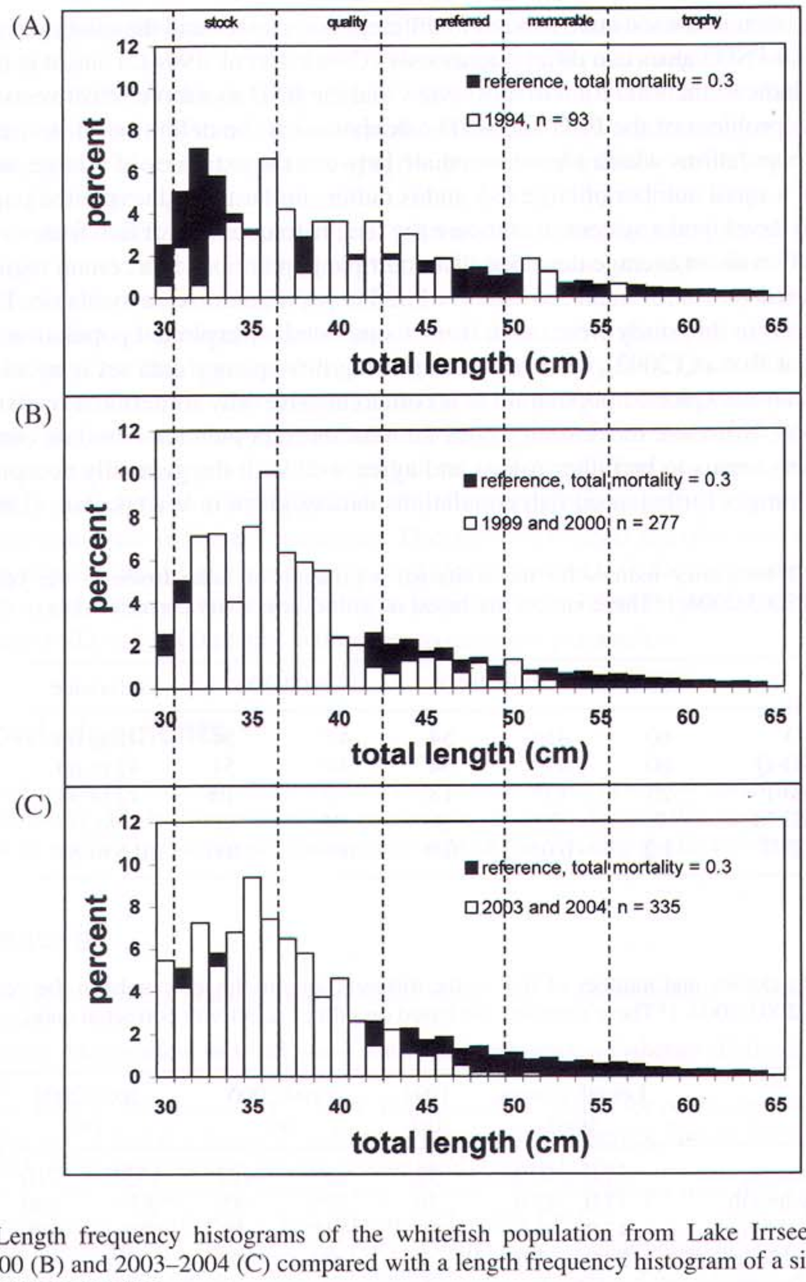

Fig. 1. Length frequency histograms of the whitefish population from Lake Irrsee in 1994 (A), 1999–2000 (B) and 2003–2004 (C) compared with a length frequency histogram of a simulated balanced whitefish population.

whitefish fishery observed during these later periods. Until approximately 1990, no effective catch techniques for whitefish existed in Lake Irrsee, thus they were underfished. Since about 1990, anglers have begun to catch whitefish intensively likely due to the development of a new angling technique called "Hegene". This technique imitates uprising chironomid pupae which are an important part of the diet of whitefish. As a consequence the whitefish population have become more and more exploited indicated by an increasing yearly harvest, and a decreasing mean weight of caught whitefish (Gassner et al. 2004). This results in low RSD values for memorable and trophy sized whitefish.

PSD alone often is not sensitive enough to different size classes and the quality of populations with similar PSD values can differ enormously (Carline et al. 1984). Thus, it is important to apply both indices, the PSD for a first overview and the RSD as a more sensitive estimator.

A common problem of the PSD and RSD calculations is the definition of desired values for balanced populations which are intermediate between the extremes of a large number of small fish and a small number of large fish and is rather similar to an unexploited population. Bonar (2002) developed a system to compare the length-frequencies of fish from one particular water body with an average developed for multiple populations in a certain region. Until now no validated values for balanced alpine whitefish populations were available. The reference values used in this study were taken from a simulated, unexploited population. Besides the approach of Bonar (2002), for which a large length-frequency data set is necessary, the simulation of an unexploited population is a comprehensive way to define a realistic reference population. However, the desired values for a balanced population based on our population simulations seems to be rather robust and agree well with the generally accepted stock density index ranges for balanced fish populations indices given in Willis et al. (1993).

Table 1. Length-frequency indices for the whitefish population of Lake Irrsee in the years 1994, 1999/2000 and 2003/2004. (*These indices are based on gillnet selectivity corrected data)

	1994	1999/2000		2003/2004		reference
PSD	60	45*	54	44*	54	42 to 60
RSD-Q	60	45*	54	44*	54	42 to 60
RSD-P	23	13*	13	9*	10	12 to 34
RSD-M	7	3*	3	0*	0	3 to 19
RSD-T	1.2	0.0*	0.0	0.0*	0.0	0.5 to 8.0

Table 2. Length classes and number of fish in the different length classes caught in the years 1994, 1999/2000 and 2003/2004. (*These numbers are based on gillnet selectivity corrected data).

	Length classes (cm)	1994 (n)	1999/2000 (n)		2003/2004 (n)	
Stock length	31.0 – 36.9	32	66*	102	135*	210
Quality length	37.0 – 42.9	30	38*	92	83*	200
Preferred length	43.0 – 49.9	13	12*	23	21*	47
Memorable length	50.0 – 55.9	5	4*	7	1*	1
Trophy length	≥ 56.0	1	0*	0	0*	0

GABLEHOUSE (1984) and WILLIS et al. (1993) define the length ranges of the five cell categorization system for more than 70 fish species based on the world-record angling lengths. To optimise this system we included the total length at 75% maturity parameter into the calculations as a biological threshold. Without this biological threshold a comprehensible calculation of the size groups is impossible and size groups could be defined only arbitrary as done by GABLEHOUSE (1984) and WILLIS et al. (1993). Total length at 75% maturity corresponds well with an efficient minimum size length for Austrian whitefish populations (HASSAN 2000). FROESE & BINOHLAN (2000) observed that length at first maturity is foremost a function of size. Large differences in the length at first maturity have been found for Austrian whitefish populations (GASSNER et al. 1998, HASSAN 2000). By defining the two thresholds, 1) "length where 75% of whitefish are mature" and 2) "80% of world record length", the specific length classes for PSD and RSD calculations can be fixed separately for different whitefish populations, reflecting population specific growth and maturity differences.

Length frequency data based on gillnet catches can be biased due to gear selectivity. In general, medium sized fish are more easily captured than very large and small fish in gillnets (WILLIS et al. 1985, JENSEN 1995). However, small fish are not included in the stock-density-index calculations, making the PSD and RSD calculations more robust against gillnet selectivity. Trophy fish are generally rare in our lakes and therefore the capture probability is low. It might be possible that high sampling effort as suggested by the CEN Norm (CEN/TC 230 N 0495) for sampling fish with gillnets could solve the problem for this category.

Overall, the stock-density-indices adapted here showed that PSD and RSD are useful methods for characterizing whitefish populations in Austria. They are appropriate numerical estimators for deviations from balanced whitefish populations and give results, which are easy to communicate to fishery managers. This method reflects the observed changes in the whitefish population of Lake Irrsee quite well. An important task for the future will be to test this method on different Austrian whitefish populations, to define optimal sample sizes and to correlate PSD and RSD results with other assessment parameters.

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