ELSEVIER
Fisheries Research 61 (2003) 19–33
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Socio-economic characterisation of specialised common carp (*Cyprinus carpio* L.) anglers in Germany, and implications for inland fisheries management and eutrophication control

Robert Arlinghaus*, Thomas Mehner

Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, P.O. Box 850119, 12561 Berlin, Germany

Received 11 February 2002; received in revised form 10 October 2002; accepted 10 October 2002

Abstract

Many freshwater ecosystems suffer from dense common carp (*Cyprinus carpio* L.) stocks. From the ecological point of view, high carp densities are not desirable because of several negative impacts (e.g. bioturbation, competition with other benthivores). A mail and internet survey among specialised carp anglers (SCAs) ($n = 710$) suggests that, in Germany, carp anglers' catch exceeds commercial carp harvest by up to 2500%. This indicates that by following at least five steps (marketing, education, specific regulations, risk communication and monitoring), carp angling may reduce carp stocks efficiently. Moreover, demographics, participation patterns, economic impact and value of SCAs suggest a great potential for marketing (tourism, commercial fishermen). Thus, specialised carp angling provides a means for inland (carp) fisheries management world-wide. However, input–output balances for total phosphorus revealed that, under certain conditions, carp angling may contribute substantially to anthropogenic eutrophication if ground- and pre-baiting is used in excess and harvest rates are low. A simple equation was developed to provide managers with a tool for a quick appraisal of the likelihood of a negative ecological impact of phosphorus inputs by angling. Further research on this topic is recommended to develop management guidelines on maximum tolerable amounts of bait because ground-baiting is intensively practised not only by carp anglers but also by the general coarse fish angler.

Keywords: Angling; Ecological impact; Ground-baiting; Human dimensions; Recreational fisheries

1. Introduction

The world-wide importance of common carp (*Cyprinus carpio* L.) in inland fisheries (e.g. Balon, 1995) stems from its role in contributing to animal protein supply for human demand. Moreover, this species is highly appreciated by many recreational fisheries, particularly in Europe (e.g. United Kingdom: Linfield, 1980; Czech Republic: Vacha, 1998; Germany: Wedekind et al., 2001). Stocking material is relatively cheap and carp are fairly resistant against handling stress and low oxygen concentrations in the water (Steffens, 1980). Therefore, common carp has been introduced and commonly stocked around the world to support commercial and recreational fisheries (FAO, 1999). However, carp often develops an avoidance behaviour against fishing gears (Hunter and Wisby, 1964; Raat, 1985; Barthelmes and

* Corresponding author. Tel.: +49-30-64181-653; fax: +49-30-64181-750.
E-mail address: arlinghaus@igb-berlin.de (R. Arlinghaus).

0165-7836/02/$ – see front matter
PII: S0165-7836(02)00243-6

Doering, 1996) such that population management by net fishing is often impossible, especially in larger lakes with varying depths and features (Barthelmes, 1994). Therefore, underfished, relatively old carp stocks are present in many fresh waters, particularly in countries where extensive and intensive carp production in lakes was common practice under a state regime (e.g. East Germany, Barthelmes, 1994), or where recreational fisheries intensively performed stocking programmes with carp (Borkmann, 2001). In several central and western European countries (e.g. Germany) these stocks have been rarely exploited by commercial fisheries because of the low demand by the human population in recent years (Anonymous, 2001).

From the ecological point of view, high carp densities are not desirable because of several negative impacts of this benthivorous fish on water quality. Due to its feeding strategy, carp contributes to increases in turbidity and internal nutrient load by resuspending sediments which may eventually reduce the density of submerged macrophytes (e.g. Meijer et al., 1990; Breukelaar et al., 1994). Therefore, to improve water quality, reduction of the biomass of benthivorous fish is a goal of food–web manipulations (e.g. Hansson et al., 1998). In addition, growth rates and stocks of other fish may be impacted by competition with carp. Most of the negative effects of high carp densities correlate positively with total carp biomass (Breukelaar et al., 1994; Lougheed et al., 1998). In turn, due to density dependence, growth rates of individual carp are low in overpopulated stocks resulting in high numbers of small-sized fish (Lorenzen, 1996).

Investigations on motivations for angling have shown that anglers may rate size of fish caught more important than number of fish caught (e.g. Hampton and Lackey, 1976). Thus, there may be a corresponding interest by both anglers and ecosystem managers to keep carp stocks at relatively low densities. Because of the low intensity of targeted commercial carp fishing in recent years, angling might be an alternative mean to reduce overpopulated carp stocks. Modern angling techniques for carp (Paisley, 1997) are highly selective. Selectivity is achieved by the use of hard baits such as cereals or so called ‘boilies’ which are made out of different meals, eggs, flavours, feeding stimulants and boiled in water until they become hard. This procedure ensures that only bigger cyprinid fishes are able to crush the baits with their pharyngeal bones. However, since ground-baits are used in large amounts to attract the fish in coarse (non-salmonid) angling (Cryer and Edwards, 1987), specialised carp anglers (SCAs) may contribute to anthropogenic eutrophication in their preferred waters. Thus, although (specialised) angling for carp may be an effective method for carp biomass reduction, the excessive use of ground-baits may reduce water quality. To evaluate more precisely these antagonistic effects of carp angling and the potentials of SCAs in contributing to carp biomass reduction, more fisheries-specific information is required. This information should encompass parameters such as catch, effort and amount and type of bait used. In addition, human dimensions of SCAs have also to be included (e.g. Brown, 1987) because fisheries management is increasingly being viewed more as people management than fish management (Ditton and Hunt, 2001). For example, if fishery managers plan to implement programmes targeting at attracting carp anglers, an understanding of the potential users of fisheries, their motivations and behaviour, is important not only for direct management purposes such as establishing regulations, but also for marketing purposes (Pollock et al., 1994).

Using results of a SCA survey in Germany, the aims of this paper are (1) to describe briefly the characteristics of the highly specialised carp angler segment, (2) to demonstrate the effectiveness of carp angling compared to commercial fisheries, (3) to calculate the total phosphorus balance of an average carp angler and evaluate the likelihood of a substantial contribution to anthropogenic eutrophication, and (4) to point out options and limitations for inland fisheries management taking SCAs into account.

2. Material and methods

In 2000/2001, a mail and internet survey was conducted among SCAs living in Germany. A self administered, 4-page questionnaire containing 28 questions was designed to gather data on demographics, participation and activity patterns, preferences, economic impact and value, motivations, catch and amount and type of baits used. Due to the fact that in Germany: (a) no address list of SCAs was available, (b) the finite population was unknown, and (c) a subsample of “ordinary” angler surveys would be too low to allow for a statistical analysis, a different sampling approach was implemented. The goal was to collect as many responses from SCAs as possible. High specialisation anglers have a higher level of mediated interaction than have low specialisation anglers (Ditton et al., 1992), i.e. communication relies more heavily on mediated means (e.g. television, internet, newspapers, magazines, journals, bulletins) than on face-to-face interaction. Therefore, questionnaires were distributed among SCAs: (a) during the only German specialised carp angling tradeshow in 2000 (Braunfels, November 2000), (b) using the leading German specialised carp angling web page (http://www.carp.de, December 2000 until May 2001) and (c) by the only two German specialised carp angling magazines (Carp Mirror, Issue 2, 2001; Carp Connect, Issue 7, 2001). In either case, SCAs were offered the opportunity to respond by mail or to fill in the questionnaire on the web. Several awards were offered to the respondents to increase participation. Objectives, background of the study and address of the scientific institution were given on the questionnaire. The anonymity of the data was guaranteed. The publication of the results in specialised carp angling magazines was announced to reduce scepticisms and encourage participation. A total of 710 questionnaires from anglers living in Germany was used for analysis. About 52% were gathered per internet and 48% per post. Additionally, 28 Austrian and one Dutch carp angler responded, but their data were not included.

Economic impact of SCAs was estimated using the following formula (Wedekind et al., 2001):

$$E_{\mathrm{Y}} = (T_{\mathrm{m}} \times E_{\mathrm{TM}}) + E_{\mathrm{FM}} + E_{\mathrm{HM}} \quad (1)$$

where E_{Y} is the total expenditures (€ per angler per year), T_{M} the mean trips per angler and year (trips per angler per year), E_{TM} the mean expenses per trip (€ per trip), E_{FM} the mean fixed expenses per angler and year (€ per angler per year) and E_{HM} the mean holiday expenses per angler and year (€ per angler per year).

Willingness-to-pay (net economic value or consumer surplus, € per angler per year) was assessed using a straightforward methodology proposed for contingent valuation (CV) studies with anglers (Pollock et al., 1994; Roth et al., 2001). First expenditures were ascertained, then SCAs were asked to estimate the maximum amount over and above those expenditures that they would have been willing to pay for the same fishing experience before they would have stopped going to the fishing sites they used. This CV methodology applied to users (i.e. recreational fishermen) only, measures mainly use value of fisheries resources and fishing (Navrud, 2001).

To compare carp catch by SCAs and carp harvest by commercial fisheries, official statistics of German commercial fisheries were used (Von Lukowicz and Brämick, 2000, 2001). The input–output-balance for total phosphorus (P) of an average SCA was based on published work on body P contents of carp (0.48% of wet matter, Schreckenbach et al., 2001) and an analysis of P contents of typical carp baits (based on wet matter: particles such as cereals, beans, nuts 0.39%, readymade and readymix boilies 0.33%, self-made boilies 0.77%, miscellaneous baits 0.78%; M. Niesar, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, unpublished data). The mass balance for an average SCA consisted of the amount of P introduced to the aquatic ecosystem by the use of ground-bait (input), and the P removal with the catch (harvest, output) (Wolos et al., 1992). In Germany, catch-and-release fishing is banned by law in 1 of the 16 federal states (Bavaria: Braun, 2000) and institutionally forbidden by local angling rules in many other regions. Consequently, to release a fish that has reached the legal size limits is a very sensitive issue (Braun, 2000). Therefore, in the questionnaire the anglers were not asked to indicate either catch amount or harvest amount, because people practising catch-and-release of carp might give untrue answers (under reporting of catch or over reporting of harvest). Thus, the P balance was based on assumed proportions of the catch taken home (harvest) by the average SCA which was considered sufficient to evaluate whether carp angling exhibited a net P-input or not.

An equation was developed to provide managers with a simple model to assess whether the amount of P introduced by angling to a particular body represents a negligible or substantial contribution to the total permissible P-load which in the latter case would necessitate further management actions (e.g. banning of ground-baiting). It was assumed that the water area Y which may be substantially impacted by P-inputs through ground-baits is a function of angler density (X), critical P-loading (A) and actual P-input through angling practices (B) and can be formalised as follows:

$$Y = f(X, A, B)$$

This function was developed by the equation for critical P-loading values of Vollenweider (1976) which is shown in parentheses in the denominator and is applicable over a large variety of lakes of different morphometry and hydraulic loads.

$$y = \frac{bx}{a(\overline{\mathrm{Psp}}(\bar{z}/\tau)(1+\sqrt{\tau}))} \quad (2)$$

where y is the critically impacted water area (m^2), x the angler numbers, a the tolerated or "substantial" contribution of P-input through angling practices (%, values between >0 and 1.0) to total permissible P-load (mg m^{-2} per year) according to Vollenweider (1976), b the mean yearly P-input per angler (mg per angler per year), $\overline{\mathrm{Psp}}$ the mean in-lake phosphorus concentration at spring overturn (mg m^{-3}), $\bar{z}$ the mean depth (m) and τ the water retention time (years). For P controlled lakes, oligotrophic lakes are likely to be found at $\overline{\mathrm{Psp}} < 10$ mg m^{-3} and eutrophic ones at $\overline{\mathrm{Psp}} > 20$ mg m^{-3} (Vollenweider, 1976). These threshold values were used for modelling two case studies of an oligotrophic and eutrophic lake and may be used when data of P concentrations at spring overturn are lacking.

The SPSS software package (Version 9.0.1) was used for data analysis. Factorial analysis by varimax method was performed for analysing items of the motivation question considering only eigenvalues >1 and factorial loadings >0.5 relevant (Lozán and Kausch, 1998). The motivation items used were based on published items with an acceptable reliability and validity (Fedler and Ditton, 1994). In social sciences, reliability is a measure of the reproducibility of results. Validity is the accuracy that an instrument truly measures what it intends to measure, here motivation of anglers.

3. Results

3.1. Human dimensions

3.1.1. Numbers and demographics

According to insider estimations, between 10 000 and 20 000 SCAs are present in Germany. A highly significant positive correlation (Pearsons product–moment correlation coefficient $r = 0.96$, $P < 0.001$) was found between the percentage of survey respondents and the percentage of inhabitants per each of the 16 German states (Länder). In contrast, there was no clear correlation between the percentage of survey respondents and the percentage of water area per state. German SCAs were predominantly young, unmarried males (Table 1). Comparing the SCA populations with the general angler population of two German states where data were available, the low proportion of retired persons among SCAs became apparent (Fig. 1). There was a relatively high share of pupils, students and academic persons in the SCA population.

3.1.2. Participation characteristics

The average SCA (age 28.9) started angling at the age of 12.2 years (Table 1). Specialisation on carp started on average at the age of 21.4. Angling time including travel duration was 36.4 h per trip on average, and therefore staying at least on night at the waterside was common practise. The yearly individual effort corresponded to 4.1 angling hours per day. More than 80% of the angling effort was spent on carp fishing.

Only around 6% of the SCAs living in Germany fished predominantly abroad (mainly in The Netherlands and France) whereas the vast majority fished in Germany. SCAs mainly fished in lakes (76.4% of the respondents), gravel pits (67.8%) and large rivers (54.2%). About one-third of the SCAs frequently fished in canals. Ponds, small rivers (trout region) and the sea were seldom (<7.8%) chosen as angling sites. Most of the SCAs undertook specific angling holidays and were organised in angling clubs.

According to the angler survey, the mean yearly expenditures of a SCA amounted to nearly 5500 € (Table 1). According to Fig. 2, 69% of these expenditures consisted of variable expenses (A), 21% of fixed expenses (B) and 10% of holiday expenses (C). Around 70 € were spend per fishing trip. Mean yearly expenditures for baits (1147 € per year) were highest among all positions. Net economic value or consumer surplus was estimated to be roundabout 1000 € per angler per year.

3.1.3. Motivations

Factorial analysis of the motivations scale revealed a set of nine factors (Table 2 and Fig. 3). Thus, SCAs were motivated by a complex set of reasons.

Table 1
Selected demographic and participation characteristics (group mean or percent of total and 95% confidence intervals) of SCAs in Germany

	Group mean or percent of total	95% confidence limit
Demographic characteristic		
Age (years)	28.9	28.2–29.5
Gender (% males)	98.4	97.4–99.3
Singles (%)	67.0	63.5–74.0
People per household	2.9	2.8–3.0
Angler per household	1.3	1.26–1.35
Academic persons (%)	16.5	13.8–19.3
Participation characteristic		
Angling experience (years)	16.7	16.1–17.3
Carp angling experience (years)	7.5	7.1–7.8
Carp angling time (%)	83.8	82.5–85.0
Hours per trip including travel time (h per trip)	36.4	32.8–40.0
Angling days (days per year)	75.9	72.8–78.9
Angling trips (trips per year)	56.4	53.5–59.3
Estimated effort (h per year)	1449.7	1381.3–1581.1
Travel distance (km)	82.1	65.7–98.4
Membership in angling clubs (%)	87.5	85.1–90.0
Share of anglers undertaking angling vacations (%)	59.5	55.9–61.3
Value of specialised tackle (€)	5951	5622.0–6280
Expenditures (€ per year)	5490	5109.0–5871
Consumer surplus (€ per year)	1019	902.0–1136

Relaxation in and enjoyment of nature were of highest importance. The catch specific factors (catch one or several fish, catch fish for consumption) were ranked of lower importance than the experience of a fighting fish or catching a specimen-sized fish. For SCAs to catch a specimen-sized fish was significantly (Wilcoxon test, $P < 0.001$) more important than catching several fish (compare item means in Table 2).

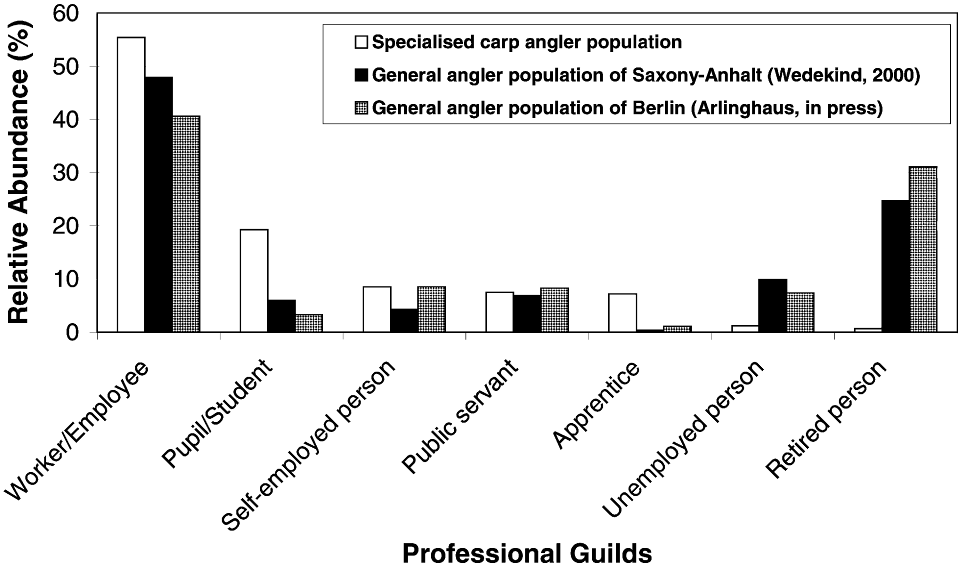

Fig. 1. Comparison of relative abundance (%) of professional guilds of the SCA and two general angler populations in Germany.

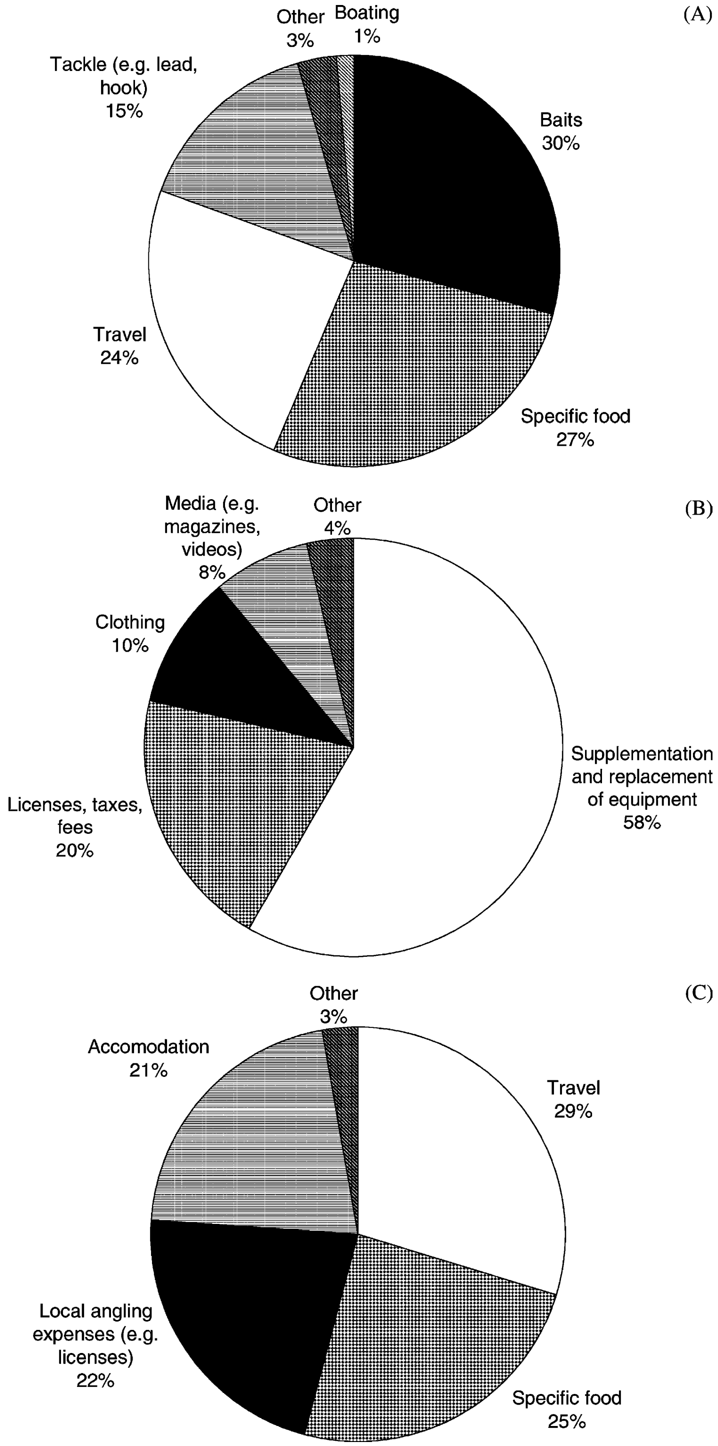

Fig. 2. Composition (%) of variable (A), fixed (B) and holiday (C) expenses of SCAs in Germany.

Table 2
Factor loadings of 25 items on motivations to fish for SCAs in Germany

Motivation for carp angling (item mean[a] in parenthesis)	Factors								
	1[b]	2[c]	3[d]	4[e]	5[f]	6[g]	7[h]	8[i]	9[j]
To get silence (4.36)	0.75								
To enjoy pleasant surroundings (4.17)	0.69								
For relaxation (4.48)	0.68								
To experience nature (4.57)	0.67								
To get away from everyday life (4.08)	0.54								
To test and experiment (3.77)		0.77							
To have new and different experiences (3.57)		0.71							
To improve knowledge and skills (3.89)		0.63							
To make pictures of catch (3.51)			0.67						
To catch trophy fish (3.13)			0.54						
To catch nothing but carp (3.78)			0.51						
To enjoy a fighting fish (3.86)				0.63					
To experience the catch of a fish (3.56)				0.61					
To test equipment (2.53)				0.57					
To be with friends (3.39)					0.73				
To be alone[k] (3.05)					−0.71				
To catch at least one fish (3.00)						0.82			
To catch several fish (2.39)						0.67			
To take fish home (1.33)							0.88		
To obtain fish to eating (1.5)							0.87		
To win a price (1.11)								0.74	
To compete with others (1.71)								0.57	
To present my catch in the public (1.22)								0.55	
Because my family urges me (1.20)									0.72
Because angling is cheap (1.22)									0.56

[a] Response format: 1: not at all important, 2: slightly important, 3: moderately important, 4: very important and 5: extremely important.
[b] Relaxation in and enjoyment of nature.
[c] Novelty and adventure feeling.
[d] Chase for trophies.
[e] Experience of fighting fish.
[f] Social gathering with friends.
[g] Catch fish.
[h] Catch fish for consumption.
[i] Public appreciation of accomplishment.
[j] Satisfy other needs at the waterside.
[k] Item scale was reversed before calculation of mean.

3.2. Comparison of SCA catch and commercial carp harvest

Respondents of the SCA survey specified a mean carp catch of 332.0 kg per year (95% CI 305.7–358.3 kg per year). The catch per unit effort (CPUE) was estimated by the ratio of means of catch and effort (Table 1) as 0.23 kg h^{-1}, 4.4 kg per day or 5.9 kg per trip. By contrast, the share of carp on the commercial fisheries yield in Germany was 6.6% or 290.6 t in 1999 and 7.4% or 268.2 t in 2000. Therefore, the catch of specialised carp angling alone exceeded commercial carp harvest by up to 2500% in 2000, if a population of 20 000 SCAs is assumed in Germany.

3.3. The possible contribution of specialised carp angling to eutrophication

The average SCA used 215 kg bait per year (95% CI 196.3–233.5 kg per year) which corresponded to 0.15 kg h^{-1} or 3.81 kg per trip. Most of the baits consisted of so called particles (48%) and boilies (40%),

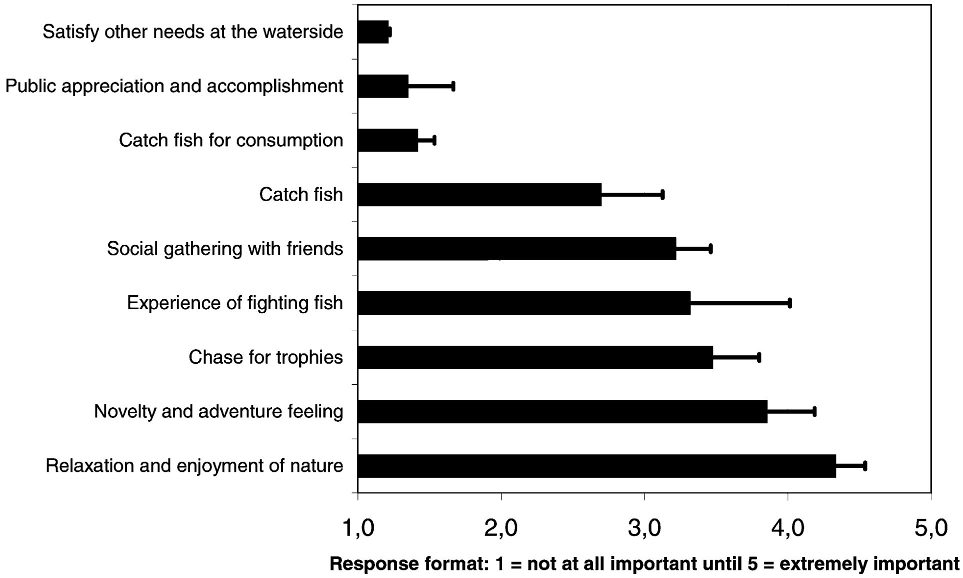

Fig. 3. Combined means of individual items in the factor and standard deviation for factors in the SCAs motivations scale.

Table 3
Fisheries-specific variables correlating positively with yearly catch (dependent variable) of SCAs in Germany according to a stepwise multiple regression model

	Standardised regression coefficient	Coefficient	S.E.	*P*-value	*R*	Durbin-watson
Dependent variable						
Catch (kg per year)					0.459	1.712
Independent variables[a]						
Constant		9.915	32.220	0.765		
Bait amount (kg per year)	0.275	0.365	0.049	<0.000		
Effort (h per year)	0.266	0.103	0.014	<0.000		
Experience (years)	0.138	5.592	1.444	<0.000		

[a] Variables excluded from the model ($P > 0.05$): specific carp fishing experience; percent of angling time spent carp fishing; angling days; angling trips; angling hours per trip; travel distance; angling locality (Germany or foreign, dichotomous variable); organisation level (dichotomous variable); share of specific type of boilies; nine dichotomous variables of preferred angling water (gravel pit, lake, high order river, low order river, canal, reservoir, river lake, pond, sea).

mainly commercially available readymades (45% of all the boilies were readymade boilies, 36% selfmade boilies, 19% boilies made of readymixes). In addition, some miscellaneous feedstuffs (dog feed, fish feed, ground-bait for coarse fishing) were used (12%). Amount of baits used per year, angling experience and yearly effort correlated significantly with yearly catch (Table 3).

The yearly amount of baits introduced corresponds to about 1.02 kg P per year. The yearly P budget of an average SCA would become balanced at a fish removal rate of 64% of the mean yearly catch of 332 kg (Fig. 4). Thus, at fish removal rates below 212 kg per year, carp angling would contribute to the P-load of the water bodies and consequently to eutrophication. At fish removal rates above 212 kg per year, SCAs would be net removers of P from the waters.

To illustrate the likely conditions for a substantial contribution of a net input of P by carp angling to anthropogenic eutrophication, Eq. (2) was parameterised

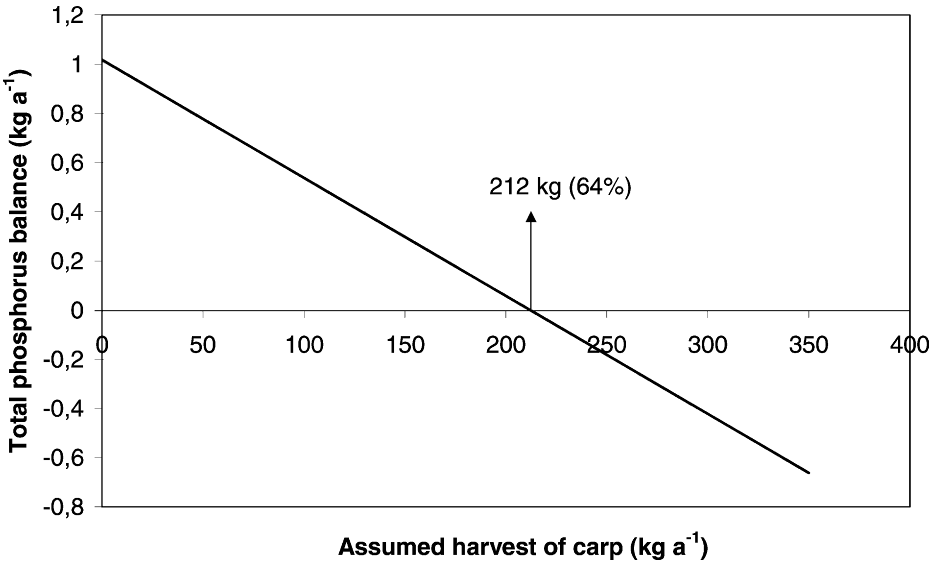

Fig. 4. Total phosphorus (P) balance of an SCA in Germany depending on the assumed carp harvest. Positive values indicate a net P-input to the water.

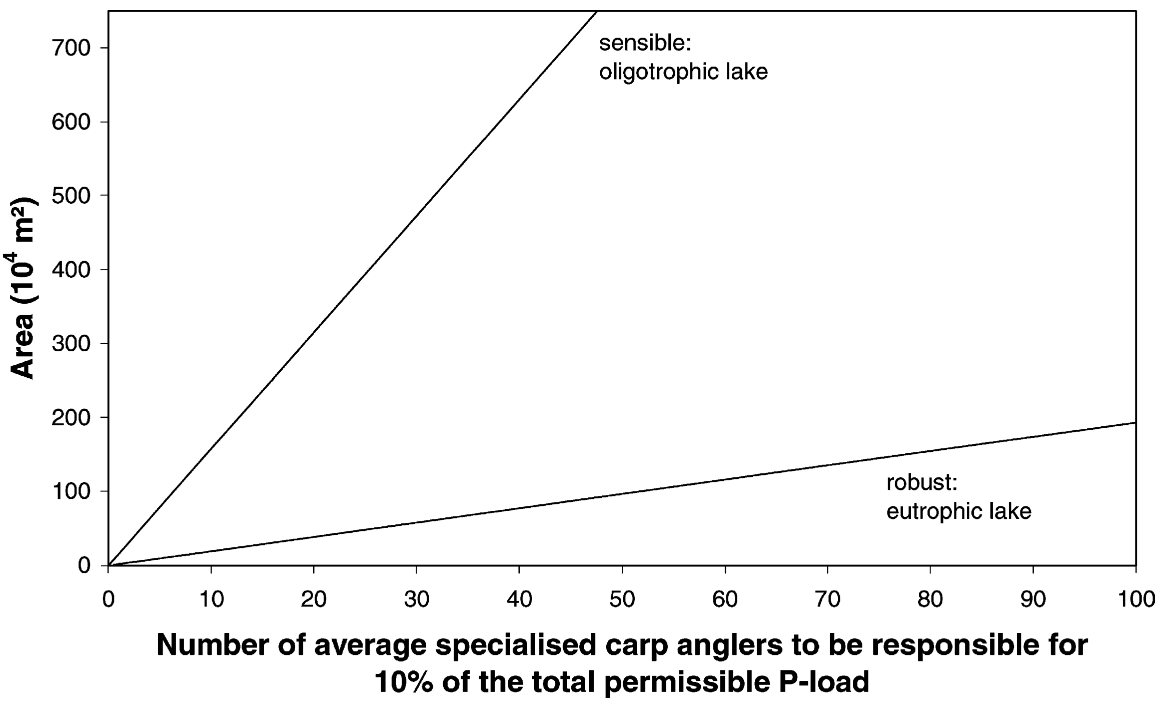

Fig. 5. Relationships between number of SCAs and water area on which ground- and pre-baiting may contribute substantially to the P-input (i.e. 10% to the total permissible P-load according to Vollenweider, 1976). The data are based on Eq. (2) and are calculated for two lakes with divergent morphometric, hydrologic and trophic characteristics.

by an arbitrarily set "substantial" contribution to the total permissible P-load of $a = 10\%$ and the mean P-input of $b = 1.02 \times 10^6$ mg per SCA per year. The range of possibilities was bounded by two extreme cases of morphometry, hydrology and trophic status of (fictive) lakes which were used to parameterise Eq. (2): one oligotrophic lake with mean depth $\bar{z} = 22$ m, water retention time $\tau = 50$ years and $\overline{\text{Psp}} = 10\,\text{mg}\,\text{m}^{-3}$ and another eutrophic lake with $\bar{z} = 2$ m, $\tau = 0.1$ years and $\overline{\text{Psp}} = 20\,\text{mg}\,\text{m}^{-3}$. Eq. (2), Figs. 4 and 5 indicate that the likelihood of SCA contributing with 10% to the total permissible P-load increases with: (a) decreasing harvest rates; (b) increasing angler densities; (c) decreasing water area; (d) decreasing water depth; (e) increasing water retention time, and is ultimately dependent on the trophic status. Nutrient-poor water bodies are more likely to be eutrophied by groundbaiting than nutrient rich waters (Fig. 5).

4. Discussion

4.1. Human dimensions, effectiveness and negative impacts of specialised carp angling

The sociological concept of specialisation has been used in the past to break up the heterogeneous angler population into more homogeneous subgroups (Hahn, 1991). SCAs as briefly described in this paper, are technique setting specialists (Bryan, 1977) or advanced species specialists (Hahn, 1991) which range at the very end of the angler specialisation continuum. Compared with the general angler population of three other states where data were available (Wedekind, 2000; Arlinghaus, 2003; Arlinghaus and Mehner, 2003), the SCA population (a) is younger, (b) spends considerably more resources (time, money), (c) has less angling experience, (d) travels on average longer distances to the waterside, and (e) has a higher share of angler organised in angling clubs. This corresponds well with the opinion of Hahn (1991), who argues that extent of species specialisation, frequency of fishing, investment in angling, years of experience, and centrality of fishing to lifestyle are indicators of specialisation that consistently discriminate between angler types. The only exception is years of experience which is lower in the SCA segment than in three general German angler populations. However, specialised carp angling with boilies is a rather modern development becoming popular in continental Europe since the 1980s which explains this pattern.

Comparable to many other angler segments (e.g. Hampton and Lackey, 1976; Paukert et al., 2001; Arlinghaus, 2003), SCAs prefer specimen-sized fish rather than the catch of many smaller fish, mainly in standing waters such as lakes and gravel pits. Thus, it is conceivable to find a compromise solution between the interests of lake managers on the one hand and fisheries managers and anglers on the other hand on how to reduce carp stocks to an extent where both carp impact on ecosystems and biomass of individual fish become acceptable for a wide range of stakeholders.

Compared with traditional carp anglers (e.g. 0.19 kg carp per day by Polish carp anglers using classical baits such as bread and worms, Wolos et al., 1992), the modern carp angler using boilies is considerably more effective. However, SCAs are not the most efficient anglers and higher catch rates ($\text{kg}\,\text{h}^{-1}$) were found in several angler studies (MacKenzie, 1991; Linløkken, 1995). Nevertheless, the relatively low CPUE a SCA is by far outweighed by the massive fishing effort. Therefore, already between 800 and 900 SCAs may catch the same amount of carp as was harvested by commercial fishermen in Germany in 1999 and 2000. By considering at least 1.47 million anglers in Germany (Von Lukowicz and Brämick, 2000, 2001), recreational fisheries greatly exceed the commercial carp harvest even if there are uncertainties in the estimation methods (see Pollock et al., 1994; FAO, 1999 for details).

According to German angler studies (Grosch et al., 1977; Wedekind, 2000), up to 50% of the catch is harvested and consumed by anglers. It was estimated that the yearly P-input of an average SCA was equivalent to a fish removal of 64% of the mean yearly catch. Therefore, and because catch-and-release fishing is common practice among angling specialists (Hahn, 1991), in contrast to earlier studies (compare Wolos et al., 1992) the nutrient balance of an average SCA is very likely to be positive. Thus, specialised carp angling may contribute significantly to anthropogenic eutrophication. However, the potential contribution of excessive ground- and pre-baiting to cultural eutrophication is dependent on local conditions of the lakes, such as morphometry, water retention time, trophic status (Vollenweider, 1976), structure of the fish stock and angling pressure (Edwards and Fouracre, 1983).

A negative impact of ground-baiting on the ecosystems may be expected in small, nutrient-poor lakes with long water retention time at high angler densities and low harvest rates. However, there is a considerable lack of knowledge about the potential effects of ground-baits on the limnology of aquatic ecosystems. In addition, the literature is also inconsistent with respect to the maximum tolerable share of nutrient loading by angling (Edwards and Fouracre, 1983; Wolos et al., 1992), as compared with critical P-loadings (Vollenweider, 1976). Therefore, further research on this topic is recommended because ground-baiting is extensively practised by many coarse anglers and there seems to exist a positive correlation between the amount of bait used and catch, at least in carp fishing (compare Wolos et al., 1992).

The yearly P-input by the average SCA as described in this paper is likely to be an overestimation of the true value because of several biases associated with mail surveys and long recollection time frames (Pollock et al., 1994). However, precautionary principles and approaches in sustainable inland fisheries management (Costanza et al., 1998; Arlinghaus et al., 2003) require safe and reversible management actions. Therefore, calculations based on overestimated nutrient inputs should lead to improved decisions in local freshwater fisheries management. The model (Eq. (2)) introduced in this paper may provide managers with a tool for a quick appraisal of the likelihood of a substantial contribution to anthropogenic eutrophication by angling. The application of this model to a particular water body requires estimates of mean angler density and mean amount and type of bait used by the local anglers. This paper and Wolos et al. (1992) provide P contents of various feedstuffs for calculation of mean P-inputs per angler if the type of bait is known. Together with data on mean depth, water retention time, mean in-lake phosphorus concentration at spring overturn and a maximum tolerable contribution of angling to the P-load (e.g. >0–5%), the model allows calculation of the area of water that will be affected negatively by introduction of ground-baits. If the area of the particular water body is below the calculated area, angling very likely contributes substantially to anthropogenic eutrophication, and vice versa. Alternatively, the model can be used to calculate maximum tolerable angler numbers given the area of a particular water body and an estimate of mean P-input per angler and year. This may aid local fisheries management decision making concerning the issue of ground-baiting. In addition to the model on the likely effect of nutrient inputs by ground-baits presented in this paper, more detailed management guidelines which can be easily understood and applied by local fisheries managers, need to be developed on the issue of groundbaiting.

4.2. *Inland fisheries management implications*

From the freshwater fisheries management perspective, owing to the increasing popularity of carp angling, rod-and-reel fishing may be a means for carp biomass reduction in local fisheries. If local management authorities plan to implement programmes to reduce numbers and biomass of carp in sensitive ecosystems to a standing stock of <25–50 kg ha^{-1} of specimen-sized carp (compare recommendations by Grimm and Backx, 1994; Meijer and Hosper, 1997), at least five steps are necessary.

First, marketing mechanisms are necessary to attract SCAs to the specific water bodies under consideration. The human dimensions of SCAs (e.g. mobile, highly involved, high level of mediated-interaction) provide excellent prerequisites for effective marketing strategies for tourism, commercial fisheries and public authorities charged with ecosystem and fisheries management. Economically threatened commercial fishermen, who in Germany normally sell angling tickets to enhance their revenues, could provide SCAs with custom tailored angling opportunities (Steffens and Winkel, 2002), e.g. big sized carp at relatively low densities in a well managed fishery (compare Tournay, 2001 in France). Marketing opportunities exist also for countries other than Germany because SCAs are increasingly travelling to carp fisheries abroad (e.g. France, Romania, The Netherlands). It might also be conceivable to instruct resident anglers with the modern carp angling techniques. This is also an option for countries where carp are normally considered an alien or pest species (e.g. Australia, Canada, USA). Due to the fact that carp are excellent sport fish, carp angling may become fashionable in countries beyond the borders of Europe (compare attempts of Cooper, 1987).

Second, education programmes targeting local fisheries managers and the general angler population should be implemented to illustrate negative impacts of dense carp stocks and the density-dependent growth pattern. In The Netherlands, education courses succeeded in reducing stocking densities of carp (Walder and van der Spiegel, 1990). If stocking is not reduced voluntarily by local angling clubs and fisheries managers, more stringent control and enforcement of stocking plans and even banning of carp stocking is recommended (e.g. Denmark: Rasmussen and Geertz-Hansen, 2001).

Third, specific catch regulations to protect larger carp such as maximum size limits or slot length limits should be implemented and communicated to the angling public to increase compliance (Noble and Jones, 1999). Regular fish faunistic and creel angler surveys should be conducted to properly evaluate the success of the regulation (Radomski et al., 2001) and to allow for adaptive management (Walters, 1986).

Forth, the potential negative impact of excessive ground- and pre-baiting should be communicated to the resident anglers. If voluntary reductions of bait amounts are not practised, in sensible water bodies at high angler densities daily bait limits or even banning of ground-baits are recommended. However, there remains the necessity of some form of control and enforcement (Hemming and Pierce, 1997) which may be implemented through local-level informal institutions (Ostrom et al., 1999) and co-management schemes (Brown, 1998).

Finally, the exploitation rate and standing stock of carp need to be monitored. Given the concern of angling specialists with conservation and their willingness to abide by regulations that enhance the fishery resource (Bryan, 1977; Ditton et al., 1992), a straightforward presentation of supportive evidence for the desired policy changes may help to gain support of SCAs (Hahn, 1991) in monitoring carp stocks. Because of the difficulty of sampling carp by conventional fishing gears, caught-and-released carp by angling might be a means of monitoring success of the carp biomass removal. There are two possibilities given that larger carp (e.g. individual body mass >5 kg) are released after being caught and usually pictures are made by the SCAs which allow the application of marc-recapture methods. Qualitatively, higher growth rates of recaptured individual carp, which dedicated SCAs easily identify via comparison of pictures of previously caught carp, indicate that pressure of overpopulated carp stocks has eased. Quantitatively, in close collaboration with SCAs fisheries managers could use diaries of SCAs to estimate population size, biomass and rate of exploitation (see application of "Petersen method" to a carp recreational fishery by Linfield, 1980).

The removal of carp by SCAs as a management measure to reduce the overall carp biomass centres around the prerequisite that the largest specimen-sized carp are protected to satisfy motivations of SCAs and encourage cooperation. However, in some regions in Germany, catch-and-release fishing is not tolerated (Berg and Rösch, 1998) which enhances intra and intersectoral conflicts (e.g. Stolzenburg, 1995) and limits the application of the approach presented in this paper. Several SCAs were challenged in court for releasing carp, mainly because according to the German Animal Protection Act there has to be a "reasonable reason to cause pain, suffering or damage to an animal" and making pictures of trophy carp, releasing fish for the catch of others or for stock conservation purposes are often not accepted as proper reasons. However, reasonable reasons for releasing fish are not specified in German laws or by-laws (Braun, 2000). Furthermore, Rose (2002) showed recently that fish lack the essential brain regions or any functional equivalent to experience pain and suffering. Nevertheless, in several adjudications, reasons for angling were often accepted only if fish were taken home for consumption. In any case, in Germany according to the 16 fishing laws every fishing rights holder has the duty to maintain, improve and manage the fish stocks and the aquatic ecosystems as a whole. The management principle of sustainability at the same time requires that stakeholder interests have to be included in management decisions (Costanza et al., 1998; Arlinghaus et al., 2003). The reduction of carp biomass by angling may improve water quality and ecosystem status and is a measure to maintain and improve aquatic ecosystem status. At the same time, the protection of smaller numbers of larger carp for the interests of SCAs by catch-and-release may be perceived to correspond with the sustainability principle (Aas et al., 2002) and is a measure to manage and protect fish stocks. It is a matter of interpretation of the German Animal Protection and Fisheries Acts by fishing protagonists, authorities, lobby groups and ultimately the courts whether catch-and-release fishing under the approach presented here will be an accepted reason for harming a fish in certain regions of Germany.

Acknowledgements

We are grateful to Volker Book (http://www.carp.de), Markus Dittgen (Carp Connect), Jürgen Meyer (M+M Baits), Christoph Schulz (tradeshow Braunfels) and Mike Zöllner (Carp Connect, http://www.carp.de) for support and partial sponsorship and three anonymous reviewers for helpful comments on an earlier version of this paper.

References

Aas, Ø., Thailing, C.E., Ditton, R.B., 2002. Controversy over catch-and-release recreational fishing in Europe. In: Pitcher, T.J., Hollingworth, C.E. (Eds.), Recreational Fisheries: Ecological, Economic and Social Evaluation. Blackwell Science, Oxford, pp. 95–106.

Anonymous, 2001. Hat der Karpfen bei uns noch Zukunft? -7 Thesen zur Misere des Karpfens. Fischmagazin (12), 83–88.

Arlinghaus, R., 2003. Charakterisierung der Berliner Angelfischerei. In: Wolter, C., Arlinghaus, R., Grosch, U.A., Vilcinskas, A. (Eds.), Fische und Fischerei in Berlin. Senatsverwaltung für Stadtentwicklung und Umweltschutz, Berlin (in press).

Arlinghaus, R., Mehner, T., 2003. Characteristics of anglers living in the metropolitan area of Berlin (Germany): implications for urban fisheries management and research. In: Proceedings of the Third World Recreational Fishing Conference, May 21–24, 2002, Darwin, Australia. Department of Business Industries and Resource Development (in press).

Arlinghaus, R., Mehner, T., Cowx, I.G., 2003. Reconciling traditional inland fisheries management with sustainability in industrialised countries, with emphasis on Europe. Fish Fish (in press).

Balon, E.K., 1995. The common carp, *Cyprinus carpio*: its wild origin, domestication in aquaculture, and selection as colored nishikigoi. Guelph Ichthyol. Rev. 3, 1–55.

Barthelmes, D., 1994. Impact of intensive fishing pressure on fish populations in lakes of Eastern Germany. In: Cowx, I.G. (Ed.), Rehabilitation of Freshwater Fisheries. Fishing News Books, Blackwell Science, Oxford, pp. 69–76.

Barthelmes, D., Doering, P., 1996. Sampling efficiency of different fishing gear used for fish faunistic surveys in stagnant water bodies. Limnologica 26, 191–198.

Berg, R., Rösch, R., 1998. Animal welfare and angling in Baden-Württemberg, Germany. In: Hickley, P., Tompkins, H. (Eds.), Recreational Fisheries: Social, Economic and Management Aspects. Fishing News Books, Blackwell Science, Oxford, pp. 88–92.

Borkmann, I., 2001. Fischereiliche Bonitierung von Still- und Fließgewässern des DAV und des VDSF in Sachsen-Anhalt. In: Weniger, U. (Ed.), Tagungsband zum 4. Landesfischereitag des Landesfischereiverbandes Sachsen-Anhalt e.V. am 17. März 2001 in Blankenburg/Harz. Landesfischereiverband Sachsen-Anhalt e.V., Halle, pp. 17–32.

Braun, M., 2000. Tierschutz im Fischereirecht. In: Keiz, G. (Ed.), Fischerei and Naturschutz. Tierschutz und Fischereiausübung-ökologische Fischhege. Schriftenreihe 2, Verband Deutscher Sportfischer e.V., Offenbach, pp. 7–15.

Breukelaar, A.W., Lammens, E.H.R.R., Klein Breteler, J.G.P., Tátrai, I., 1994. Effects of benthivorous bream (*Abramis brama*) and carp (*Cyprinus carpio*) on sediment resuspension and concentrations of nutrients and chlorophyll a. Freshwater Biol. 32, 113–121.

Brown, T.L., 1987. Typology of human dimensions information needed for Great Lakes sport-fisheries management. Trans. Am. Fish. Soc. 116, 320–324.

Brown, R.C., 1998. Community-based cooperative management: renewed interest in an old paradigm. In: Pitcher, T.J., Hart, P.J.B., Pauly, D. (Eds.), Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, pp. 185–194.

Bryan, H., 1977. Leisure value systems and recreational specialization: the case of trout fishermen. J. Leisure Res. 9, 174–187.

Cooper, E.L. (Ed.), 1987. Carp in North America. American Fisheries Society, Bethesda, MD.

Costanza, R., Andrade, F., Antunes, P., van den Belt, M., Boersma, D., Boesch, D.F., Catarino, F., Hanna, S., Limburg, K., Low, B., Molitor, M., Pereira, J.G., Rayner, S., Santos, R., Wilson, J., Young, M., 1998. Principles for sustainable governance of the oceans. Science 281, 198–199.

Cryer, M., Edwards, R., 1987. The impact of angler ground-bait on benthic invertebrates and sediment respiration in a shallow eutrophic reservoir. Environ. Pollut. 46, 137–150.

Ditton, R.B., Hunt, K.M., 2001. Combing creel intercept and mail survey methods to understand the human dimensions of local freshwater fisheries. Fish. Manage. Ecol. 8, 295–301.

Ditton, R.B., Loomis, D.K., Choi, S., 1992. Recreation specialisation: re-conceptualization from a social world perspective. J. Leisure Res. 24, 33–51.

Edwards, R.W., Fouracre, V.A., 1983. Is the banning of ground-baiting in reservoirs justified? In: Proceedings of the Third British Freshwater Conference. University of Liverpool, Liverpool, pp. 89–94.

FAO (Food and Agricultural Organization of the United Nations), 1999. Review of the State of World Fishery Resources: Inland Fisheries, FAO Fisheries Circular No. 942. FAO, Rome.

Fedler, A.J., Ditton, R.B., 1994. Understanding angler motivations in fisheries management. Fisheries 19 (4), 6–13.

Grimm, M.P., Backx, J.J.G.M., 1994. Mass removal of fish from Lake Wolderwijd, The Netherlands. Part I. Planning and strategy of a large-scale biomanipulation project. In: Cowx, I.G. (Ed.), Rehabilitation of Freshwater Fisheries. Fishing News Books, Oxford, pp. 390–400.

Grosch, U.A., Buchin, H.E., Brandt, G., 1977. Zusammensetzung, Fangaufwand, -ziel und -ertrag der Berliner Sportfischerei. Arbeiten des Deutschen Fischereiverbandes 22, 129–145.

Hahn, J., 1991. Angler specialisation: measurement of a key sociological concept and implications for fisheries management decisions. In: Guthrie, D., Hoenig, J.M., Holliday, M., Jones, C.M., Mills, M.J., Moberly, S.A., Pollock, K.H., Talhelm, D.R. (Eds.), Creel and Angler Surveys in Fisheries Management, Proceedings of the American Fisheries Society Symposium, vol. 12, Bethesda, MD, pp. 380–389.

Hampton, E.L., Lackey, R.T., 1976. Analysis of angler preferences and fisheries management objectives with implications for management. Proc. Southeast. Assoc. Game Fish Commis. 29, 310–316.

Hansson, L.A., Annadotter, H., Bergman, E., Hamrin, S.F., Jeppesen, E., Kairesalo, T., Luokkanen, E., Nilsson, P.A., Søndergaard, M., Strand, J., 1998. Biomanipulation as an application of food-chain theory: constraints, synthesis, and recommendations for temperate lakes. Ecosystems 1, 558–574.

Hemming, B., Pierce, B.E., 1997. Fisheries enforcement: our last frontier. In: Hancock, D.A., Smith, D.C., Grant, A., Beume, J.P. (Eds.), Developing and Sustaining World Fisheries Resources: the State of Science and Management. CSIRO, Collingwood, pp. 675–679.

Hunter, J.R., Wisby, W.J., 1964. Net avoidance behavior of carp and other species of fish. J. Fish. Res. Bd. Can. 21, 613–633.

Linfield, R.S.J., 1980. Catchability and stock density of common carp, *Cyprinus carpio* L. in a lake fishery. Fish. Manage. 11, 11–22.

Linløkken, A., 1995. Angling pressure, yield and catch per effort of grayling, *Thymallus thymallus* (L.), and brown trout, *Salmo trutta* L., on the rivers Glomma and Rena, southeastern Norway. Fish. Manage. Ecol. 2, 249–262.

Lorenzen, K., 1996. A simple von Bertalanffy model for density-dependent growth in extensive aquaculture, with an application to common carp (*Cyprinus carpio*). Aquaculture 142, 191–205.

Lougheed, V.L., Crosbie, B., Chow-Fraser, P., 1998. Predictions on the effect of common carp (*Cyprinus carpio*) exclusion on water quality, zooplankton, and submergent macrophytes in a Great Lakes wetland. Can. J. Fish. Aquat. Sci. 55, 1189–1197.

Lozán, J.L., Kausch, H., 1998. Angewandte Statistik für Naturwissenschaftler, 2nd ed. Parey Buchverlag, Berlin.

MacKenzie, C., 1991. Comparison of northern pike catch and harvest rates estimated from uncompleted and completed fishing trips. In: Guthrie, D., Hoenig, J.M., Holliday, M., Jones, C.M., Mills, M.J., Moberly, S.A., Pollock, K.H., Talhelm, D.R. (Eds.), Creel and Angler Surveys in Fisheries Management, Proceedings of the American Fisheries Society Symposium, vol. 12, Bethesda, MD, pp. 47–50.

Meijer, M.L., Hosper, H., 1997. Effects of biomanipulation in the large and shallow Lake Wolderwijd, The Netherlands. Hydrobiologia 342/343, 335–349.

Meijer, M.L., de Haan, M.W., Breukelaar, A.W., Buiteveld, H., 1990. Is reduction of the benthivorous fish an important cause of high transparency following biomanipulation in shallow lakes? Hydrobiologia 200/201, 303–315.

Navrud, S., 2001. Economic valuation of inland recreational fisheries: empirical studies and their policy use in Norway. Fish. Manage. Ecol. 8, 369–382.

Noble, R.L., Jones, T.W., 1999. Managing fisheries with regulations. In: Kohler, C.C., Hubert, W.A. (Eds.), Inland Fisheries Management in North America, 2nd ed. American Fisheries Society, Bethesda, MD, pp. 455–477.

Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B., Policansky, D., 1999. Revisiting the commons: local lessons, global challenges. Science 284, 278–282.

Paisley, T., 1997. To Catch a Carp. The Crowood Press, Wiltshire.

Paukert, C.P., Klammer, J.A., Pierce, R.B., Simonson, T.D., 2001. An overview of northern pike regulations in North America. Fisheries 26 (6), 6–13.

Pollock, K.H., Jones, C.M., Brown, T.L., 1994. Angler Survey Methods and their Applications in Fisheries Management. American Fisheries Society, Bethesda, MD.

Raat, A.J.P., 1985. Analysis of angling vulnerability of common carp, *Cyprinus carpio* L., in catch-and-release angling in ponds. Aquacult. Fish. Manage. 16, 171–187.

Radomski, P.J., Grant, G.C., Jacobson, P.C., Cook, M.F., 2001. Visions for recreational fishing regulations. Fisheries 26 (5), 7–18.

Rasmussen, G., Geertz-Hansen, P., 2001. Fisheries management in inland and coastal waters in Denmark from 1987 to 1999. Fish. Manage. Ecol. 8, 311–322.

Rose, J.D., 2002. The neurobehavioral nature of fishes and the question of awareness and pain. Rev. Fish. Sci. 10, 1–38.

Roth, E., Toivonen, A.L., Navrud, S., Bengtsson, B., Gudbergsson, G., Tuunainen, P., Appelblad, H., Weissglas, G., 2001. Methodological, conceptual and sampling practices in surveying recreational fisheries in the Nordic countries-experiences of a valuation survey. Fish. Manage. Ecol. 8, 355–367.

Schreckenbach, K., Knösche, R., Ebert, K., 2001. Nutrient and energy content of freshwater fishes. J. Appl. Ichthyol. 17, 142–144.

Steffens, W., 1980. Der Karpfen. A. Ziemsen Verlag, Wittenberg Lutherstadt.

Steffens, W., Winkel, M., 2002. Evaluating recreational fishing in Germany. In: Pitcher, T.J., Hollingworth, C.E. (Eds.), Recreational Fisheries: Ecological, Economic and Social Evaluation. Blackwell Science, Oxford, pp. 130–136.

Stolzenburg, H., 1995. Boilieangeln, (4) AFZ-Fischwaid, pp. 12–15.

Tournay, B., 2001. French win in game market. Fish Farming Int. 28, 34.

Vacha, F., 1998. Information on Czech Republic fisheries. In: Hickley, P., Tompkins, H. (Eds.), Recreational Fisheries: Social, Economic and Management Aspects. Fishing News Books, Oxford, pp. 48–57.

Vollenweider, R.A., 1976. Advances in defining critical loading levels for phosphorus in lake eutrophication. Mem. Ist. Ital. Idrobiol. 33, 53–83.

Von Lukowicz, M., Brämick, U., 2000. Freshwater fisheries in 1999. In: Bundesministerium für Ernährung, Landwirtschaft und Forsten (Ed.), Jahresbericht für die deutsche Fischwirtschaft. Köllen Druck + Verlag, Bonn, In German, with English summary, pp. 59–83.

Von Lukowicz, M., Brämick, U., 2001. Freshwater fisheries in 2000. In: Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft (Ed.), Jahresbericht für die deutsche Fischwirtschaft. DCM Verlag, Meckenheim, In German, with English summary, pp. 43–68.

Walder, J., van der Spiegel, A., 1990. Education for fisheries managers in The Netherlands. In: van Densen, W.L.T., Steinmetz, B., Hughes, R.H. (Eds.), Proceedings of the Symposium on Management of Freshwater Fisheries, European Inland Fisheries Advisory Commission, Göteborg, Schweden, May 31–June 3, 1988. Pudoc, Wageningen, pp. 372–381.

Walters, C.J., 1986. Adaptive Management of Renewable Resources. MacMillan, New York.

Wedekind, H., 2000. Sozio-ökonomische Untersuchungen zur Angelfischerei in Sachsen-Anhalt. Institut für Binnenfischerei e.V., Potsdam Sacrow.

Wedekind, H., Hilge, V., Steffens, W., 2001. Present status, and social and economic significance of inland fisheries in Germany, and social and economic significance of inland fisheries in Germany. Fish. Manage. Ecol. 8, 405–414.

Wolos, A., Theodorowicz, M., Grabowska, K., 1992. Effect of ground-baiting on anglers' catches and nutrient budget of water bodies as exemplified by Polish lakes. Aquacult. Fish. Manage. 23, 499–509.