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A Telephone-Diary-Mail Approach to Survey Recreational Fisheries on Large Geographic Scales, with a Note on Annual Landings Estimates by Anglers in Northern Germany

MALTE DOROW*
Institute for Fisheries
State Research Center Mecklenburg-Vorpommern for Agriculture and Fisheries
Fischerweg 408, 18069 Rostock, Germany
and
Department of Biology and Ecology of Fishes
Leibniz-Institute of Freshwater Ecology and Inland Fisheries
Müggelseedamm 310, 12587 Berlin, Germany

ROBERT ARLINGHAUS
Department of Biology and Ecology of Fishes
Leibniz-Institute of Freshwater Ecology and Inland Fisheries
Müggelseedamm 310, 12587 Berlin, Germany
and
Inland Fisheries Management Laboratory, Department for Crop and Animal Sciences
Faculty of Agriculture and Horticulture, Humboldt-University of Berlin
Philippstrasse 13, Haus 7, 10115 Berlin, Germany

Abstract.—Fisheries managers are looking for valid information on basic characteristics of recreational fisheries, such as landings data, to inform management decisions. We present a complementary survey approach designed to generate data on effort and harvest as well as various human dimensions of anglers using a telephone-diary-mail survey design for a multispecies, multi-site fishery in a water-rich state in northern Germany (Mecklenburg-Vorpommern). First, a nationwide telephone screening was applied to estimate the total number of active resident and nonresident anglers in the study area. Afterwards, a 1-year diary study with randomly recruited resident and nonresident anglers was conducted. Routine check-up telephone calls were used to encourage the participants, generate detailed human dimensions data on the characteristics of anglers, and evaluate diary entries. After the end of the diary study, 648 anglers (58%) returned complete diaries. Responding diarists were significantly older, had a higher level of education, and encompassed more avid anglers than the nonresponding participants. Thus, diarists were weighted against external characteristics of a random sample of the resident angler population to reduce the risk of biased catch and harvest estimates. Indeed, estimates for harvest and effort based on weighted samples were significantly lower than unweighted mean estimates. Extrapolations of average annual harvest rates per angler to the population level revealed that for the most economically important fish species such as European eel *Anguilla anguilla*, Atlantic cod *Gadus morhua*, northern pike *Esox lucius*, common carp *Cyprinus carpio*, or Eurasian perch *Perca fluviatilis*, recreational fishing landings greatly exceeded commercial fisheries landings. Because diary estimates of annual angler landings were generally smaller relative to estimates of angler harvest stem-

* Corresponding author: m.dorow@lfa.mvnet.de

ming from 3-month recall periods using telephone surveys and on-site creel surveys, we concluded that the use of diary data likely resulted in conservative estimates of total landings. Our survey design may serve as a model for further studies because of its cost-effectiveness relative to standard creel surveys and because the panel structure of diary studies allows rich insights into individual angler behavior that is not possible to be accomplished by cross-sectional creel surveys.

Introduction

World-wide, recreational fishing is a popular leisure activity (Arlinghaus and Cooke 2009). In most industrialized countries, recreational fishing constitutes the most important use of freshwater fish stocks (Arlinghaus et al. 2002), and its importance is rising rapidly in coastal areas (Coleman et al. 2004) and less developed countries (Cowx 2002). Recently, the possible contribution of recreational fishing to fish stock declines has been prominently discussed (McPhee et al. 2002; Post et al. 2002; Coleman et al. 2004; Arlinghaus and Cooke 2005; Lewin et al. 2006). Major fisheries management authorities such as the European Commission in Brussels (Belgium) are now beginning to discuss regulating the recreational fishing sector alongside commercial fishing (CEC 2008). However, in contrast to well-established monitoring systems in the United States that are designed to regularly estimate key marine recreational fisheries statistics (Essig and Holliday 1991; Gentner and Lowther 2002; NRC 2006), no such system is in place for marine recreational fisheries of Europe. Thus, even basic estimates of total landings by recreational anglers in countries such as Germany are generally not available, and the available estimates are highly uncertain (Brämick 2007) and thus of limited use for stock assessment purposes.

In the face of the fishery resource use shift from commercial to primarily recreational use in most industrialized countries (Arlinghaus et al. 2002), a pressing need for accurate and precise data on recreational fishing effort, catch, and harvest and other information (e.g., angler attitudes towards management issues) exists. In addition to collecting data sometimes referred to by human dimensions researchers as "surrogate biology" (Brown 1987; e.g., catch, harvest and effort), the need for monitoring selected social and economic indicators on a routine basis is increasing (Arlinghaus et al. 2002; NRC 2006). Obtaining this information in a cost-efficient way for large geographic scales is important because of the minimal public funding for monitoring of recreational fisheries in many European countries.

Seven basic survey designs are commonly used to gather information about recreational fishing activities: mail surveys, telephone surveys, door to door surveys, diary and logbook surveys, access-point surveys, roving surveys, and aerial surveys (Pollock et al. 1994). These approaches can be divided into off-site methods (the first four) that contact anglers outside the fishery and on-site methods (the last three) intercepting anglers directly while fishing. From a biological perspective, these surveys obtain information on fishing effort, catch, and harvest on species level, as well as size and weight of the fishes. From a social and economic perspective, angler surveys gather information such as motivations for fishing, beliefs, perceptions, attitudes and other human dimensions (Ditton 2004), and the economic impact (based on expenditure) and value (based on the concept of consumer surplus) of recreational fisheries (Pollock et al. 1994). The methods used to collect data on recreational fishing are usually driven by the underlying research or management questions, the temporal and spatial scale where the fishing activity occurs, and the available resources. The type of survey used is also dependent on the characteristics of the angler population (NRC 2006).

Every survey method has advantages and disadvantages that researchers and managers trade off (Pollock et al. 1994; NRC 2006). In the past two decades, complementary on-site/off-site survey designs that allow researchers to control for certain survey-specific biases have not been used intensively, despite some authors having called for their application (Pollock et al. 1994; Ditton and Hunt 2001; Henry and Lyle 2003). However, complementary designs that take advantage of the various features of different survey types may indeed be an optimal choice of approach if decision makers are interested in generating rich data sets on diverse topics in a cost-effective and timely manner while controlling biases of particular survey methods.

The objective of the present paper is to report the development, application, and evaluation of a large-scale complementary survey approach to collect a rich set of data on recreational fishing, including catch, harvest, and effort, as well as social and economic information. Our contribution focuses on the description of the overall design of the complementary telephone-diary-mail survey and its ability to provide catch and harvest estimates alongside other pertinent information on recreational fisheries exploiting a water-rich state in northern Germany.

Study Area

The study was conducted in the German state of Mecklenburg-Vorpommern (Figure 1a). Mecklenburg-Vorpommern (M-V) is located in northeast Germany and borders the Baltic Sea. Around 2,000 inland lakes greater than 1 ha are located in M-V (Winkler et al. 2007), along with several river networks. The high diversity of aquatic habitats coupled with a rather sparse population density of 73 people/km^2 makes M-V highly attractive for resident and nonresident anglers, including angling tourism from all states in Germany (Wichmann et al. 2008). Only limited fishing activity from foreigners living outside Germany is supposed to happen in M-V, but there are no data available to support this statement. There is generally a large gap in knowledge about the biological and socioeconomic importance of recreational fisheries in M-V. Indeed, only rough data are available on total numbers of resident anglers in the study area (Hilge 1998; Arlinghaus 2004; Brämick 2007), and no information on nonresident anglers (i.e., persons coming from other German states to fish in M-V) was available at the onset of our study. We focused our initiatives on people residing in Germany for financial reasons.

Selection of Survey Method

One of the main objectives of our survey was to reliably estimate the catch, harvest, and ef-

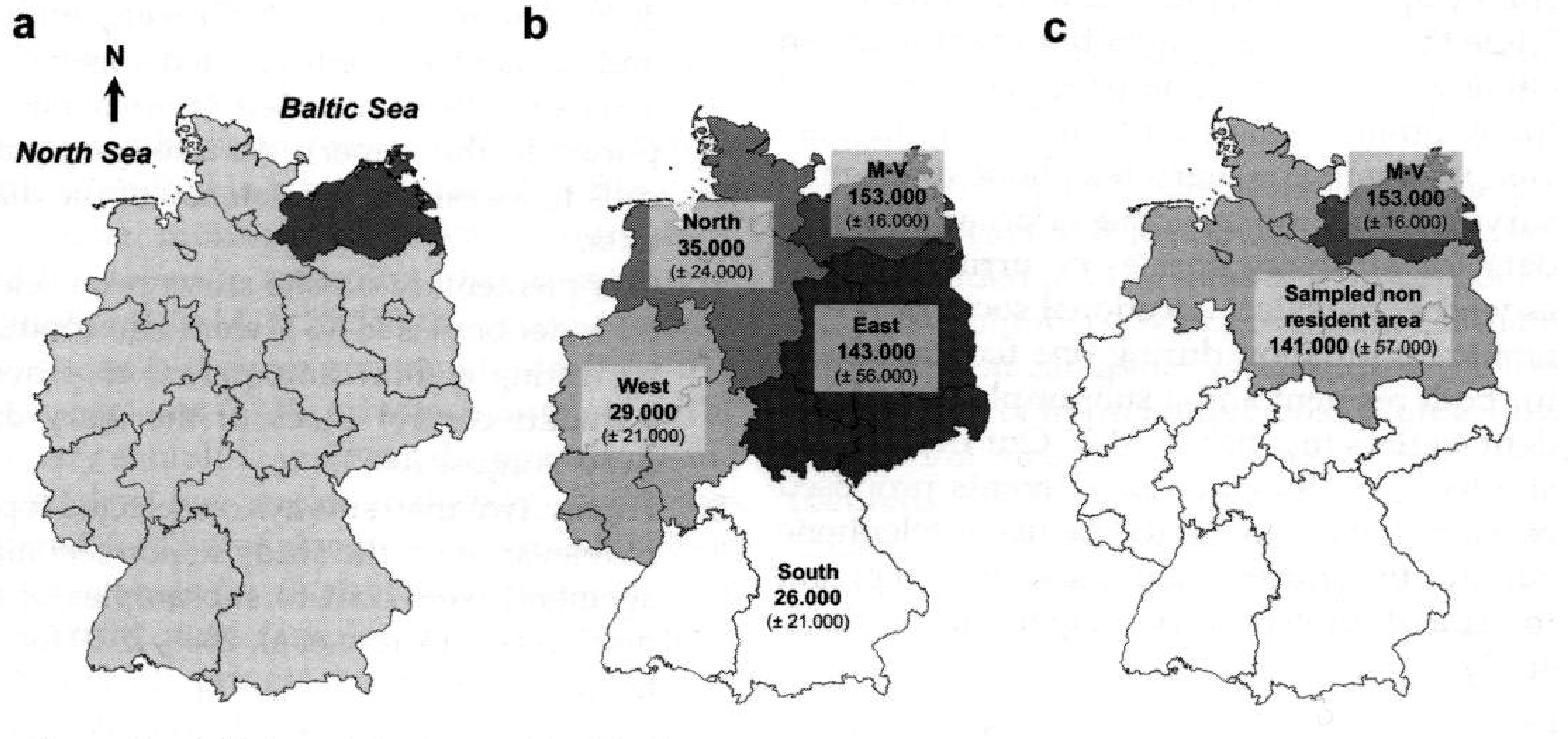

Figure 1.—(a) Map of Germany. Mecklenburg-Vorpommern (M-V), the study area, is located in the northeast. (b) Estimated total number of active anglers fishing in M-V per region. The estimate in the parentheses is the 95% confidence interval. (c) Sampled regions for the recruitment of diary participants. In addition to the study area M-V also a nonresident area was defined based on the German-wide screening. From both regions, approximately 77% of the total number of anglers who fished in M-V were represented in the diary survey. The total numbers of anglers with 95% confidence interval are shown for the sampled resident and nonresident area.

fort of recreational anglers residing within and outside M-V in inland and coastal waters in this state. Unfortunately, standard creel surveys specifically designed to measure catch and effort in recreational fisheries (Pollock et al. 1994) were cost-prohibitive considering the vast amount of lakes and rivers in M-V. Moreover, one of the focal species of the study, the European eel *Anguilla anguilla*, is primarily targeted at night, and the application of on-site survey approaches is limited during this time period as anglers are hardly observable as well as for safety reasons (Cooke et al. 2000).

In the search for alternative approaches to estimate catch and harvest for the entire state of M-V, complementary designs were suggested by Pollock et al. (1994) and Ditton and Hunt (2001), among others. Large scale angler surveys are commonly conducted with off-site techniques because of the lower costs and the ability to sample large numbers of anglers dispersed over a large geographical area (Henry and Lyle 2003), as is the case in M-V. A complementary survey approach, which uses a diary as memory aid was developed in Australia (Lyle et al. 2002; Henry and Lyle 2003). Lyle et al. (2002) concluded from their telephone-diary study that, compared to other large-scale survey approaches, the overall costs were low while the quality and quantity of information gathered was high. The promising results of the Australian studies inspired us to also develop a complementary telephone-diary-mail survey design for collecting effort and harvest data for all major species occurring in M-V, as well as to collect additional social and economic information during one fishing season for both resident and a subsample of nonresident anglers that fish in M-V. Our design constituted a combination of elements proposed by Henry and Lyle (2003) by using telephone surveys to estimate total angler numbers and to remind anglers to participate in the diary study.

Method

Our telephone-diary-mail approach necessitated that we first estimate the number of active anglers in M-V, including both resident and nonresident anglers. Second, catch and harvest rates at species level were assessed based on a sample of active anglers fishing in M-V participating in a 1-year diary study. Complementary telephone, mail, and on-site surveys were added to the sample of diarists to better understand the socioeconomic dimension of recreational fisheries (Dorow et al. 2009, 2010) and to provide quality control of the catch and effort estimates from the diary. The basic intent of the survey design was to generate data on effort, catch, and harvest, as well as a detailed demographic and psychological profile of each angler at the end of the survey. Our final survey design had five major components (Figure 2):

1. Estimation of the population size of active anglers in M-V (April–July 2006).
2. Recruitment of anglers for a 1-year diary study (May–August 2006).
3. Diary study accompanied by additional panel calls with the aim to increase motivation of the participants and to provide an in-depth characterization of the participants (September 2006–August 2007). During these surveys, for example, the concepts of angler specialization (Bryan 1977; Ditton et al. 1992; Scott and Schafer 2001), commitment (Buchanan 1985), and consumptive orientation (Aas and Vittersø 2000; Anderson et al. 2007) were applied, and further basic self-reported angler characteristics were assessed (results not reported in this paper). We also used panel calls to assess the consistency of the diary data.
4. Complementary on-site surveys on selected water bodies in M-V were also conducted during a short time period to provide a quality-control check of the diary data (July–August 2007).
5. Finally, two mail surveys on selected topics of relevance for the study region (eel management) were sent to subsamples of the diarists (see Dorow et al. 2009, 2010 for details).

Estimation of the Angler Population Size

Because a complete listing of anglers fishing in M-V was not available, a random telephone screening of households throughout Germany

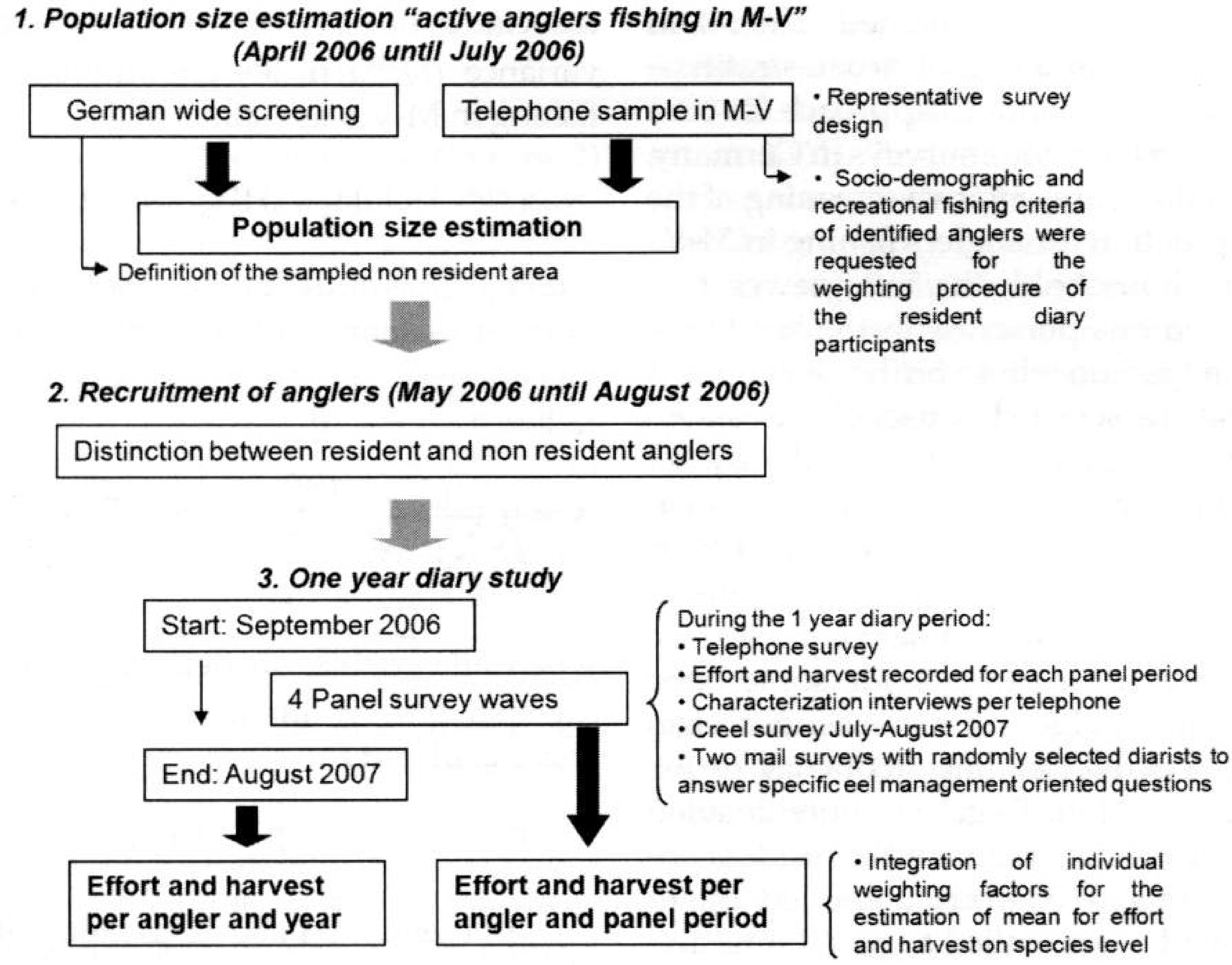

Figure 2.—Schematic overview of the large-scale survey for the assessment of the biological and socioeconomic importance of the recreational fishery in Mecklenburg-Vorpommern (M-V; Germany).

was conducted to estimate the population size of resident and nonresident anglers fishing in waters in the study area (Figure 2). Using a random digit dialing method to screen the general population in Germany in total, 128,602 telephone numbers were generated (gross sample), which resulted in a net sample of 19,815 valid telephone numbers of private households. For the separate screening of resident angler households in M-V, 25,553 telephone numbers (gross sample) were generated, resulting in a net sample of 3,955 private households. The primary sampling unit was the household and all anglers per angler household were considered for the angler population estimate at the household level (stratified simple random household quota sample). The sampling frame included all private households with a private telephone. For the telephone screening of households, the ADM (Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V.—Working Group of German Market and Social Research Institutes) master sample design (ADM and AG.MA 1999) was applied, which ensured the drawing of a random sample of private households in Germany (Gabler and Häder 1997). Telephone numbers were generated proportionally to the population size of the 16 German states, and within every state, quota-based sampling based on the population density of countries was conducted. To account for the urban-rural distribution of the population, so-called BIK-population size-classes were included in the generation process of the telephone numbers, which stratified Germany into different categories representing the true distribution of households across counties and population size of residencies within states (Behrens 1999). This spacing of telephone calls is possible based on the prefixes of telephone numbers that are associated with counties within a given state. To achieve a random sample of telephone numbers, the telephone area code was used as the prefix. For each area code, the randomly generated telephone number was then produced by varying the last the two numbers in a 100 block (00 until 99), which ensured also that households with nonlisted telephone numbers were included in the sample. The sampling was continued until the quota for each state was obtained. The ADM design, together with the rural-urban stratification, constitutes the standard approach for conducting random telephone surveys in Germany, which ensured a representative screening of the German population for anglers fishing in M-V.

In every household, the interviewer randomly selected one person with the last birthday question (person whose birthday was most recent within the selected household) to assess the incidence of anglers within randomly selected private households. Active anglers fishing in M-V were defined as a person aged 14 or older who had fished in M-V in the previous 12 months. For every identified active angler, the interviewee was asked to provide some basic personal demographic (age, household size) and angling related (angling frequency or experience) information. To gather more detailed data about the characteristics of the resident angler population in M-V, every identified angler household in M-V was called a second time and an interview with the angler in the household was conducted.

To estimate the total number of anglers fishing in M-V, we distinguished between resident anglers (resident in M-V) and nonresident anglers (resident outside of M-V but within Germany) as two strata (Figure 1A). The reason for the explicit consideration of the nonresident anglers was the assumption that this angler group could contribute substantially to the total effort and harvest in M-V. Total numbers of anglers were estimated at the scale of each household using household samples. To estimate the total number of active anglers fishing in M-V (N_h^{MV}) coming from a different region (stratum h), the number of active anglers fishing in M-V in the sampled households was counted. The angler population estimate based on a weighted household sample mean was then calculated as

$$\hat{N}_h^{MV} = \frac{\sum_{i=1}^{n\mathrm{HH}_h} w_{hi} y_i}{\sum_{i=1}^{n\mathrm{HH}_h} w_{hi}} \times \mathrm{HH}_h ,$$

where HH_h is the total number of households in a stratum h based on the census data (Statistisches Bundesamt 2007; Federal Statistical Agency), y_i number of anglers in household i, and w_{hi} is the associated household weight (see below). The variance (N_h^{MV}) of the total number of anglers fishing in M-V was estimated as

$$\mathrm{var}(N_h^{MV}) = \mathrm{HH}_h \times (\mathrm{HH}_h - n\mathrm{HH}_h) \times s_h^2 / n\mathrm{HH}_h ,$$

where HH_h is as defined above, and $n\mathrm{HH}_h$ is the number of sampled households in the stratum h (Thompson 1992). The s_h^2 was calculated as follows:

$$s_h^2 = \frac{1}{(\sum_{i=1}^{n\mathrm{HH}_h} w_{hi} - 1)} \times \left[\sum_{i=1}^{n\mathrm{HHs}} (w_{hi} y_i)^2 - (\sum_{i=1}^{n\mathrm{HHs}} w_{hi} y_i)^2 / \sum_{i=1}^{n\mathrm{HHs}} w_{hi} \right] ,$$

where all variables are defined as above. The associated 95% confidence interval 95% CI(N_h^{MV}) was calculated as

$$95\%\ \mathrm{CI}(N_h^{MV}) = N_h^{MV} \pm 1.96 \times \sqrt{\mathrm{var}(N_h^{MV})} .$$

As mentioned above, the estimation of angler number was based on a household sample. The household weight w_{hi} adjusted the distribution of household sizes to the true distribution in the nationwide sample, as well as in the specific sample of M-V. Note that because of the quota sampling approach, the final household sample already represented the true distribution of households across states and along the urban-rural gradient within states, which was achieved through the ADM master sample design (Gabler and Häder 1997). Thus, weighting factors for the household sample were still needed for the household size distribution in the sample, which should reflect the true distribution in Germany. To this end, interviewed households were grouped into one of four household size-classes (one-person, two-person, three-person, four and more-person households with the observed frequency $f_{i,\mathrm{HH}}^{o}$) and were adjusted using w_{hi} against the official census data for the distribution of the household sizes within states $f_{i,\mathrm{HH}}^{o}$ (Statistisches Amt M-V 2007; Statistisches Bundesamt 2007). The calculated household weighting factor w_{hi} constituted the quotient between the expected frequency of the household size $f_{i,\mathrm{HH}}^{e}$ and the observed frequency $f_{i,\mathrm{HH}}^{o}$, as

$$w_{hi} = \frac{f_{i,\mathrm{HH}}^{e}}{f_{i,\mathrm{HH}}^{o}} .$$

Recruitment of Anglers for a 1-Year Diary Study

The aim of the recruitment phase (Figure 2) was to identify a sample of resident and nonresident anglers fishing in M-V who were willing to participate in a 1-year diary study. Within M-V, the fishing license holder frame administered by the public order offices in M-V was used to recruit diarists. In the first step, a random sample of all public order offices in M-V was drawn. From every selected office, 120 randomly selected fishing license addresses were requested. In total, 4,752 addresses from 41 public order offices were obtained. These addresses were screened for telephone numbers using publicly available directories. Where no official telephone number was available, a letter was mailed along with a request to supply a telephone number. This procedure resulted in 3,135 telephone numbers for active fishing license holders in M-V. These anglers were contacted, and those anglers who indicated that they planned to fish in M-V in the next 12 months were asked if they would participate in the diary program.

Based on the results of the nation-wide telephone screening phase, the seven states surrounding M-V (Figure 1c) formed the area with the greatest number of active nonresident M-V anglers. Financial constraints prevented sampling nonresident anglers in other German states or abroad outside Germany. To recruit anglers from the nonresident angler area in Germany for the 1-year diary study, a second telephone screening was conducted using the ADM design (Gabler and Häder 1997). The gross sample of randomly generated telephone numbers was 128,211, resulting in a net sample of 42,672 private households. The identified angler in a households were asked for their interest in M-V as a fishing destination in the upcoming 12 months, and anglers that indicated some interest were asked for their willingness to participate in the diary study. Only one angler per household was randomly recruited for the diary study.

Diary Study

Diary studies in recreational fisheries have been reported to have low participation rates and suffer seriously from nonresponse bias (Anderson and Thompson 1991; Tarrant et al. 1993; Connelly and Brown 1996; Bray and Schramm 2001). To avoid low response rates and reduce the potential for nonresponse bias, we used high-quality incentives (an angling reel) and also regularly, once every 3 months, called each participant to remind him or her about the study and also to respond to questions and concerns (as per the recommendations of Henry and Lyle 2003). To further increase participation in the survey, the complete survey was designed to be transparent to the participants. For example, diary participants were regularly informed about preliminary results using written materials, and each angler received a personal diary report and a summary of the diary results from the entire study at the end of the study.

The recruited anglers from the M-V and the sampled nonresident area received the diary kit in August 2006. This kit contained the diary book and additional information (e.g., handling instructions, data security information). As in traditional diary approaches (Sztramko et al. 1991), the diary was employed as the primary data source to estimate effort, catch, and harvest. Anglers were asked to record every angling trip taken in M-V from the beginning of September 2006 until the end of August 2007. For each trip, trip date, total effort, directed effort, social group, catches and harvest, and angler satisfaction at the species level were recorded (Figure 3). To reduce the burden of documenting the length of each retained fish, anglers were only asked to document the length of the largest retained fish per species. Participants were explicitly asked to record all angling trips, including also those where no fish was caught (zero catches). Continued participation was encouraged by the regular panel calls. These telephone contacts also allowed us to control the number of active anglers in the diary sample, as well as to record the number of dropouts (anglers refusing further participation).

Diaries were intensively pretested under real life conditions with a sample of anglers. Additionally, in December 2006, a random sample of participants ($N = 150$) was asked to return their diaries for new ones, allowing us to examine the data quality. In total, 110 an-

Please use one page for every angling trip

Trip information

1. Start of the trip (leaving home)	Date:	Time:
2. End of the trip (coming home)	Date:	Time:
3. Net angling period (hours)		

Fished waterbody

4. Name of the waterbody		
5. Nearest town		
6. Waterbody type	☐ Running water ☐ Canal ☐ Natural lake ☐ Artificial standing water (e.g. quarry pond) ☐ Commercial angling pond	☐ Inner coastal water ☐ External coastal water ☐ Open sea ☐ Other type ____

Information about trip type and used gear

7. With whom were you fishing?	☐ Alone ☐ With family	☐ With friends ☐ Guide/Party boat	Number of anglers in the group: ____
8. Angling location	☐ Natural shore ☐ Artificial shore ☐ Boat ☐ Commercial Party Boat		
9. Number of used rods per angling method	___ Pole fishing (fishing small cyprinids) ___ Fish with dead fish bait ___ Fish with natural baits (corn, worm) ___ Fishing with boilies ___ Surfcasting	___ Heavy spin fishing (large fish) ___ Light spin fishing (small fish) ___ Pilk fishing Other method: ____	

Target species (How long did you fish for one of these species?)

10.	___h Eel	___h Herring	___h Zander
	___h Perch	___h Carp	___h Cyprinids
	___h Cod	___h Flatfish	___h Other species ____
	___h Pike	___h Salmonids (Trout, Salmon)	☐ No target species

Information about catch and harvest

Fish species		Number caught	Number retained	Size of the largest retained fish (cm)
11.	A.			
	B.			
	C.			
	D.			
	E.			
	F.			

Additional information

12. How many anglers did you see?	
13. Satisfaction with the catch?	1 2 3 4 5 6 7 8 9 10 (totally dissatisfied) ⟷ (totally satisfied)

Comments: (For example: Why did you release the fish?)

Diary

LANDESFORSCHUNGSANSTALT FÜR LANDWIRTSCHAFT UND FISCHEREI – *INSTITUT FÜR FISCHEREI*

Figure 3.—Example of a diary page. In addition to recording angling effort and harvest, the anglers were asked to give additional information for each trip including species specific targeted effort, angling method, and satisfaction with the harvest. The comments box was utilized to capture species-specific reasons for releasing a fish.

glers send their diaries back (response rate 73%). This test also revealed the usefulness of the graphical layout of the diary, facilitating easy completion of data entries by the angler.

Weighting Procedure of Diarists

To correct for potential nonresponse or avidity biases of those anglers sending back their diaries, an individual weighting factor was assigned to all responding resident diarists. To this end, selected external characteristics, which were known for the responding anglers and the angler-population of M-V (based on random household screening, Figure 2), were used. This type of weighting was only possible for resident anglers because an insufficient sample of nonresident anglers (N = 63 anglers fished in past 12 month in M-V) in the screening phase prevented development of a valid random distribution of external characteristics for this group.

Calculation of angler-weights was deemed necessary because voluntary participants in a diary study who were committed enough to complete and return their diaries over a full year are known to differ from the general angling population (Connelly et al. 2000; Bray and Schramm 2001). Therefore, a biased estimation of total effort and harvest would be the result if this avidity and other nonresponse bias are not considered in the calculation. Hence, it was crucial that the responding resident diary participants were adjusted by a weighting procedure to the resident angler population prior the estimation of total effort or harvest. The application of weighting factors is an accepted approach to correct biased samples in social surveys (Little 1986; Gabler et al. 1994). Individual weighting factors for every responding resident diary participant were calculated based on an iterative proportional fitting approach following Deming and Stephan (1940) and Gabler et al. (1994). In our study, we used seven criteria previously estimated by the telephone screening in the area of M-V (Figure 2), which were considered to be representative for the resident angler population. In terms of sociodemographic characteristics, the variables age (four age-classes), sex, resident area in M-V (four resident areas), education level (four levels), and employment status were included. To account for angling specific criteria in the weights, angling experience (in years, four experience levels) and angling frequency (angling days per year, four activity levels) entered the iterative weighting factor calculation process. The proportional distributions of these criteria were summarized for the representative sample of resident anglers and the responding resident diarists. Generally speaking, with the individual weighting factors ascribed to each responding diarists, the distribution of the responding resident diary sample was adjusted to the distribution of sociodemographic and angler characteristics previously determined by the representative telephone survey in the study area, assuming a random angler sample.

The weighting procedure proceeded stepwise in an iterative manner. First, the proportion of one criterion (criterion A) of the diarist sample was adjusted to the distribution of the angler population by calculating the quotient between the expected (based on the household survey, $f^e_{i,\text{criterion\_A}}$) and observed (responding diarist, $f^o_{i,\text{criterion\_A}}$) frequency for each criteria level, resulting in a starting weighting factor for each diarist i ($w_{i,\text{criterion\_A}}$).

$$w_{i,\text{criterion\_A}} = \frac{f^e_{i,\text{criterion\_A}}}{f^o_{i,\text{criterion\_A}}}.$$

For the second criterion (criterion B), the quotient $w_{i,\text{criterion\_B}}$ between expected and observed frequency was calculated as described above for criterion A for each responding diarist. By applying this procedure to each of the seven criteria, the first weighting run was finalized resulting in an integrated weighting factor (w^m_i), as follows:

$$w^m_i = w_{i,\text{criterion\_A}} \times w_{i,\text{criterion\_B}} \times \ldots \times w_{i,\text{criterion\_G}}.$$

Afterwards, starting with the first criterion A, the complete weighing procedure was repeated several times to increase the accuracy of the individual weighting factors and minimize the differences between the weighted dairy sample and the representative resident angler sample. During this iterative procedure, the previously estimated integrated weighting factor w^m_i was incorporated in the calculation of the next weighting factor (w^{m+1}_i) as

$$w^{k\_1,m+1}_i = w^m_i \frac{f^e_{i,\text{criterion\_A}}}{f^o_{i,\text{criterion\_A}}} \rightarrow w^{k\_1,m+2}_i = w^{k\_1,m+1}_i \frac{f^e_{i,\text{criterion\_B}}}{f^o_{i,\text{criterion\_B}}}.$$

This weighting procedure was iterated k times with all criteria in the same order. Under certain circumstances (e.g., no zero values for the defined criteria levels), these iterative procedure converge, so that with every new weighting run, the calculated weighting factors only change minimally. In our study, 10 weighting runs (k = 10) were found sufficient as the calculated individual weighting factors changed only marginally between the two last iteration runs. The resulting individual weights (w_i) scaled in the way that they sum to the sample size of resident anglers (N = 566). An individual weighting factor less than 1 indicated that a responding diary angler with certain demographic and angling related characteristics was overrepresented in the responding diarist sample compared to the overall angler population, whereas a personal weight greater than 1 displayed that a certain angler type was underrepresented in the diary sample and thus was upweighted. By applying the final, converged weighting factors (w_i) to the original sociodemographic and angling specific criteria distribution of the responding diary sample, only marginal differences between the resident angler population and resident responding diary sample existed, indicating that the weighting procedure was successful (Table 1).

On-Site Survey

To control the harvest data collected in the diary, on-site creel surveys were conducted in cooperation with the State Fishery Agency M-V. To this end, selected water bodies in the freshwater and coastal areas of M-V were sampled by official and voluntary inspectors during daytime (0800 hours until 1900 hours) in July and August 2007. This on-site sampling was conducted during the routine monitoring and enforcement activities of the agency and thus was not centered on particular times during the day or on particular water bodies. For the routine monitoring and enforcement activities, no standardized sampling plan like for stratified roving or access-point creel surveys was applied (compare Pollock et al. 1994, 1997). Thus, the data generated only served qualitative purposes because of the lack of a rigorous sampling design guiding the creel survey. Nevertheless, the creel surveys allowed the generation of (likely biased) harvest rate estimates for particular fishes on site and was used for qualitative comparisons with harvest rates estimates from the diary data. If diary data would result in substantially overestimated harvest rate estimates, as previously suggested (Pollock et al. 1994), one would expect our creel survey estimates to differ in a systematic way from the diary survey estimates for harvest rates.

Estimation of Effort and Harvest

To calculate the total effort and harvest of anglers in the study area, the diary data were used. To extrapolate these values to the total population of active resident and sampled nonresident anglers (Figure 1c), we assumed that between the date of the screening surveys and the diary period, the total number of active anglers did not change substantially in the study area. Thus, the population size estimate of active anglers based on the screening surveys was used to assess total effort and harvest. Further, resident and nonresident anglers were treated separately where resident anglers received an individual weighting factor in the calculation of average effort and harvest.

The total annual fishing effort was expressed as the total number of angling trips per year separated for resident and nonresident anglers. Total angler effort was estimated by multiplying the average number of trips per resident or nonresident angler and year with the associated angler population size. Average effort (trips per angler and year) were calculated with the standard formulas given by Pollock et al. (1994). In the case of the resident angler sample, a weighted mean was calculated by integrating the individual weighting factors into the calculation (weighted average). Similarly, the overall harvest per species was estimated. The total harvest per species was the product of multiplying the average number of retained fish per angler and year (separated for resident and nonresident angler) with the associated angler population size. The average number of retained individual fish of a given species (number of fish per angler and year) were calculating according to Pollock et al. (1994). For the calculation of the mean harvest per species of the resident anglers sample, the individual weighting factors were incorporated (weighted average).

A bootstrapping approach (N = 5,000 samples per species and resident area) was used to estimate the associated 95% confidence in-

Table 1.—Distribution (%) of angler characteristics entered in the weighting produce for the unweighted diarist sample, the weighted diarist sample and the representative angler sample based on the representative screening in Mecklenburg-Vorpommern (M-V) (see Figure 2).

		Proportion (%)		
Characteristic	Levels	Diarists unweighted	Diarists weighted	Representative angler sample
Age (years)	<30	17.5	27.5	27.5
	30–39	13.8	15.9	15.9
	40–59	50.5	38	38
	>60	18.2	18.6	18.6
Sex	Male	95.9	89.3	89.3
	Female	4.1	10.7	10.7
Education	Basic school	24.6	21.9	21.7
	Secondary school	44.5	43.5	43.1
	University entrance diploma/academic degree	25.3	23.1	22.8
	Student/school age	5.1	11.1	10.9
Employment status	Yes	57.7	49.0	49.2
	No	42.3	50.8	50.8
Region	West M-V	37.1	30.6	30.6
	Middle M-V	13.4	22.6	22.5
	West Pomerania	21.2	29.2	29.2
	Sea District	28.3	17.6	17.6
Angling experience (years)	0–5	20	20.8	20.6
	6–19	23.9	24.8	24.6
	20–29	12.5	20.1	19.9
	>30	43.6	34.3	34.0
Angling frequency (trips in M-V last 12 months)	1–3	8.1	23.3	23.3
	4–10	21.7	29.5	29.5
	11–20	22.1	21.3	21.3
	>20	48.1	25.9	25.9

tervals of the point estimate for total annual harvest per species (Efron and Tibshirani 1993; Haddon 2001). For each sample, the number of anglers (separately for resident and nonresident anglers) was drawn with replacement from a normal distribution of angler number with the mean and standard deviation of the distribution determined from empirical data (Figure 2, population size estimation). For each angler group, the harvest per angler was randomly sampled with replacement from empirical harvest data based on the diary data (including zero harvest and weighted values for resident anglers). Harvest per angler was then summed over all anglers to produce an estimate of total landings per year conducted separately for the resident and nonresident angler group. The resulting distribution from the 5,000 samples was used to calculate 95% confidence intervals.

To calculate the total biomass retained of each species, the average size of the retained fish was calculated using diary trip entries where only one fish of a given species was caught and retained, because anglers were asked only to document the size of the largest retained fish per species and trip. For this approach, the assumption was made that the average size per species does not differ between trips where only one fish was retained and those with multiple retained fish. Further-more, obvious errors in length data (e.g., fish larger than their maximum size, e.g., an eel of 150 cm) were eliminated for the average size calculation. The filtered fish lengths per species were commuted to fish weights by using length–weight relationships per species available from the Institute for Fisheries of the State Research Center M-V (unpublished data).

To appreciate and judge the quality of harvest estimates based on the diary, the effort and harvest data recorded by the four telephone panel calls with a 3-month recall period was used. In each contact, anglers were asked to recall their number of angling trips and their harvest for the most important fish species. In previous studies, the harvest overestimation by panel studies had been documented as a result of the recall bias, which increases with recall length (Tarrant et al. 1993; Connelly and Brown 1995), and it was thus assumed in our study that panel data would yield significantly higher estimates compared to diary data. Such finding would provide confidence into the diary data set. To check for these assumed differences, the average harvest per species for the four panel periods was calculated separately for resident and nonresident anglers using individual weighting factors for the residents, as presented above. The total harvest for the complete diary period was the sum of the harvest per panel wave and species. As in the estimates based on the diary data, the same bootstrapping approach was applied to calculate the 95% confidence intervals per panel wave for the total number of retained fishes per species, which were summed over the four waves for the total estimate for the complete diary season using panel call data. To calculate the total retained biomass, the same average weights per species like in the exploration of the diary data were applied to the panel telephone data.

To further check the self-reported catches and harvests of the diarists, on-site surveys were conducted during July and August in 2007, as previously explained. During the on-site survey, incomplete trips were recorded because anglers were interviewed during their angling trips. To allow a comparison with the self-reported data in the diaries, the assumption was made that catch rates from incomplete trips sampled during a wide spread of times within days in the creel survey would be similar to those from completed trips. Harvest rates on species level as number fish per angling hour were calculated based on the formula for completed trips (ratio of the means, diary) and incomplete trips (mean of the ratios, creel survey) presented by Pollock et al. (1994) by including zero catches. Afterwards the harvest rates for selected species were compared between dairy and on-site survey.

Statistical Analysis

A chi-square analysis was used to compare categorical data (e.g., education level) between responding and nonresponding diarists. To test for significant differences between two groups (e.g., diary versus on-site or responding and nonresponding diarist) for parametric data such as catch rates *t*-tests were applied in case of homogeneity of variance. If variance failed the test for homogeneity (Levené-test, $p < 0.05$), the normal distribution was tested. In the case of a normal distribution, the *t*-test for unequal variances was used to detect significant differences. If the test for normal distribution failed, a nonparametric U-test was applied for detecting significant differences between two groups. To detect differences between the mean annual harvest estimates per angler based on the diary and the panel calls, a Wilcoxon test was applied. All analyses were conducted with SPSS version 13.0.

Results and Discussion

Number of Anglers in the Study Area

The initial household surveys designed to estimate the total number of anglers in M-V achieved response rates of 51%. In terms of angler population size, 387,000 (±138,000, 95% confidence interval [CI]) German residents aged 14 or older were found to have fished at least once in the previous 12 months in the study area M-V (Figure 1b). The total number of nonresident anglers was estimated at 234,000 (±122,000, 95% CI), with 141,000 (±57,000, 95% CI, Figure 1c) coming from states with direct or close vicinity to M-V. These angler groups together with an estimated 153,000 (±16,000, 95% CI) anglers from M-V were included in the diary study. In total, 77% of the population of active anglers in M-V was covered in the diary study.

In 2007, the official fishery agency quote for yearly license for resident anglers in M-V was 97,533 (State Fishery Agency MV 2007). Our estimate of active resident anglers in M-V significantly exceeded ($t(0.95;\infty)=1.65; t<-1.65; p<0.05$) the official statistic (compare Figure 1b), suggesting a greater interest in recreational fishing than is reflected in license sales. Therefore, the total harvest of resident anglers would be underestimated if the official statistic on angler numbers had been used for extrapolation purposes. Several reasons can cause the difference between official license statistic and our estimation of the resident angler population size. First, the official license frame might be fraught with errors or be not up to date. Second, resident anglers can own a fishing license from another German state than M-V or fish with a tourism license that is not part of the above-mentioned license estimate. Third, recreational angling activities without an official licenses can contribute to the observed differences. It is highly likely that a fraction of M-V residents did fish without a license in the study area because about 13% of the identified active resident anglers in the representative screening survey (Figure 2) admitted to not own a valid fishing license for M-V, despite having fished in this state. Fourth, in the screening phase in some households nonanglers provided information about other household members that were anglers. Thus, some nonangling members might have indicated that fishing activities took place in M-V of another household member while that person fished outside M-V in reality. This would have inflated the estimated numbers of anglers based on the telephone sample. Generally, however, using telephone surveys similar to the one used in the present study other studies from Germany (Arlinghaus 2004), Austria (Kohl 2000), and Great Britain (Simpson and Mawle 2001) have also identified higher angler interest in a country or region than was reflected in official license sales have previously been reported, and our results agree with these reports.

Development of Diarist Recruitment and One-Year Diary Study

During the recruitment process, 1,452 resident anglers were identified who were planning to fish in M-V in the following angling year. Of these, 865 (59.6%) agreed to participate in the 1-year diary study. In the nonresident area, household screening surveys identified 1,378 angler households (3.2%). In these households, 382 anglers were identified who intended to fish in M-V in the next 12 months. From this sample, 256 anglers (67%) were willing to participate in the diary study. At the end of the recruitment phase (mid-August 2006), 1,121 anglers were recruited. More anglers were recruited in the resident area because of the assumption that these anglers would contribute to a higher degree to the total effort and harvest.

At the beginning of the first round of panel calls (October 2006), 1,109 anglers were still in the sample (dropout rate 1.1%). Between the first and second panel call (February 2007), 77 anglers dropped out (6.9%). During the second and third wave (May 2007), 59 anglers refused further participation (5.9%). Prior to the last panel wave in September 2007, 924 active participants (dropout 5%) were still active participants. The number of successfully interviewed anglers in each of the four panel calls varied during the four panel contacts. In the first panel wave, 1,016 (91.6%); in the second wave, 974 (94.4%); and in the third wave 782 (80.4%) and the fourth wave 806 (86.8%) participants were successfully interviewed.

At the end of August 2007, prior to the last panel call, all diarists received a high-quality angling reel and were asked to return their completed or uncompleted dairy books. Those that did not send back a diary were contacted at least three more times by mail and telephone to solicit the mail-back. In November 2007, at the end of this procedure, N = 746 anglers had send back their diary. In total, 648 anglers diaries came back with at least one trip resulting in an overall response rate of 58%. The response rate was higher for resident anglers (65%) compared to nonresident anglers (32%). The diary entries of these 648 active anglers (at least one trip) and the population of active anglers (fishing at least once) were combined for the estimation of total effort and harvest.

A comparison between resident diary respondents (N = 566) and resident diary nonrespondents (N = 290) showed significant differences between both groups regarding their angler and sociodemographic characteristics (Table 2). Responding participants were signif-

Table 2.—Characteristics (average ± SD; proportion in %) for selected angling and sociodemographic attributes for responding and nonresponding resident diarists. n.s. = not significant.

	Respondents (N = 566)	Nonrespondents (N = 290)	U*-, t+- or chi2# value	df	p
Angling characteristics					
Number of anglers in the household	1.4 (±0.6)	1.3 (±0.6)	80,551*		n.s.
Angling experience in years	23.1 (±16.3)	18.8 (±15.7)	3.6+	854	<0.001
Number of angling trips in M-V in previous 12 months	33.3 (±44.4)	24.8 (±30.1)	68,250.5*		<0.001
Importance of fishing[a]	2.2 (±1.2)	2.5 (±1.2)	0.6+	852	<0.05
Sociodemographic characteristics					
Age	45 (±15.2)	40.8 (±16.5)	127,516.5*		<0.001
Gender (% male)	95.9	95.5	0.1#	1	n.s.
Household size (% of two-person households)[b]	35.8	34.7	3#	4	n.s.
Education (% with academic degree)[c]	18.8	11.5	12.8#	5	<0.05
Employment status (% with employment)	57.7	57.3	0.02#	1	n.s.
Income (% with monthly income of 1,500–2,000€)[d]	24.2	18.3	7.3#	5	n.s.

[a] Item measured on the scale: 1 – most important, 2 – second most important, 3 – third most important, and 4 – one leisure activity among many.
[b] Household size categories were 1 – one-person household, 2 – two-person household, 3 – three-person household, 4 – four-person household, and 5 – five and more person household.
[c] Education categories were 1 – basic school without apprenticeship, 2 – basic school with apprenticeship, 3 – secondary school, 4 – high school, 5 – academic degree, and 6 – scholar.
[d] Income categories were 1 – less than 1,000€, 2 – 1,000€ to 1,500€, 3 – 1500€ to 2,000€, 4 – 2,000€ to 2500€, 5 – 2500€ to 3000€, and 6 – more than 3000€.

icantly older than the nonresponding participants. Further, responding diarists had a higher level of education than nonrespondents. Responding diarists tended to have significantly more angling experience and a higher level of angling avidity. Moreover, the responding anglers placed a higher level of importance on their recreational activity compared to nonresponding anglers. Based on previous studies, this avidity bias was expected (e.g., Bray and Schramm 2001; Hartill et al. 2008). Generally, it can be assumed that more avid and higher experienced anglers participate more frequently in diary surveys than less avid ones.

To account for avidity bias and also control for nonresponse bias, individual weighting factors assigned to each responding resident diarist were integrated into the calculation of the means of effort and harvest rates. By contrasting the weighted and unweighted means for effort and harvest rates for selected fish species, the effect of the weighting procedure can be demonstrated (Table 3). All weighted means for effort (e.g., annual angling trips) and annual harvest were lower compared to the corresponding unweighted ones, but differences were not always significant. Taking the mean effort and annual harvest rate for the popular angling species northern pike *Esox lucius* and Eurasian perch *Perca fluviatilis* as examples, the weighting factors resulted in a significantly lower estimation of the average annual harvest rate. This indicated that using unweighted means would lead to an overestimation of total effort and harvest for resident anglers by overrepresenting more avid, committed, and successful anglers.

Table 3.—Contrasting weighted and unweighted means (±95% confidence interval) for effort and harvest rates for selected fish species for resident anglers. n.s. = not significant.

	Weighted effort or harvest rate (no. of trips or fish per angler and year)	Unweighted effort or harvest rate (no. of trips or fish per angler and year)	t^*- or $U^\#$-test value	df	p-value
Trips	18.4 (±1.3)	21.8 (±1.5)	2.5*	1,130	<0.05
Common carp *Cyprinus carpio*	1.0 (±0.2)	1.1 (±0.3)	0.8*	1,130	n.s.
Atlantic cod *Gadus morhua*	6.6 (±1.4)	7.8 (±1.8)	0.3*	1,130	n.s.
European eel *Anguilla anguilla*	1.9 (±0.4)	2.5 (±0.5)	154,097#		n.s.
Northern pike *Esox lucius*	3.3 (±0.5)	4.6 (±0.6)	144,409.5#		<0.05
Zander *Sander lucioperca*	0.9 (±0.3)	1.1 (±0.4)	1*	1,130	n.s.
Eurasian perch *Perca fluviatilis*	25.4 (±4.5)	32.1 (±5.7)	148,353.5#		<0.05

Effort

In total, 12,937 angling trips were recorded by the 648 diary participants that recorded one or more trips. Resident anglers completed, on average, 18.4 (±1.3, 95% CI, weighted mean) fishing trips per angler and year, whereas nonresident anglers documented, on average, 7.2 (±1.5, 95% CI) trips per angler and year in M-V. Based on average number of annual trips and the population size of active anglers (i.e., fishing at least once or more in the study area, see above) a total effort of 3.83 million angling trips in M-V were calculated that had taken place during the 1-year diary period from September 2006 to August 2007. Nearly 75% of these trips were realized by resident anglers (2.82 million trips per year). The nonresident anglers accounted for around 25% of the total angling trips per year (1.02 million trips).

Harvest of Key Species and Reliability of Diary Data

In the 12 months between September 2006 and August 2007, the estimated total harvest for the most popular freshwater and saltwater species was substantial, a finding that becomes apparent when the estimated total recreational harvest for resident anglers using diary data is contrasted with estimates for the commercial harvest for selected species (Table 4). A few examples of the realized recreational total harvest from freshwater and saltwater species follow: common carp *Cyprinus carpio* 628 metric tons (mt) per year (±119.9, 95% CI), Atlantic cod 3,860 mt/year (±1,798.9, 95% CI), European eel 187 mt/year (±45.2, 95% CI), Eurasian perch 1,523 mt/year (±227.1, 95% CI), northern pike 1,657 mt/year (±354.8, 95% CI), and zander (also known as pikeperch) 438 mt/year (±87.9, 95% CI). All these recreational fishing landings were found to greatly exceed the commercial fisheries landings (Table 4). Nonresident anglers were found to contribute substantially to total harvest, between 13% and 61% depending on the fish species (Table 4). Comparative analysis of harvest rates (in number of fishes per angler and year) indicated that nonresident anglers on average harvested more Atlantic cod than resident anglers while resident anglers harvested more Eurasian perch per angler on average compared to nonresident anglers (Table 4). For most other fish species, resident anglers exhibited slightly higher annual harvest rates compared to nonresident anglers (Table 4).

To judge the reliability of the above-mentioned landing estimations based on diary data, we compared the harvest estimates from the diary data to those derived from the quarterly panel telephone calls. As mentioned previous-

Table 4.—Harvest rate estimates based on the diary data survey, and total harvest based on the dairy survey and panel survey separated for resident and nonresident anglers in Mecklenburg-Vorpommern, Germany. The 95% confidence limits are in the parentheses. The relationship between recall study (panel; 3-month recall) estimates and diary data is shown. The total landings of the commercial fishery in Mecklenburg-Vorpommern for the year 2007 are summarized in the right column. mt = metric tons; CI = confidence interval.

		Annual harvest rate (no. of fish per year ±95% CI)	Total annual harvest (mt/year ± 95% CI)		Relationship	Commercial fishery total harvest[a] (mt/year)
			Diary	Panel	Recall panel/diary	
Common carp	Resident	1.0 (±0.2)	452.2 (±48.3)	681.2 (±74.5)	1.51	
(mean weight 3.1 kg)	Nonresident	0.4 (±0.3)	175.9 (±71.6)	312.2 (±128.7)	1.77	
	Harvest total		628.1 (±119.9)	993.4 (±203.2)		30
Atlantic cod	Resident	6.6 (±1.4)	1,505.2 (±381.7)	1,630.1 (±415.4)	1.08	
(mean weight 1.5 kg)	Nonresident	11.1 (±6.9)	2,354.9 (±1,417.2)	1,617.6 (±959.2)	0.69	
	Harvest total		3,860.1 (±1798.9)	3,247 (±1,374.6)		2,268
European eel	Resident	1.9 (±0.4)	102.1 (±10.9)	122.6 (±13.4)	1.2	
(mean weight 0.355 kg)	Nonresident	1.7 (±1.2)	85.1 (±34.3)	75.9 (±30)	0.89	
	Harvest total		187.2 (±45.2)	198.5 (±43.4)		136
Northern pike	Resident	3.3 (±0.5)	1,065.1 (±112.3)	1,774.4 (±190.1)	1.67	
(mean weight 2.1 kg)	Nonresident	2.0 (±1.5)	592.2 (±242.5)	399.6 (±168.4)	0.67	
	Harvest total		1,657.3 (±354.8)	2,174 (358.5)		156
Zander	Resident	0.9 (±0.3)	307.8 (±33)	383.7 (±42.8)	1.25	
(mean weight 2.3 kg)	Nonresident	0.4 (±0.3)	130.6 (±54.9)	139 (±57.5)	1.06	
	Harvest total		438.4 (±87.9)	522.7 (±100.3)		299
Eurasian perch	Resident	25.4 (±4.5)	1,319.2 (±144.4)	1,594.1 (±171.4)	1.21	
(mean weight 0.34 kg)	Nonresident	4.2 (±2.3)	203.5 (±82.7)	172.2 (±69.8)	0.85	
	Harvest total		1,522.7 (±227.1)	1,766.3 (±241.2)		408

[a] Excluding aquaculture production based on the data provided by the State Fishery Agency M-V (2010) for the coastal fishery and Brämick (2007) for the inland fishery.

ly, higher harvest rates estimated by panel data would provide some assurance of the reliability of the harvest levels estimated by diary data because recall bias should increase harvest rates in telephone calls with a 3-month recall period. Indeed, regarding the resident anglers, the recall-influenced estimates of total harvest for all species were found to be larger than those derived from the diary data by a factor between 1.08 and 1.67, depending on the fish species (Table 4). Similar results were reported in a study on recreational harvest of rock lobster *Jasus edwardsii* and abalone *Haliotis* spp. in Tasmania (Lyle 1999; Lyle and Morton 2004). In contrast, harvest estimates for the nonresident anglers exhibited an opposite relationship between telephone recall and diary sources for some fish species. Because of the lower response rate of nonresident anglers and the inability to weight those anglers, more avid and successful anglers are likely to be overrepresented in the sample of diary respondents for nonresident anglers. Larger estimates found from the diary data (Table 4) might therefore be the result of the overrepresentation of the more avid nonresident anglers compared to the panel estimates where higher response rates of nonresident anglers were observable.

For resident anglers, the larger harvest estimates reported in the panel data relative to diary data are likely to be a result of a combination of recall, prestige, and digit biases (Tarrant and Manfredo 1993; Pollock et al. 1994). Generally, as expected, we found larger harvest estimates from the panel calls when contrasting annual harvest rates for participants returning diaries and being interviewed in all four panel waves (Figure 4). However, no clear trend in deviance between the annual harvest rate in the diary and the degree of the deviation from the harvest estimates in the recall surveys was detectable across species (Figure 4). Deviations in terms of higher annual harvest estimates were particularly pronounced for common carp and northern pike, with values in the panel survey being more than 70% larger relative to the harvest estimates from the diary survey. In contrast, differences between the panel and the diary surveys were less than 30% for European eel, zander, Atlantic cod, and Eurasian perch. In general, anglers in the study area tend to rate the consumptive value of the latter four species higher than the consumptive value of common carp and northern pike. For these higher-valued species, it is conceivable that anglers better remembered such harvest events, and therefore the harvest of these species might be more precisely reported in the telephone interview, with a 3-month recall period resulting in fewer differences relative to diary estimates. Prestige bias might further explain the species-specific differences in deviations of panel and diary estimates because anglers might tend to increase their number and size of caught fishes as well as conceal zero catches to impress the interviewer. This might be particularly pronounced for species such as common carp and northern pike that have a higher value as trophy fish (Arlinghaus and Mehner 2003; Arlinghaus et al. 2010). Also, digit bias could lead to higher average effort and harvest estimates in the panel waves compared to the diary study (Tarrant and Manfredo 1993; Vaske et al. 1996). As shown in Figure 5, these patterns were also observable in our diary study. Anglers tended to round their harvest number for more abundant species such as Atlantic herring *Clupea harengus* and roach *Rutilus rutilus* that can be harvested in higher numbers during a single angling trip, while a digit effect was not detectable for northern pike and zander that are rare catch events. These species are more memorable for an angler likely facilitating the fairly accurate documenting of these events in diaries some time after the end of the angling trip. This observation agrees with earlier studies (Tarrant et al. 1993; Connelly et al. 2000) and provides an indirect justification for the quality of the diary harvest data in the present study, at least for those species that comprise relatively rare catch events.

One further source of bias that is potentially associated with diary is the effect of misidentification of species (Cooke et al. 2000; Lyle et al. 2002). Because of the relative low number of species that are caught by anglers in our study region and the distinctiveness of many of them (e.g., European eel), we assumed that most diary participants should identify most fish correctly, particularly the larger bodied species reported in Table 4. For these more valued and distinct species, we also are certain that recall bias should generally be minimal in diary data because, except for Eurasian perch, large catch rates for legally sized specimens of these species are rare events that can be well remembered (Table 4). Because no evidence exists to suggest that a sub-

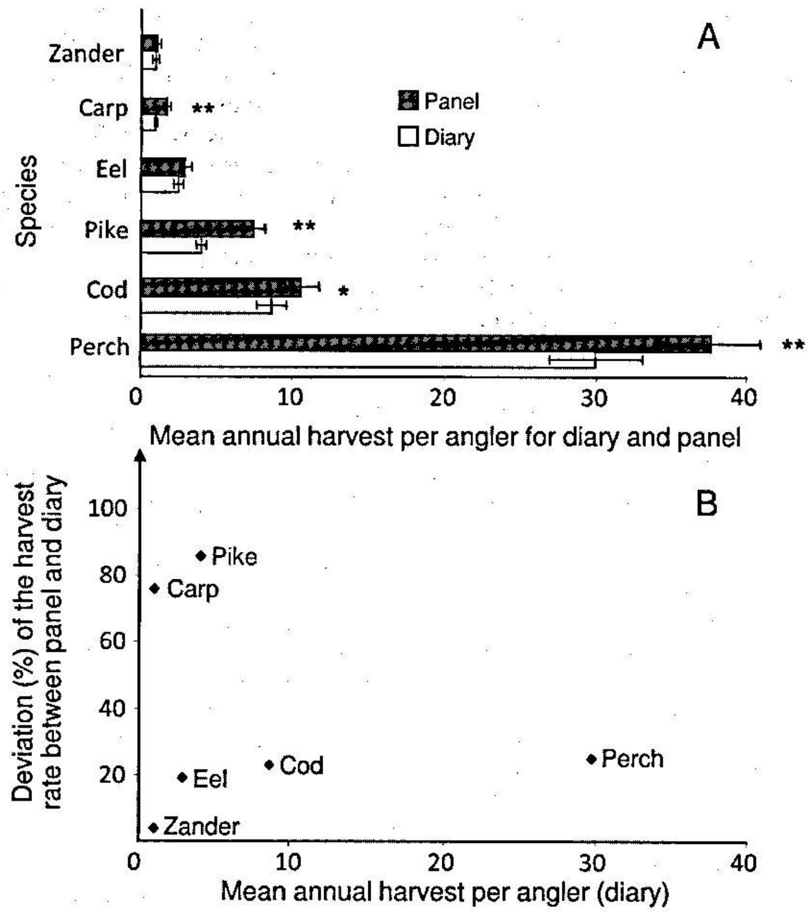

Figure 4.—Comparison between the estimates for average annual harvest rate (with standard errors) based on the diary and panel data for people returning the diary and being interviewed in all four panel waves ($N = 474$). Panel A shows mean values while panel B expresses the percent deviation between the panel and diary annual harvest rates per species. In panel A, * represents significance (Wilcoxon-Test; ** $p < 0.001$, * $p < 0.05$).

stantial delay occurred between the end of the angling trip and documentation in the diary, while at the same time the quality of the documentation remained high, we assume there was limited recall bias and species misidentification in the present diary study.

A further control instrument for the plausibility of the diary data was the on-site survey allowing a qualitative comparison of the average hourly harvest rates (fish per angling hour) for selected fish species (European eel, Eurasian perch, northern pike, roach, bream *Abramis brama*) between diary and creel survey. Except for average harvest per unit effort (HPUE) of roach and northern pike, significant differences between diary study estimates and creel survey estimates were found (Table 5). Generally, the average HPUE estimated from creel surveys was higher than those estimates based on diary data, which contradicts the observations in Australian studies (L. J. H. Olyott, Recfish Australia, personal communication). Similarly, in their comparison of number fish landed between diarists and anglers, Hartill et al. (2008) observed that diarists tended to report fewer zero catches and higher catch rates than recorded during a boat ramp creel survey. The authors concluded that estimates from diary studies might lead to overestimated total harvest estimates. Bray and Schramm (2001) detected no clear trend across

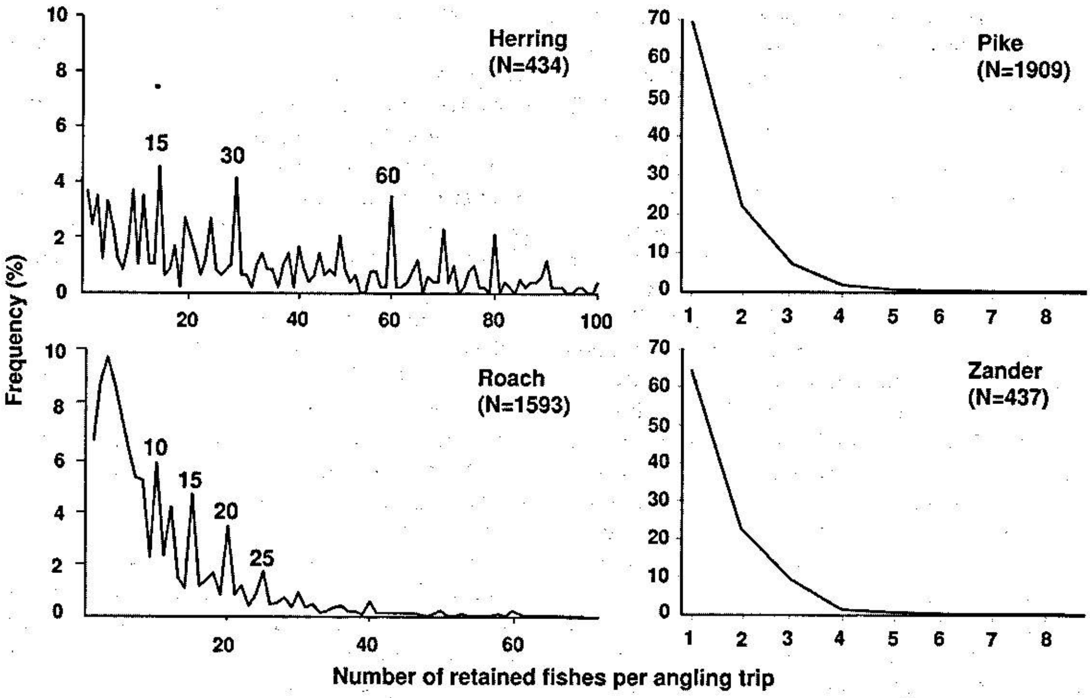

Figure 5.—Relative distribution of the number of retained fishes from successful fishing trips estimated from the diary data.

different species and water bodies in terms of the relationships between diary and creel harvest rates. The authors concluded that the creel data might be similarly affected by bias associated with anglers characteristics (fishing avidity), but the generally lower diary HPUE values

Table 5.—Comparison of the average hourly harvest rates (HPUE) for selected species based on the diary data and the on-site survey for the time period July and August 2007 in Mecklenburg-Vorpommern, Germany. *N* is number of trips in sample. n.s. = not significant.

		N	Mean (± SE)	*t**- or *U*#-value	df	*p*-value
European eel						
HPUE	Diary	2,363	0.04 (± 0.003)	628,661#		<0.01
(No. retained fish per hour)	Creel	587	0.02 (± 0.01)			
Eurasian perch						
HPUE	Diary	2,363	0.3 (±0.03)	650,471#		<0.05
(No. retained fish per hour)	Creel	587	0.7 (±0.08)			
Bream						
HPUE	Diary	2,363	0.03 (±0.006)	669,749#		<0.01
(No. retained fish per hour)	Creel	587	0.08 (±0.01)			
Northern pike						
HPUE	Diary	2,363	0.03 (±0.007)	0.4*	2,948	n.s.
(No. retained fish per hour)	Creel	587	0.06 (± 0.02)			
Roach						
HPUE	Diary	2,363	0.2 (± 0.03)	−1.33*	2,938	n.s.
(No. retained fish per hour)	Creel	587	0.4 (±0.08)			

reported in our study for most species suggests that harvest rates based on diary data might provide conservative estimates and be not be overestimated as suggested by Hartill et al. (2008). We foresee that for species with more abundant catch rates, errors of diary studies might be inflated likely leading to overestimates.

Irrespective of this speculation, a further cause for our finding of higher harvest rates for bream and perch in the creel survey compared to the diary might be related to the fact that successful anglers stayed longer and therefore were more likely to be interviewed during the creel survey (length of stay bias, Pollock et al. 1994). On the other hand, unsuccessful anglers might have become frustrated and might therefore have quit earlier. Thus, these anglers might have been less likely to be interviewed, resulting in an upward biases of the creel-based HPUE estimates. By contrast, anglers participating in a diary study would likely document trips that were less successful, potentially explaining the higher HPUE values found for most species in the creel survey compared to the diary survey. However, this statement must be viewed with caution given that the creel survey did not follow a rigorous random sampling scheme and there might have been timing-related biases in the creel data stemming from nonrandom sampling of time within days. Such nonrandom sampling might have resulted in differently productive times within a day to have been unevenly sampled resulting in biased creel estimates for particular species. We cannot discount this source of error in the creel survey. However, the general lack of substantial differences in HPUE effort between diary and creel survey adds further weight to the validity of the diary data in the present paper.

In our study, the HPUE of European eel was the only estimate that proved larger in diary data compared to the creel data. It should be noted, however, that the observed differences in the harvest rate between diary and creel data were quite small. A possible explanation might be related to the timing of the creel surveys (0800 to 1900 hours). Eel fishing, however, is more effective at dawn and night, which was not covered by the creel survey. Therefore, a diary approach is likely more suitable for the extrapolation of eel harvest than creel surveys conducted during daytimes. To further verify diary studies, standardized creel survey programs (Pollock et al. 1994) are needed to validate diary studies with creel data collected from the same systems. To this end, also completed trip data should be generated during future on-site surveys, if possible using access point surveys to ensure a fully comparability of the harvest rate estimates (compare Pollock et al. 1997).

In conclusion, our data indicate that average effort and harvest estimates based on the diary information may lead to a more conservative estimation for total effort and harvest than the panel data because different bias are likely to inflate estimates generated from panel estimates, although we are unsure if the diary data or the panel data are biased more. The consistency with which estimates from panel data were higher compared to estimates from diary data and the lack of lower harvest estimates from diary data compared to creel data generally support the conclusion that our diary data provide robust and conservative harvest and effort estimates when avidity biases is addressed by weighting factors as applied in the present survey.

Potentials and Constraints of Telephone-Diary Studies

Our survey design constitutes a methodological extension within the field of large-scale survey approaches for assessing recreational fisheries. The survey methodology that was applied allowed sampling various types of fishing activities at the trip level over a large geographical scale (coverage of different water body types, fishing location, and angling methods). Through the implementation of several control instruments, the overall reliability of the methodology was assessed and found acceptable. However, we have to note that our angler population was never surveyed before in such a great detail, so survey fatigue associated with an abundance of recreational fishing surveys did not yet exist in our study area. Several advantages arise from this situation to sample a "pristine" population. For example, surveys can be efficiently conducted because during the diary period, the number of drop outs was relatively low, necessitating no additional recruitment. Based on our experiences, the telephone-diary-mail approach described in this paper has the potential for use in other contexts as well as where data are needed to be collected for large geographical areas in a time-efficient and cost-effective way. The approaches can be greatly simplified if valid and complete address lists of anglers are available to avoid time consuming and costly prescreening phases.

The telephone-diary-mail approach implemented in the present project differs from the pioneering Australian study (Lyle et al. 2002; Henry and Lyle 2003) in use of the diary itself. In Australia, the diary only was used a "memory jogger" and the trip data were recorded by telephone on monthly intervals, which limited the information that can be obtained for every trip. In contrast, the diary in our survey was utilized as the primary data recording tool and a rich set of information was obtained from each trip in addition to catch and harvest (Figure 2). The high response rate obtained together with the integrated weighting procedure allowed an unbiased extrapolation of the diary data to the angler population. Application of weights necessitates that information on the true distribution of angler characteristics is available. Obtaining data necessary for weighting is a major constraint for application in future studies. The exclusive use of diary data without weights is discouraged as it might lead to overestimation of key variables.

Although not presented in the present paper, in addition to providing basic data on catch, effort, harvest, and associated human dimensions, repeated telephone contacts with anglers and the collection of trip-level data in a panel design through a diary offers the potential to learn more about the dynamics of anglers in space and time. For example, individual fishing behavior at the trip level can be analyzed in terms of its timing and duration, fishing location (water body name, type of water body, platform), social group, angling method, targeted species, effort (total effort and targeting effort), catch, and harvest, as well as congestion and satisfaction with angling success. Moreover, a panel design allows application and testing of general human dimensions data to predict catch rates, and spatial site choice models can be developed for use in quantitative models of fish–angler interactions on large spatial scales (Hunt et al. 2007; Johnston et al. 2010). The pairing of the diary instrument with detailed telephone interviews and a follow-up mail survey designed to capture dimensions of recreational specialization (Bryan 1977) or place attachment (Moore and Graefe 1994) enhances the usefulness of collecting individual angler data and also allows explicit testing of recreational theory.

The total running costs of the implementation of the recreational fishing survey M-V 2006/2007 present here and elsewhere (Dorow et al. 2009, 2010) was about 186,000 euros (gross costs), including the population screening, recruitment phase, the diary study, and the complementary human dimension surveys, as well as incentives (Table 6). Additional costs of about 89,000 euros (€, gross costs) occurred

Table 6.—Survey costs overview for the separate survey steps and the human capital (* assumed US$ exchange rate of 1:1.3)

	Gross survey costs in euros (€)	Gross survey costs in US$*
Angler population estimation	23,800	30,940
Recruitment	65,450	85,085
Diary study and the four panel waves	66,640	86,632
Two mail surveys (included 15 pages per survey and a second mailing)	9,520	12,376
Major incentive reel and shipping	19,635	21,450
Incentive for the mail surveys	1,309	1,430
Ph.D. student 3 years[a]	57,827	75,174
Gross yearly income scientist 3 years[b]	31,074	40,396
Total	275,254	353,483

[a] Gross yearly income 19,276€.

[b] Gross yearly income 41,431€ where 25% of the working time was assigned to the project.

for the scientific attendance during the complete survey period (in our case, one scientist and one Ph.D student, Table 6). All surveys were conducted by a professional market and social research institute (USUMA GmbH, Berlin, Germany) under the auspices of the authors. Different advantages are associated with working together with a professional market and social research institute. For example, besides the logistics of running such a research program, this cooperation ensured interviewer reliability and integrity as well as computer-based checks on the responses during a telephone interview. Overall, the wealth of data that included yearly estimates and within-year dynamics of catches, effort, and harvest, as well as detailed characteristics of the human dimensions of a random sample of anglers (see Dorow et al. 2009, 2010), indicates the cost-efficient potential of a complementary telephone-diary-mail survey design approach compared to more traditional creel surveys.

While creel survey will probably almost always offer superior reliability and validity for estimating catches and harvest, the combined approach developed here might thus serve as a cost-effective alternative for large-scale monitoring. One might still wonder if overall survey costs of more than 250,000€ are warranted to be invested into the study area. While detailed economic studies are missing, the recreational fisheries sector in Germany is valued at 6.4 billion € per year, with more than 52,000 jobs dependent on fishing (Arlinghaus 2004). Moreover, recreational fisheries landings are increasingly important at the level of the Common Fisheries Policy of the European Union (e.g., concerning Atlantic cod and Eurasian eel). Major conflicts have emerged between commercial and recreational fisheries, which can only be sorted out with better quality data. These conflicts and the increasing need expressed by some European countries in providing reliable data on recreational fisheries (see ICES 2009) call for development and promotion of cost-efficient methodologies to address the challenges. As mentioned, it is unrealistic to assume that creel surveys will be designed for all European coasts in the near future. In such situations, our survey design might offer a suitable alternative for large geographical areas. Complementary survey approaches can and will further improve the scientific understanding of heterogeneous anglers and thus are of value for research as well as for management. However, if a panel of anglers is developed for long-term use (e.g., in the context of monitoring coastal fish catches in Europe; CEC 2008), it is advised to invest considerably into incentives to secure participation and high response rate. At the same time, fair and appropriate treatment of the surveyed anglers and maintaining information transparency during and after the study are important steps to successful angler–researcher partnerships.

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