Assessment of a brown trout
Salmo trutta population in the River Gallo (central Spain): angling effects and management implications (Salmonidae)

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ABSTRACT

The brown trout population of the River Gallo (central Spain) was monitored every two months during 1996 to determine the current impact of angling. To evaluate the influence of additional parameters, physical habitat and food availability were also studied. To assess fishing pressure, trout harvest and angling exploitation, a partial creel census was conducted during the 1996 fishing season. Differences were found in densities and biomass between exploited (1182.4 fish ha⁻¹, 68.3 kg ha⁻¹) and unexploited areas, the latter being markedly higher (3135.1 fish ha⁻¹, 208.2 kg ha⁻¹). Production was quite superior in the unexploited area and decreased (from 144.5 kg ha⁻¹ yr⁻¹ to 37.2 kg ha⁻¹ yr⁻¹) as fishing pressure increased. However, no consistent differences were observed in growth, condition factor, age diversity, mortality, recruitment age and turnover ratio. Sport fishing seems to be the main negative factor influencing the balance within population of brown trout in the River Gallo and therefore management should be focused on more restrictive angling measures.

INTRODUCTION

Angling of brown trout Salmo trutta L. is considered the most important and popular recreational fishery in Spanish rivers. However, owing to stream habitat degradation caused by water regulation and pollution, local brown trout stocks are not always sufficient to support the increasing demand of sport fishery. Mortality produced by excessive angling can reduce the spawning stock density to such a low level that natural recruitment becomes insufficient to maintain the fishery (Avery & Hunt, 1981). Magnuson (1991) and Kitchell & Carpenter (1993) identified sport fishing as a potent ecological force, which produces strong direct and indirect effects on aquatic ecosystems. Magnuson (1991) also stated that sport fisheries are dynamic and complex systems notoriously variable due to their unpredictable recruitment. In addition, a disturbance in population structure induced by angling can also affects patterns of habitat use, growth rate and fecundity (Healey, 1978, 1980; Fraser et al., 1987; Donald & Alger, 1980).

The relationship between angling and wildlife conservation is complex and often ambiguous. Maitland (1995) pointed out that many anglers consider themselves naturalists and stewards of water quality and freshwater habitats. On the other hand, some people believe that angling involves substantial cruelty to fish and causes considerable damage to aquatic ecosystems. Likewise, Johnson & Carpenter (1994) noted that a poor understanding of fish-angler interactions can hinder both our understanding of how fishing affects ecosystem function and our ability to manage fisheries effectively. Thus, analysis of catch records can provide a valuable indication of changes in abundance associated with the recovery or decline of a fishery (Jenkins & Morris, 1971; Aqgus et al., 1980; Gee & Milner, 1980; Swales & Fish, 1986).

Several papers deal with the population dynamics and production of brown trout in Spanish rivers (Lobón-Cerviá & Penczak, 1984; Lobón-Cerviá et al., 1986; Montañés & Lobón-Cerviá, 1986; Lobón-Cerviá, 1996; García de Jalón et al., 1986; García de Jalón, 1992), but only Braña et al. (1992) and Almodóvar & Burgalea (1993) evaluated the effect of angling on fish stocks.

As Elliott (1994) suggested, salmonid populations comprise important fisheries and knowledge concerning their population dynamics, growth and production is essential for the conservation and effective management of their stocks. Thus, the objective of this study was to analyse the population dynamics, stream habitat and angling catch of brown trout in the river Gallo, one of the rivers most disturbed by angling pressure in central Spain, in order to provide basic biological data as a basis for management of the fishery.

MATERIALS AND METHODS

Study area

This study was conducted on the low sections of the River Gallo, a first-order tributary to the River Tagus. The River Gallo has a
basin area of 1312 km² and its altitude averages 930 m. The river flows over a limestone watershed with a total length of 106 km. The water chemistry shows evidence of pollution (phosphate 0.44 mg l⁻¹, nitrite 12.17 mg l⁻¹ and ammonia 0.65 mg l⁻¹) most probably as a result of agricultural activities. The ionic balance exhibits a dominance of HCO₃⁻ (392 mg l⁻¹, 971 µS cm⁻¹ conductivity) and Ca²⁺ (61 mg l⁻¹). The water temperature is from a low of 8°C in winter to a high of 18°C in summer, with a pH of 7.9.

The bank vegetation at the site is dominated by some riparian deciduous vegetation (Populus sp., Salix fragilis, S. purpurea) and pine (Pinus pinaster). The aquatic vegetation consists primarily of Phragmites australis, Nasturtium officinale, Typha latifolia, Sparganium erectum, Iris pseudacorus and the submerged Potamogeton pectinatus, Myriophyllum verticillatum, M. spicatum, Greenlandia densa, and Cladophora sp. The fish community of the River Gallo is comprised of five native species, Salmo trutta L., Barbus boscai Steindachner, Chondrostoma polypleis Steindachner, Leuciscus pyretnicus Günther and L. albunrnoides Steindachner and one introduced species, Gobio gobio (L.). Brown trout S. trutta is the prevailing species throughout the study area and constitutes the principal sport fish in this river.

Three sites were sampled (see Fig. 1) with enough distance between them to avoid any migration and to cover the different angling regulations in this river. The sampling sites were between 80 and 100 m long and included two exploited sections and one unexploited section, each with different limitations concerning daily bag limit, number of anglers per day and type of bait:

1. Regulated section (4000 m): daily bag size of five trout, four anglers/day, only artificial baits.
2. Free section (12600 m): daily bag size of six trout, no limita­tion in number of anglers/day, only fly fishing.
3. Catch and release section (2000 m): no harvest, no limita­tion in number of anglers/day, only fly fishing.

Habitat

Physical habitat variables were estimated at each site where fish were sampled following Platts et al. (1983). Transects were spaced 10 m apart and point measurements were made along the transects at 1 m intervals (Simonsen et al., 1994). At each point, the water column depth (cm) and mean water velocity (m·s⁻¹) were measured. Also, the percentage of each of six substrate categories (Platts et al., 1983), cover and shading were visually estimated to the nearest 5%. Cover was defined as any submerged structure beneath which fish could hide from an overhead view as well as undercut banks and overhanging vegetation less than 50 cm above the water surface (Heggenes et al., 1990). The pool/riffle ratio was also estimated at each sampling site.

Fig. 1- Map of the study area showing sampling sites (1, regulated; 2, free and 3, catch & release).

Benthic macroinvertebrates

Benthic macroinvertebrates were sampled in riffles every two months during 1996. Three replicate samples per site, taken progressively upstream of each other, were collected on each sampling date by means of a Neil cylinder with a 250 µm mesh net. Invertebrate samples were preserved in 10% formalin for later laboratory identification. Sorting and counting. Specimens were dried in an oven at 60°C for 24 hours and density and biomass (dry weight) were determined. An analysis of variance (ANOVA) and multiple comparison tests (Tukey test) were employed to estimate differences between sampling sites in total biomass of macroinvertebrates.

Sport fishery

Anglers impact was determined through a creel survey conducted in the study area from March to August 1996 (fishing season). Data collected from individual anglers included section fished (angling regulation), hours fished, angling method and the number and fork length of trout kept or released. Retained trout were measured to the nearest millimeter and a sample of scales was taken for age determination. Angling effort was estimated by calculating the mean number of hours fished per hectare in each section in a day. Catch rate was calculated per section as the number of trout captured (kept and released) per hectare in a given day. Also, the fishing mortality or harvest rate was estimated per section as the number of trout kept per hectare per day. Exploitation rate was determined by taking into account the biomass of legal size trout and the total harvest in the fishing season at each site. The Kruskal-Wallis analysis of variance was applied to compare these parameters between sections. Multiple comparisons were then carried out using Dunn’s procedure (Zar, 1984).

Brown trout

Fish were sampled every two months during 1996 at each site by electrofishing using a 220 V DC generator. Once caught, fish were anesthetized with tricaine methane-sulphonate (MS-222 SAN­DOZ) and their fork lengths (to within 1 mm) and weights (to within 1 g) were measured. Scales were taken for age determination. After this, fish were placed in holding boxes to recover and then returned to the stream. Trout density was estimated by applying the three-catch removal method (Zippin, 1956). Standing crop was calculated following the formula proposed by Malton et al. (1979). Population estimates were determined separately for each year class. Age structure complexity was assessed for each sampling site by means of Pielou’s (1969) diversity index D = 1 - Σ p² where p is the proportion of fish belonging to the ith age class.

The condition coefficient (K) of the trout was determined by means of Fulton’s formula K = 100 W / FL² where W designates the body weight in grams and FL the fork length measured in cm. The daily instantaneous or specific growth rate (G, % day⁻¹) was derived from the formula G = 100 (ln W₂ - ln W₁)/(t₂ - t₁) where W₁ and W₂ (in g) were the mean weights of each year class of fish at times t₁ and t₂ (in days). Growth was also examined by assessing the mean length of each age class in Autumn, since growth in trout populations virtually ceases by this time of the year. The parameters of the von Bertalanffy’s growth equation were also estimated...
RESULTS

Physical habitat characteristics did not differ significantly between sampling sites (MANOVA, $F_{18,2} = 7.41$, $P > 0.05$; Tukey test, $P > 0.05$ in all cases). The river aged 8.12 m wide and 0.5 m deep and had a mean water velocity of 0.65 m s$^{-1}$. The streambed was composed chiefly of gravel and the availability of cover for fish was mainly due to submerged vegetation. With regard to food availability, the total biomass of macroinvertebrates did not exhibit significant changes (ANOVA, $F_{2,8} = 0.39$, $P > 0.05$; Tukey test, $P > 0.05$) throughout the study area, having an average value of 4.94 g m$^{-2}$.

The analysis of sport fishing parameters showed that fishing pressure was significantly higher in the exploited sections (Kruskal-Wallis, $H = 11.92$, $P < 0.01$; Dunn tests, $P < 0.01$), especially within the regulated area (Table I). However, fishing mortality was not significantly different (Kruskal-Wallis, $H = 1.03$, $P > 0.05$) within exploited sections, constituting 20% of the total mortality and 50% of the mortality of legal fish size classes. In contrast, considerable differences were found in the exploitation rate. The mean recruitment age or the age at which attained the minimum size limit (22 cm TL) was estimated to be around three years.

In relation to trout populations, total density varied from 3135.08 to 1163.48 ind ha$^{-1}$ and biomass ranged between 208.22 and 67.26 kg ha$^{-1}$ (Table II). Abundance parameters differed significantly (ANOVA, density: $F_{2,8} = 20.85$, $P < 0.001$; biomass: $F_{2,8} = 22.30$, $P < 0.001$; Tukey tests, $P < 0.001$) between exploited and unexploited sections, the latter being markedly higher (Tukey tests, $P < 0.001$). In addition, production was considerably lower in exploited areas (Table II). On the contrary, no differences were found between the turnover ratios of the sections studied.

The legal size trout comprised 13.7% in the catch and release section, but varied from 1.2 to 9.8% in the exploited areas. Furthermore, both density and biomass of trout above the legal fishing size from total exploited sections were significantly lower (ANOVA, density: $F_{2,8} = 20.85$, $P < 0.001$; biomass: $F_{2,8} = 22.30$, $P < 0.001$; Tukey tests, $P < 0.001$) for exploited-unexploited interactions) than in the catch and release zone (Table II). Notwithstanding, the results of the age structure complexity were similar between sampling sites (ANOVA, $F_{2,8} = 0.86$, $P > 0.05$).

The condition coefficients did not vary significantly (ANOVA, $F_{2,8} = 1.07$, $P > 0.05$) with angling regulations (Table III). The observed means of length-for-age classes demonstrated no significant differences between sampling sites at ages 0+, 1+ and 2+ years (see Table III). The spawning took place within the River Gallo during late November and December. The fry emerged from the stream bed following April. Maximum growth rates were recorded from April to June. Throughout the winter growth continued although from late November to early March the growth rate was found to be slightly negative or close to zero. No evident variation was found in the daily instantaneous growth rate for all year classes between sites. Nevertheless, the highest rate was obtained in the unexploited area (Table IV). In addition, a clear decrease in growth rate was observed with increasing age.

The parameters of the von Bertalanffy growth equation are given in Table IV. The growth coefficient, $K$, was similar between sampling locations. Plots of these equations, together with the observed mean length for age of this population are shown in Figure 2. The exploited areas presented a slightly higher daily instantaneous mortality rate than the catch and release location.

DISCUSSION

The results did not reflect any dissimilarity in both habitat structure and food availability between the areas.
studied. Thus, it seemed that angling was the factor most likely to exert the greatest influence on the trout population of the River Gallo. Moreover, creel surveys indicated that angling pressure was unequal throughout the river. So, the exploited sectors, especially the regulated one, were subjected to a high fishing pressure and an overexploitation. These effects of harvest were clearly manifested in density, biomass and production of the exploited and the unexploited areas. Thereby, an important decrease in abundance parameters was found in the exploited stocks. Similar results have been found by Anderson & Nehring (1984) in a Colorado river, who noted that a catch and release regulation exceptionally impoverished the densities and biomass of brown trout during four years of monitoring. In contrast, the exploited sectors studied as a control maintained their abundance parameters but at a lower level. These results differed from those obtained by Braña et al. (1992) in several mountain streams of northern Spain where no apparent changes in total densities were detected between fished and unfished sections. On the contrary, the main effects of angling upon those populations involved a pronounced decrease in the age structure complexity and life span, which did not agree with our results. While growth is usually favoured by harvest (Healey, 1980; Donald & Alger, 1989; Braña et al., 1992), this was not the case in this study where no consistent differences were observed in growth parameters.

Healey (1978) suggested that fecundity may increase with exploitation, a fact which would compensate the higher fish mortality. This latter involves that there is sufficient remaining mature stock, or that an enough number of individuals can reach reproductive size rapidly. It would seem that this proposal takes place in the River Gallo, characterized by a fast growing and early maturity of the population.

The decline in the abundance parameters observed in exploited areas of the River Gallo is consistent with that expected after overfishing. If angling pressure continues depleting the mature stock, sufficient reproductive capacity to sustain the population may decrease. Moreover, fish extraction can also act in a disadvantageous way on maturity age (Werner et al., 1983; Fraser et al., 1987; Huntingford et al., 1988). Therefore, the survival of some mature individuals would be necessary to allow the development of population interactions and to maintain a quality fishery.

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**Table III** - Mean fork length (cm) for age classes in the different sections. F values corresponding to analysis of variance for sections within age classes, and results of Tukey multiple comparison test are also shown.

<table>
<thead>
<tr>
<th>Section</th>
<th>Age 0+</th>
<th>Age 1+</th>
<th>Age 2+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean length</td>
<td>Mean length</td>
<td>Mean length</td>
</tr>
<tr>
<td></td>
<td>(± 1 sd)</td>
<td>(± 1 sd)</td>
<td>(± 1 sd)</td>
</tr>
<tr>
<td>Regulated</td>
<td>8.7 ± 1.41</td>
<td>14.9 ± 1.35</td>
<td>19.1 ± 1.35</td>
</tr>
<tr>
<td>Free Catch &amp; Release</td>
<td>10.8 ± 0.25</td>
<td>15.6 ± 1.67</td>
<td>19.8 ± 1.86</td>
</tr>
<tr>
<td></td>
<td>9.8 ± 1.67</td>
<td>15.1 ± 1.20</td>
<td>17.7 ± 1.58</td>
</tr>
<tr>
<td>F</td>
<td>2.14, P &gt; 0.05</td>
<td>0.78, P &gt; 0.05</td>
<td>0.44, P &gt; 0.05</td>
</tr>
<tr>
<td>Tukey</td>
<td>P &gt; 0.05</td>
<td>P &gt; 0.05</td>
<td>P &gt; 0.05</td>
</tr>
</tbody>
</table>

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**Table IV** - Coefficients of the von Bertalanffy equation, daily instantaneous growth rate and condition factor obtained for sampling sites.

<table>
<thead>
<tr>
<th>Condition factor (g cm⁻¹)</th>
<th>Regulated</th>
<th>Free</th>
<th>Catch &amp; Release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth rate (% g day⁻¹)</td>
<td>1.20</td>
<td>1.20</td>
<td>1.15</td>
</tr>
<tr>
<td>Growth coefficient, K</td>
<td>0.250</td>
<td>0.193</td>
<td>0.208</td>
</tr>
<tr>
<td>t₀</td>
<td>0.622</td>
<td>1.247</td>
<td>0.865</td>
</tr>
</tbody>
</table>

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Fig. 2 - Von Bertalanffy growth model (lines) and observed (points) mean lengths for age classes in the three section studied (Regulated, Free, Catch & Release).
EFFECTS OF ANGLING ON A BROWN TROUT POPULATION IN SPAIN

In summary, if sport fishing pressure continues in this way, there could be a considerable change in both fish community and population dynamic.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

First: creel-survey data have proved an essential tool to use in this kind of studies. Unfortunately, their application in Spanish rivers is still scarce. We consider it necessary to connect research results with resource use data in order to adjust the regulatory measures in a way that are not detrimental to the fishery.

Second: more protective regulations are strongly recommended, since the use of catch and release angling is apparently effective in maintaining an abundance of large trout within the fishery. Catch and release appears to be the most suitable fishing regulation to sustain a quality recreational fishery subjected to high fishing pressure. Such regulations also avoid supplemental stocking with allochtonous specimens. However, the eventual success of this kind of regulation depends upon angler attitudes.

Finally: since the main effects of angling on the River Gallo are changes in numerical composition and as for the moment apparent regulatory mechanisms within the population to mitigate this disturbance have not been found, such as an increase in growth and recruitment, a more restrictive harvest would be an appropriate measure to adopt in order to protect the fishery from depletion.

REFERENCES


