

Influence of anatomical hooking depth, capture depth, and venting on mortality of painted comber (*Serranus scriba*) released by recreational anglers

Josep Alós

Alós, J. 2008. Influence of anatomical hooking depth, capture depth, and venting on mortality of painted comber (*Serranus scriba*) released by recreational anglers. – ICES Journal of Marine Science, 65: 1620–1625.

Immediate (4–5 h) and delayed (10 d) hooking mortality for released fish kept in tanks was evaluated for painted comber (*Serranus scriba*) taken by the recreational fishery of the Balearic Islands (western Mediterranean). Results showed low rates of immediate (10.8%) and delayed (3.3%) hooking mortality, a total mortality of 14.1%. Anatomical hook location and capture depth were the most significant predictors of mortality; 70.4% of fish caught with a deep location of hook died as a consequence of the damage caused, bleeding, and long unhooking times. Fish caught in depths >16 m showed evidence of external barotrauma caused by rapid decompression, which increased the probability of death. The most common forms of barotrauma were swimbladder enlargement and stomach inversion. For fish vented with the aid of a hypodermic needle to extract excess gas, mortality was reduced by half. Factors such as surface temperature, fish size, and hook type ("I" hook vs. circle hook) could not explain the mortality of fish released into tanks. Therefore, the results confirm that a practice of catch-and-release (voluntary or mandatory) for *S. scriba* needs to be promoted among recreational anglers.

Keywords: catch-and-release, circle hooks, deep-hooking, management, recreational fisheries, sustainable development.

Received 25 March 2008; accepted 27 August 2008; advance access publication 16 September 2008.

J. Alós: *Instituto Mediterráneo de Estudios Avanzados, IMEDEA (CSIC-UIB), Calle Miquel Marqués 21 07190, Esporles, Illes Balears, Spain; tel: +34 971 610829; fax: +34 971 611736; e-mail: pep.alos@uib.es.*

Introduction

The painted comber, *Serranus scriba* (Osteichthyes, Serranidae), is a littoral benthic species found over rocky bottoms covered by *Posidonia oceanica* and *Cymodocea nodosa* meadows. It is distributed along the coasts of the Mediterranean and Black Seas as well as in the eastern Atlantic, from the Bay of Biscay to Mauritania, and including the Canary Islands, the Azores, and Madeira (Bauchot, 1987). It is a simultaneous hermaphrodite (Tuset *et al.*, 2005; Zorica *et al.*, 2006) and has biological and ecological characteristics that make it vulnerable to overexploitation (Cardona *et al.*, 2007).

In the Balearic Islands (western Mediterranean), recreational fishing is one of the main leisure activities, with 5–10% of the population participating (Morales-Nin *et al.*, 2005). In this fishery, *S. scriba* is one of the most targeted species for recreational anglers, especially those using boats, and represents 24% of the total catch (Morales-Nin *et al.*, 2005). Minimum legal size and daily bag limits have been used as management tools in the fishery. In recent years, voluntary catch-and-release and its promotion in local tournaments has become popular among both managers and anglers. However, the utility of these mandatory (e.g. release of undersized fish) and voluntary practices as a management tool requires survival rates among the released fish to be reasonable (Bartholomew and Bohnsack, 2005; Cooke *et al.*, 2006; Lewin *et al.*, 2006; Arlinghaus *et al.*, 2007; Coggins *et al.*, 2007).

In recent decades, evaluating the factors that influence mortality of the released fish has been a specific focus of scientists and managers in the USA, Canada, and Australia (Arlinghaus *et al.*, 2007). However, for the Mediterranean Sea, there is a critical lack of studies estimating the mortality of released fish (Arlinghaus *et al.*, 2007). Bartholomew and Bohnsack (2005), reviewing the factors influencing the mortality of released fish, found that anatomical hooking location and capture depth had the most important impact on post-release mortality. In many marine recreational fisheries, fish are hooked deep within the body, such as in the oesophagus, stomach, and gills, leading to high rates of mortality (Diggles and Ernst, 1997; Ayvazian *et al.*, 2002; Aalbers *et al.*, 2004; Broadhurst *et al.*, 2005; St John and Syers, 2005; Butcher *et al.*, 2006; Alós *et al.*, in press). For the Serranidae, it has been reported that increasing the depth of capture produces different forms of barotrauma, which increase the rate of mortality (Wilson and Burns, 1996; Diggles and Ernst, 1997; Collins *et al.*, 1999). The formation of gas bubbles in blood and tissues can cause embolism, haemorrhaging, and clotting, as well as haematological changes. Moreover, swimbladder overexpansion renders fish positively buoyant, precluding their return to the original capture depth, and making them easy prey for predatory birds and fish (Bartholomew and Bohnsack, 2005; St John and Syers, 2005). Several studies have suggested that venting positively buoyant fish with a hypodermic needle to extract the excess gas formed by rapid decompression can be effective in reducing

post-release mortality in some marine fisheries (Collins *et al.*, 1999; St John and Syers, 2005). Furthermore, other factors such as species, size of fish, gear characteristics, length of time before release, environmental conditions, and post-release depredation have been reported as factors likely influencing post-release mortality (Bartholomew and Bohnsack, 2005; Arlinghaus *et al.*, 2007).

The aim of this study was to evaluate the immediate (4–5 h) and delayed (10 d) hooking mortality in *S. scriba* released by recreational anglers. For this purpose, a logistic regression model was fitted to investigate the relationships between post-release mortality and a number of putative factors: intrinsic factors (fish size and hooking injury), environmental conditions (surface temperature and capture depth), and gear characteristics (hook type). Further, the effect of capture depth on forms of barotrauma and the effectiveness of venting were also investigated.

Material and methods

Field site and experimental procedures

Experimental boat-angling sessions with *S. scriba* as target species were conducted on the south coast of Mallorca (western Mediterranean) from October 2006 to September 2007 (Figure 1). Different sites in depth categories with similar bottom characteristics, such as a *P. oceanica* bed, were selected randomly. Angling sessions were between 08:00 and 15:00 local time.

The experimental gear comprised three hooks, with the same hook treatment mounted on a 9.5-lb main leader with three side-leaders (the hook line). To test the effects of hook type, two different hook treatments (standard “J” hook and circle hook) were used (Figure 2). Front length, gap, outside bend, and shaft length were measured on five hooks of the same model (Figure 2). All hooks were baited with pieces of shrimp (*Penaeus vannamei*), covering the whole hook surface except the point of the hook. Two volunteer anglers were selected, and one researcher was assigned to each angler during the angling sessions. When an angler caught a fish, the anatomical hook location (AHL; the region where the hook penetrated the fish body) was recorded as “deep-hooking” when the injury was in the stomach, oesophagus, or gills, or “shallow-hooking” when the fish was caught in the lips or jaw. Such categorization is normally used for small fish such as *S. scriba* (Alós *et al.*, 2008, in press). The presence of blood at the hooking location was recorded as “presence” or “absence”.

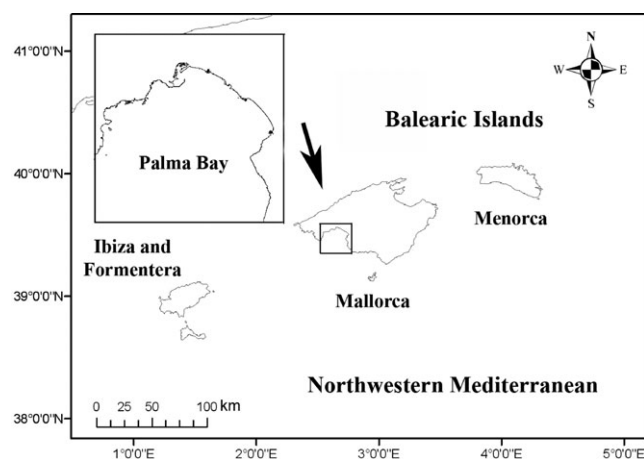


Figure 1. Geographic location of Palma Bay in the Balearic Islands (northwestern Mediterranean).

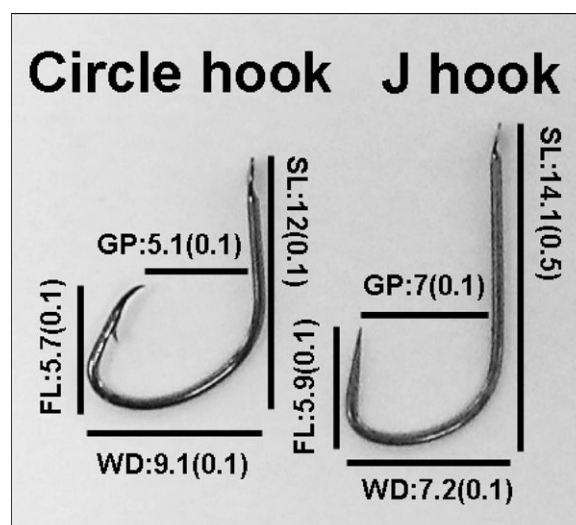


Figure 2. Dimensions of a standard “J” hook (size 8, GAMAKATSU model 1060) and a circle hook (size 10, TEKLON model 7400), as used here for experimental angling. The mean \pm s.d. (in mm) are shown here for front length (FL), width (WD), gap (GP), and shaft length (SL), for five hooks of each hook type measured.

Additionally, the time taken to unhook the fish was recorded as “easy” (<30 s) or “difficult” (>30 s).

Once the hooking injury had been recorded, total fish length (to the nearest mm), capture depth (m), and water surface temperature ($^{\circ}\text{C}$) were recorded for each fish. To test the effect of capture depth on mortality, evidence of external barotrauma injuries [as described by St John and Syers (2005) and summarized in Table 1] was recorded for each fish. Additionally, for fish without external evidence of barotrauma, the swimbladder of alternate captures, from the entire range of depths, was vented using a hypodermic needle (21G \times 1/2”). The needle was inserted on the left side of the fish below the lateral line, near the base of the pectoral fin, with a bias of 45° under the scales until the swimbladder was punctured. Once the needle had been inserted, the researcher

Table 1. External signs of barotrauma, anatomical description, and their causes as described by St John and Syers (2005) for *G. hebraicum* following catch-and-release.

Barotrauma form	Description	Cause
Swimbladder enlarged (SE)	Swimbladder enlarged and visible in mouth	Rapid decompression during capture leads to air expanding in the swimbladder
Stomach in mouth (SM)	Stomach everted and visible in mouth	Air expanding in the swimbladder in the peritoneal cavity leads to the stomach being pushed into the mouth
Exophthalmia (EX)	Eyes protruding from orbits	Rapid decompression within or behind the eyeball causes the rupture of the capillaries in the choroid body in the eyeball
Bubbles in eyes (BE)	Gas bubbles visible to the naked eye	Rapid decompression during capture leads to air expansion, and bubbles are visible in the eyes

pressed the abdominal cavity to extract the gas formed by rapid decompression. When no more gas could be extracted, the needle was removed and cleaned to use on other fish. The venting action was recorded as “vented” or “not vented”. Each fish was then individually tagged with an Anchor T-bar (Floy Tags[®]) and placed into an 80-l onboard aerated fish-holding tank. The fish remained in these tanks for 4–5 h to determine immediate hooking mortality (Pollock and Pine, 2007). During the angling sessions, some 75% of the water was exchanged manually each hour. To investigate delayed hooking mortality (Pollock and Pine, 2007), all fish were transported to a 5000-l polyvinyl chloride holding tank, mounted with flow-through seawater, and individually monitored three times a day over 10 d. Containment studies have been used traditionally to monitor mortality after release. However, such a study has limitations, e.g. the elimination of post-release predation (Cooke and Schramm, 2007; Pollock and Pine, 2007). Ideally, control fish would be required to test the effects of mortality of some fish on other retained fish. However, the properties of the local fishery (with its range of depth and surface temperatures), and of the specific fishery for *S. scriba* (difficult to catch with methods other than hook and line), made it impossible to obtain control fish. All fish that died during the monitoring period were identified and subjected to necropsy, to determine the cause of death. Necropsy procedures included visual inspection of the body and the bottom of the fins, as well as squashing the liver and gills, to determine if the cause of death was a bacterial, viral, or protozoan infection. All fish surviving at the end of experiment were released into the wild.

Data analysis

A logistic regression model was fitted to the data, using maximum likelihood to describe the relationships between total hooking mortality (Y_i) after 10 d (0 survival; 1 death) and nine explanatory variables: fish size, capture depth, and surface temperature, treated as continuous variables, and hook type, AHL, unhooking duration, bleeding, barotrauma, and venting, treated as categorical variables:

$$\text{logit}(Y_i) = \beta_1 + \beta_2(\text{size}_i) + \beta_3(\text{depth}_i) + \beta_4(\text{temperature}_i) + \beta_5(\text{hook}_i) + \beta_6(\text{AHL}_i) + \beta_7(\text{duration}_i) + \beta_8(\text{blood}_i) + \beta_9(\text{barotrauma}_i) + \beta_{10}(\text{venting}_i) + \varepsilon_i,$$

where β_j are the model parameters, and ε_i the binomial error term.

Interpreting a model with so many variables is difficult, so to reduce the number of explanatory variables, I carried out a correlation analysis using contingency tables with Pearson's Chi-squared test and Yates' continuity correction for categorical variables (Crawley, 2005). For correlated variables, the variable that best represented the group was selected for inclusion in the model. Stepwise forward selection with Akaike's Information Criterion (AIC) as the criterion for selection was used to select the best model; all main effects and interactions were tested. Then, a simpler model with only main effects was fitted and the two models compared with ANOVA (Crawley, 2005). If the simpler model was not significantly worse, it was accepted, and only the main effects were tested using a partial z-test (Crawley, 2005). Statistical analyses were carried out using the statistical package R version 2.6.0.

Results

In all, 213 *S. scriba* were caught during ten experimental angling sessions and were individually monitored for 10 d. Total fish length ranged from 96 to 227 mm (mean 145.7 ± 96 mm). Fish were caught in locations with surface temperatures ranging from 16.2°C to 25.7°C, and at depths of 4–30 m. With respect to hook type, 120 fish (56.3%) were caught using standard “J” hooks and 93 (43.7%) with circle hooks. Average immediate hooking mortality was 10.8% (23 fish), and delayed hooking mortality after 10 d was an additional 3.3% (7 fish), making a total hooking mortality of 14.1% (30 fish).

Correlation analysis revealed that AHL, presence of blood, and unhooking time were highly correlated (Figure 3). Therefore, 70.4% of fish caught deep anatomically bled as a consequence of unhooking ($\chi^2 = 119.71$, d.f. = 1, $p < 0.001$; Table 2), and

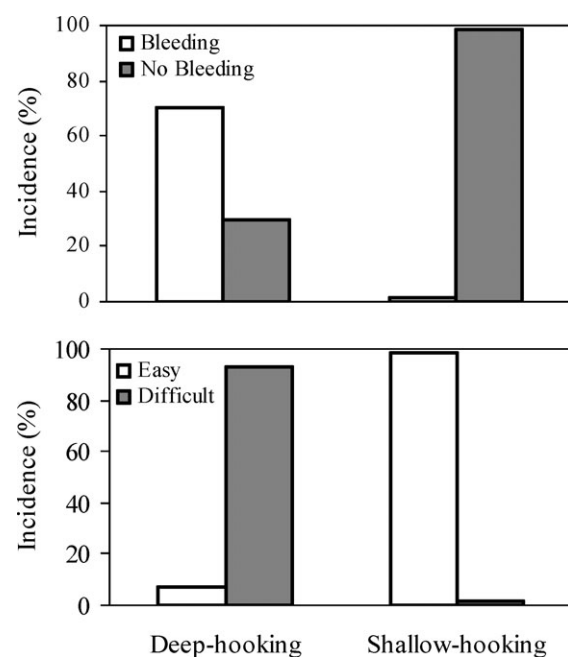


Figure 3. Percentage of *S. scriba* showing different combinations of bleeding (bleeding or no bleeding), unhooking (easy or difficult), and anatomical hooking location (deep or shallow).

Table 2. Percentages of total (immediate and delayed) mortality by hook location (deep or shallow), hook type, unhooking time, and presence of blood.

Parameter assessed	n	Deep-hooked		Shallow-hooked	
		%	Mortality (%)	%	Mortality (%)
Hook type					
“J” hook	120	15.8	63.2	84.2	8.9
Circle hook	93	8.6	87.5	91.4	2.4
Unhooking time					
Difficult	28	89.3	72.0	10.7	0.0
Easy	185	1.1	50.0	98.9	6.0
Bleeding					
Absence	192	4.2	37.5	95.8	6.0
Presence	21	90.5	84.2	9.5	0.0

usually (92.6%) the fish were difficult to unhook ($\chi^2 = 163.1$, d.f. = 1, $p < 0.001$; Table 2). Consequently, only AHL was retained as an explanatory variable, but not the presence of blood or unhooking time. Capture depth and the presence of barotrauma were also highly correlated, as expected ($p < 0.001$; Figure 4). Logistic regression modelling showed that capture depth was a significant predictor of the presence of some form of barotrauma, because an increase in capture depth influenced their presence ($p < 0.001$, Figure 4). Therefore, capture depth was retained as an explanatory variable. The preliminary analysis allowed a reduction in the number of explanatory variables from nine to six: fish size, temperature, capture depth, AHL, hook type, and venting.

Stepwise forward selection retained three factors for explaining total hooking mortality: AHL, capture depth, and venting (Table 3). Of these, only AHL and capture depth had a very significant effect on hooking mortality ($p < 0.001$; Table 3). Fish caught deep-hooked had a higher rate of mortality (70.4%) than those caught shallow-hooked (5.9%; Table 2). AHL did not vary significantly among hook types ($\chi^2 = 1.86$, d.f. = 1, $p = 0.172$). In terms of the effect of capture depth, the rate of mortality increased as

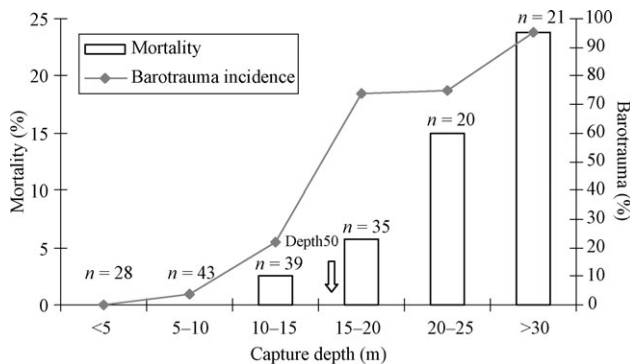


Figure 4. Total hooking mortality and incidence of barotrauma in *S. scriba* caught at six depths ($n = 186$). Fish caught deep-hooked are excluded. Depth₅₀ (16.2 m) corresponds to the capture depth for which the probability of suffering some form of barotrauma was 0.5.

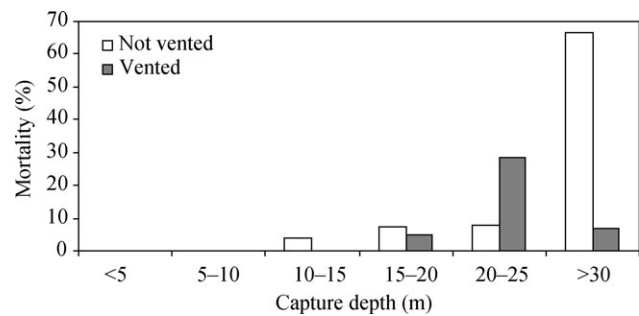


Figure 5. Total hooking mortality (%) of vented and not vented *S. scriba* caught at six depths. Only fish caught shallow-hooked are included ($n = 186$).

depth increased ($p < 0.001$; Table 2, Figures 4 and 5). Fish caught deeper than 16.2 m (Depth₅₀) had a probability value of 0.5 of developing some form of barotrauma (Figure 4). In all, 137 fish (64.3%) showed no form of barotrauma, and 39 (18.3%) had swimbladder enlargement, in 35 fish (16.4%) the stomach being visible in the mouth. However, only one fish (0.5%) showed exophthalmia, and one (0.5%) had bubbles in the eyes.

Finally, although venting was included in the best model using the AIC, the effect was not significant in the partial z-test ($p = 0.142$; Table 3), and similarly for first-order interactions between the factors retained in the best model ($p = 0.258$). However, in fish that showed some form of barotrauma (76 fish), the rate of mortality was halved when the excess gas formed during rapid decompression was vented with a hypodermic needle (Figure 5).

Discussion

The utility of mandatory and voluntary controls as management tools for recreational fisheries that result in a large number of released fish surviving require good rates of survival (Bartholomew and Bohnsack, 2005; Cooke *et al.*, 2006; Lewin *et al.*, 2006; Arlinghaus *et al.*, 2007; Coggins *et al.*, 2007). Bartholomew and Bohnsack (2005) stated that post-release mortality depended on several factors and that rates of mortality $>20\%$ were too high. The factors can be divided into intrinsic

Table 3. Logistic regression models and parameter estimates for total hooking mortality (after 10 d) following catch-and-release of *S. scriba* by recreational fishers.

Model description	Parameter	Estimate	s.e.	z-value	Pr(> z)
Full model $Y_i = \beta_1 + \beta_2(\text{Fish size}_i) + \beta_3(\text{Temperature}_i) + \beta_4(\text{Depth}_i) + \beta_5(\text{AHL}_i) + \beta_6(\text{Hook}_i) + \beta_7(\text{Venting}_i) + \varepsilon_i$	Intercept	-8.65	2.41	-3.6	***
	Fish size	0.01	0.01	1.0	0.315
	Temperature	0.08	0.09	0.93	0.353
	Capture depth	0.14	0.05	2.84	**
	Deep-hooking	4.82	0.76	6.35	**
	"J" type	0.64	0.58	1.11	0.269
	Venting	-0.91	0.61	-1.48	0.139
Best model $Y_i = \beta_1 + \beta_2(\text{AHL}_i) + \beta_3(\text{Depth}_i) + \beta_4(\text{Venting}_i) + \varepsilon_i$	Intercept	-5.34	0.94	-5.7	***
	Deep-hooking	4.86	0.76	6.42	***
	Capture depth	0.16	0.04	3.86	***
	Venting	-0.86	0.59	-1.47	0.142

The full model includes explanatory variables after preliminary correlation analysis. The best model was obtained by stepwise forward selection with AIC. Estimates correspond to linear slopes, and for categorical factors they show the effect of the category with respect to the intercept. Estimates and their standard error (s.e.) are on a logit scale.

** $p < 0.01$; *** $p < 0.001$.

ones (species, fish size, and hooking location), fishing gear and angler practice (fishing method, techniques of handling and release), and environmental conditions (capture depth and surface temperature). The results here showed low immediate (10.8%) and delayed (3.3%) rates of hooking mortality, a total mortality of 14.1%, confirming that the common gear used in this recreational fishery results in low mortality among the *S. scriba* released. Compared with the mortality rates obtained for other marine serranids, *S. scriba* had a lower rate than *Epinephelus morio* (29%; Wilson and Burns, 1996), a higher rate than *Epinephelus quoyanus* (1–8%; Wilson and Burns, 1996; Diggles and Ernst, 1997), and within the range of mortalities obtained for *Centropomus striata* (0–39%; Collins *et al.*, 1999).

Post-release mortality increased by just 3.3% after 10 d of monitoring fish retained in tanks. This suggests that death of *S. scriba* angled is generally in the first minutes after capture and as a result of hooking injury to vital organs, or severe bleeding, or poor handling practice (Pollock and Pine, 2007). Clearly, studies to evaluate post-release mortality need to use control fish to separate the effects of the study from the effects of retention in tanks on the fish. When there are no control fish available, the mortality estimated must be taken as conservative (Pollock and Pine, 2007). However, the few fish that died during the long-term monitoring period here showed that the effect of retention in a tank was negligible or non-existent. Moreover, five of the seven fish that died during the longer period were caught deep-hooked, a situation predicted by the logistic model to lead to greater mortality rates.

Deep-hooking was the critical mortality factor observed in *S. scriba* in this study, because fish caught deep-hooked had a higher probability of dying than shallow-hooked fish. The results are consistent with most catch-and-release mortality studies, which consider deep-hooking as the most important factor influencing mortality (Arlinghaus *et al.*, 2007). This has been recorded in many marine recreational fisheries: *Pomatomus saltatrix* (Ayvazian *et al.*, 2002), *Acanthopagrus australis* (Broadhurst *et al.*, 2005), *Glaucosoma hebraicum* (St John and Syers, 2005), *Sillago ciliata* (Butcher *et al.*, 2006), and *Trachynotus ovatus* (Alós *et al.*, in press). My preliminary analysis testing correlations between explanatory variables showed that fish caught deep-hooked bled and were more difficult to unhook than those caught shallow-hooked. As a consequence, the causes of death were bleeding and the increased physiological stress caused by the time taken to unhook the fish. These results support statements in the literature and have been proposed as the main consequence of deep-hooking (Bartholomew and Bohnsack, 2005; Arlinghaus *et al.*, 2007).

Increased capture depth is an important factor inducing mortality following catch-and-release (Bartholomew and Bohnsack, 2005; St John and Syers, 2005), especially for serranids (Wilson and Burns, 1996; Diggles and Ernst, 1997; Collins *et al.*, 1999). In this study, fish caught in deeper water had a greater probability of suffering some form of external barotrauma caused by rapid decompression. Specifically, fish caught at depths >16.2 m (Depth₅₀) had a >50% probability of suffering some form of barotrauma. Four forms of external barotrauma described by St John and Syers (2005) were observed in the various *S. scriba* caught here. The most common forms observed were swimbladder enlargement, and stomach eversion visible in the mouth. With respect to other forms of barotrauma, only one fish was affected by exophthalmia, and one by bubbles in the eyes. St John and Syers

(2005) reported that these more critical forms of barotrauma are more frequent at depths >45 m. *Serranus scriba* lives over rocky substrata covered by *P. oceanica* and *C. nodosa* meadows, and in the Balearic fishery is rare at depths >35–40 m.

Venting fish to reduce mortality induced by barotrauma is a common practice in recreational fisheries (Bartholomew and Bohnsack, 2005). In some marine fish, the excess gas formed by rapid decompression can be reduced by venting the swimbladder with the aid of a hypodermic needle (Collins *et al.*, 1999; St John and Syers, 2005). For *S. scriba*, venting fish showing some form of barotrauma reduced the mortality by half, although venting was not a significant factor explaining hooking mortality in the logistic regression analysis. Globally, therefore, it neither increased nor decreased hooking mortality. This phenomenon has been described for *G. hebraicum* too (St John and Syers, 2005). Therefore, for fish that are positively buoyant, venting may allow a fish to return swiftly to its capture depth, reducing its likelihood of becoming prey for predatory birds or fish. However, before managers promote and implement this practice, anglers need to be instructed and educated in good practice to maximize the survival of vented fish (Cooke *et al.*, 2006).

Factors such as fish size, water surface temperature, and hook type have been considered as potential mortality-inducing factors in recreational fisheries (Bartholomew and Bohnsack, 2005). However, the results here failed to link them significantly with *S. scriba* mortality. In the specific case of hook type, circle hooks have recently become popular with managers, scientists, and anglers because they reduce the incidence of deep-hooking (Cooke and Suski, 2004). In the present case, however, the use of circle hooks did not cause a significant reduction in the incidence of deep-hooking. As *S. scriba* has a larger mouth diameter and volume than other target species in the fishery (Karpouzi and Stergiou, 2003), hook size needs to be considered if circle hooks are to be rendered less injury-causing than “J” hooks (Cooke *et al.*, 2005).

Serranus scriba is an important target species in the recreational fisheries of the western Mediterranean, and it is vulnerable to over-exploitation (Morales-Nin *et al.*, 2005; Cardona *et al.*, 2007). The results presented here confirm that the gear commonly used in this recreational fishery results in low mortality of the fish released as long as the factors described above are taken into account. Future research should involve telemetry and video studies to estimate the physiological disturbance and changes of behaviour of *S. scriba* in their natural environment. Finally, I hope that the results of this study will help scientists and anglers minimize mortality and contribute more to the sustainable development of recreational fisheries in the western Mediterranean.

Acknowledgements

I thank the anglers (A. Beltran, M. Cabanellas, A. Box, and M. A. Simó) for their cooperation, and the Laboratori d'investigacions marines i Aqüicultura d'Andratx (LIMIA) for support. I am also grateful to my assistants for their help during experimental angling sessions, especially M. Palmer and A. M. Grau, and to editor Verena Trenkel and three anonymous referees for their valued comments and suggestions. The study was funded by the research project “The case of painted comber, *Serranus scriba* as sustainable development of recreational fisheries in the Mediterranean Sea (BII04007)”, by FOGAIBA (Department of Agriculture and Fisheries of the Balearic Government) and by

the research project ROQUER (CTM2005-00283) funded by Ministerio de Educación y Ciencia of the Spanish Government.

References

- Aalbers, S. A., Stutzer, G. M., and Drawbridge, M. A. 2004. The effects of catch-and-release angling on the growth and survival of juvenile white seabass captured on offset circle and J-type hooks. *North American Journal of Fisheries Management*, 24: 793–800.
- Alós, J., Cerdà, M., Deudero, S., and Grau, A. M. Influence of hook size and type on short-term mortality, hooking location and size selectivity in a Spanish recreational fishery. *Journal of Applied Ichthyology*, in press.
- Alós, J., Palmer, M., Grau, A. M., and Deudero, S. 2008. Effects of hook size and barbless hooks on hooking injury, catch per unit effort, and fish size in a mixed-species recreational fishery in the western Mediterranean Sea. *ICES Journal of Marine Science*, 65: 899–905.
- Arlinghaus, R., Cooke, S. J., Lyman, J., Policansky, D., Schwab, A., Suski, C., Sutton, S. G., *et al.* 2007. Understanding the complexity of catch-and-release in recreational fishing: an integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. *Reviews in Fisheries Science*, 15: 75–167.
- Ayvazian, S. G., Wise, B. S., and Young, G. C. 2002. Short-term hooking mortality of tailor (*Pomatomus saltatrix*) in Western Australia and the impact on yield per recruit. *Fisheries Research*, 58: 241–248.
- Bartholomew, A., and Bohnsack, J. A. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries*, 15: 129–154.
- Bauchot, M. L. 1987. *Serranidae*. In *Fiches FAO d'Identification des Espèces pour les Besoins de la Pêche (Révision 1)*, Méditerranée et Mer Noire. Zones de pêche 37, II (Vertébrés), pp. 1301–1319. Ed. by W. Fischer, M.-L. Bauchot, and M. Schneider. FAO, Rome.
- Broadhurst, M. K., Gray, C. A., Reid, D. D., Wooden, M. E. L., Young, D. J., Haddy, J. A., and Damiano, C. 2005. Mortality of key fish species released by recreational anglers in an Australian estuary. *Journal of Experimental Marine Biology and Ecology*, 321: 171–179.
- Butcher, P. A., Broadhurst, M. K., and Brand, C. P. 2006. Mortality of sand whiting (*Sillago ciliata*) released by recreational anglers in an Australian estuary. *ICES Journal of Marine Science*, 63: 567–571.
- Cardona, L., Lopez, D., Sales, M., De Caralt, S., and Diez, I. 2007. Effects of recreational fishing on three fish species from the *Posidonia oceanica* meadows off Minorca (Balearic archipelago, western Mediterranean). *Scientia Marina*, 71: 811–820.
- Coggins, L. G., Catalano, M. J., Allen, M. S., Pine, W. E., and Walters, C. J. 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. *Fish and Fisheries*, 8: 196–210.
- Collins, M. R., McGovern, J. C., Sedberry, G. R., Meister, H. S., and Pardieck, R. 1999. Swim bladder deflation in black sea bass and vermilion snapper: potential for increasing post-release survival. *North American Journal of Fisheries Management*, 19: 828–832.
- Cooke, S. J., Barthel, B. L., Suski, C. D., Siepker, M. J., and Philipp, D. P. 2005. Influence of circle hook size on hooking efficiency, injury, and size selectivity of bluegill with comments on circle hook conservation benefits in recreational fisheries. *North American Journal of Fisheries Management*, 25: 211–219.
- Cooke, S. J., Danylchuk, A. J., Danylchuk, S. E., Suski, C. D., and Goldberg, T. L. 2006. Is catch-and-release recreational angling compatible with no-take marine protected areas? *Ocean and Coastal Management*, 49: 342–354.
- Cooke, S. J., and Schramm, H. L. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. *Fisheries Management and Ecology*, 14: 73–79.
- Cooke, S. J., and Suski, C. D. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? *Aquatic Conservation—Marine and Freshwater Ecosystems*, 14: 299–326.
- Crawley, M. J. 2005. *Statistics. An Introduction using R*. Wiley, New York.
- Diggles, B. K., and Ernst, I. 1997. Hooking mortality of two species of shallow-water reef fish caught by recreational angling methods. *Marine and Freshwater Research*, 48: 479–483.
- Karpouzi, V. S., and Stergiou, K. I. 2003. The relationships between mouth size and shape and body length for 18 species of marine fishes and their trophic implications. *Journal of Fish Biology*, 62: 1353–1365.
- Lewin, W. C., Arlinghaus, R., and Mehner, T. 2006. Documented and potential biological impacts of recreational fishing: insights for management and conservation. *Reviews in Fisheries Science*, 14: 305–367.
- Morales-Nin, B., Moranta, J., Garcia, C., Tugores, M. P., Grau, A. M., Riera, F., and Cerdà, M. 2005. The recreational fishery off Majorca Island (western Mediterranean): some implications for coastal resource management. *ICES Journal of Marine Science*, 62: 727–739.
- Pollock, K. H., and Pine, W. E. 2007. The design and analysis of field studies to estimate catch-and-release mortality. *Fisheries Management and Ecology*, 14: 123–130.
- St John, J., and Syers, C. J. 2005. Mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum* (Richardson 1845) following catch and release: the influence of capture depth, venting and hook type. *Fisheries Research*, 76: 106–116.
- Tuset, V. M., Garcia-Diaz, M. M., Gonzalez, J. A., Lorente, M. J., and Lozano, I. J. 2005. Reproduction and growth of the painted comber *Serranus scriba* (Serranidae) of the marine reserve of Lanzarote Island (Central–Eastern Atlantic). *Estuarine Coastal and Shelf Science*, 64: 335–346.
- Wilson, R. R., and Burns, K. M. 1996. Potential survival of released groupers caught deeper than 40 m based on shipboard and *in-situ* observations, and tag-recapture data. *Bulletin of Marine Science*, 58: 234–247.
- Zorica, B., Sinovic, G., Pallaoro, A., and Kec, V. C. 2006. Reproductive biology and length–weight relationship of painted comber, *Serranus scriba* (Linnaeus, 1758), in the Trogir Bay area (middle–eastern Adriatic). *Journal of Applied Ichthyology*, 22: 260–263.

doi:10.1093/icesjms/fsn151