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Effects of forest certification on the ecological condition of Mediterranean streams

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Summary

1. Forest certification, a proxy for sustainable forest management, covers more than 10% of the world's forests. Under forest certification, forest managers and landowners must comply with environmental, economic and social management standards aiming to promote forest conservation. Despite an increasing area of certified forests, there is a dearth of data on how forest certification is affecting the conservation of forest ecosystems and associated habitats.

2. Here, we assess the effects of Forest Stewardship Council (FSC) certification, one of the largest certification schemes in the world, on the ecological condition of streams crossing Mediterranean evergreen oak woodlands.

3. We used the Stream Visual Assessment Protocol (SVAP) to compare the ecological condition of streams located in areas with 3 and 5 years of certification, in non-certified areas and in least disturbed streams.

4. Forest certification positively affected the ecological condition of the surveyed streams, but its effects were only measurable after 5 years of certification. Streams with 5 years of certification had more continuous, dense and diverse riparian vegetation when compared to streams located in non-certified areas. Moreover, the condition of streams located in areas with 5 years of forest certification was similar to the condition of least disturbed streams.

5. *Synthesis and applications*. Forest certification promotes the ecological condition of streams occurring within Mediterranean evergreen oak woodlands. This mainly happens because in areas under forest certification, managers and landowners have to comply with management practices that require them to remove or reduce the main causes for stream degradation, allowing riparian habitats to recover. Within landscapes with large and increasing areas under forest certification, such as the Mediterranean cork oak woodlands, the positive effects of certification on the ecological condition of streams may spread across the hydrographic network in the medium to long term.

Key-words: cork oak, forest management, Forest Stewardship Council, freshwater habitats, rapid bio-assessment protocol, riparian vegetation, Stream Visual Assessment Protocol

Introduction

Sustainable forest management is crucial for the conservation of forest ecosystems, their biodiversity and the ecosystem services they provide (Millennium Ecosystem Assessment 2005a). Forest certification aims to promote sustainable forest management by adding market value to products generated according to environmental and socio-economic standards (Auld, Gulbrandsen & McDermott 2008; Gomez-Zamalloa, Caparros & Ayanz 2011). Forest certification relies on the willingness of consumers to pay more for sustainable products and seeks to reward producers who adopt sustainable forest management practices (Brown *et al.* 2001; Auld, Gulbrandsen & McDermott 2008; Suzuki & Olson 2008). To obtain certification, forest managers must comply with management standards developed through public participation of governmental

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agencies, non-governmental organizations, industry associations and social groups. The compliance with these standards is audited and monitored by an independent third party (Auld, Gulbrandsen & McDermott 2008). The two main forest certification schemes are the Program for the Endorsement of Forest Certification (PEFC) and the Forest Stewardship Council (FSC) (Auld, Gulbrandsen & McDermott 2008) certification, which cover 251 and 186 million hectares, corresponding to 6·1 and 4·5% of the world's forests, respectively (Forest Stewardship Council 2013; PEFC 2013). Both certification schemes aim to promote forest management practices that are economically viable, socially just and contribute for the conservation of biodiversity and ecosystem services provided by forests (Forest Stewardship Council 2014, www.fsc.org, accessed on 28 January 2014; Program for the Endorsement of Forest Certification, www.pefc.org, accessed on 28 January 2014).

Streams, rivers, lakes and ponds are important components of forest ecosystems (Naiman 2005), which account for <1% of the Earth's surface but harbour 10% of all described species (Strayer & Dudgeon 2010). Freshwater ecosystems also provide key ecosystem services such as water provisioning and purification, flood control, harvestable organisms, hydropower and recreational use (Millennium Ecosystem Assessment 2005a; Abell, Allan & Lehner 2007; Kareiva & Marvier 2010). Despite their importance, freshwater ecosystems and the ecosystem services they provide are among the most threatened in the world (Ricciardi & Rasmussen 1999; Millennium Ecosystem Assessment 2005b; Tedesco *et al*. 2013). In the Mediterranean, streams and riparian habitats support a dense and productive forest ecosystem, which is very distinguishable from the adjacent semi-arid habitats (Naiman 2005; Salinas & Casas 2007; Santos 2010). These habitats also play an important role in shaping and structuring Mediterranean landscapes by supporting a wide variety of biotic assemblages in a seasonally water-stressed environment (Gasith & Resh 1999; Naiman 2005). Mediterranean riparian habitats are often threatened by livestock grazing along the river margins, vegetation clearing, soil mobilization and channelization, which restrict the riparian habitat to narrow vegetation corridors along the streams (Aguiar, Ferreira & Pinto 2002; Ferreira, Aguiar & Nogueira 2005; Santos 2010). Despite these disturbances and their small size, riparian habitats perform a disproportionate role in Mediterranean ecosystems (Gasith & Resh 1999).

Forest management practices have wide implications for the conservation of streams and rivers, both within and outside of forest management units. In several countries, there are laws and directives to protect stream and river habitats in managed forests. For example, in the United States of America, the Clean Water Act and the National Forest Management Act address the protection of rivers and the impacts of forest management on water quality (Naiman 2005). In the European Union (EU), the Water Framework Directive (WFD) (Directive 2000/60/EC) requires all EU member states to achieve 'good ecological status' for all ground and surface waters (European Commission 2009). This legal context creates an incentive for forest managers to evaluate how their management practices affect freshwater habitats and to adopt strategies to preserve and restore riparian habitats located in forest ecosystems (Stella *et al*. 2013). Assessing the effects of forest certification on the ecological condition of streams is both a timely and important goal.

In this study, we assess the effects of the implementation of FSC forest certification on the ecological condition of low-order streams (Strahler 1957) in cork oak woodlands. Cork oak woodlands are silvopastoral systems with high economic and conservation value (Bugalho *et al*. 2011) typical of the west Mediterranean basin that cover 1·5 million hectares in south-western Europe and 1 million hectares in North Africa (Pausas, Pereira & Aronson 2009). This ecosystem is characterized by a sparse tree cover (30–60 trees ha^{-1}) of cork oak *Quercus suber* L., frequently mixed with other evergreen oaks, for example holm oaks *Quercus rotundifolia* Lam., or pine trees (e.g. *Pinus* spp.) and an understorey of shrub species (e.g. *Cistus* sp.) interspersed with grasslands, pastures, fallows and sometimes cereal crops (Bugalho *et al*. 2009). Streams and riparian areas are key habitats in cork oak woodland ecosystems because they support high levels of plant diversity (Gasith & Resh 1999; Santos 2010), are an important habitat for mammalian carnivores (Matos *et al*. 2009) and harbour several threatened species of fish, such as the critically endangered river lamprey *Lampetra fluviatilis* L. (recently described by Mateus *et al*. 2013) and the endangered cyprinid *Iberochondrostoma lemmingii* Steindachner (Cabral *et al*. 2006). As in other regions, these streams are threatened by vegetation clearing and livestock grazing.

FSC certification covers 90 000 ha of cork oak woodlands in Portugal (Dias *et al*. 2013), and its management standards address the impacts of forest management on freshwater habitats by preventing logging, vegetation clearing and waste disposal in and around freshwater ecosystems and by reducing livestock grazing. The development of new roads or pathways is prohibited, and the use of fertilizers and pesticides is highly regulated to prevent run-off. Freshwater ecosystems are frequently classified as 'conservation zones'; these are areas delimited within forest management units for the purpose of maintaining or restoring forest biodiversity and its ecological functions (Tollefson, Gale & Haley 2009). Despite an increasing area of FSC-certified cork oak woodlands, the impact of FSC certification on the condition of streams in these ecosystems is unknown.

Here, we assess the effects of FSC certification on the ecological condition of Mediterranean streams crossing cork oak landscapes. Specifically, we (i) compare the ecological condition of streams located in certified and non-certified areas, (ii) assess the differences in the ecological condition of streams located in areas with 3 and 5 years of forest certification and (iii) compare the ecological condition of least disturbed streams with that of streams located in certified areas.

Materials and methods

STUDY AREA

The study area is located in southern Portugal in a sub-basin of the Tagus River (Fig. 1). This is a moderately hilly region, with a mean altitude of 54 m. Soils are mainly composed of limestone and other sedimentary formations. The climate is subhumid Mediterranean, with a mean annual temperature of 16 °C and an average rainfall of 730 mm year^{-1} (AEM & IM 2011). Streams and rivers of the study area are classified as 'rivers of the sedimentary deposits of Tagus and Sado – type S3′, according to the Portuguese national typology of rivers developed with the Water Framework Directive's criteria (INAG 2008). These streams have a mean drainage area of 390 km^2, high floods are common during autumn and winter, but the flow decreases and streams dry out during late spring and summer. Riparian vegetation is dominated by a dense shrub layer (3–6 m high) mainly composed of willows such as *Salix salviifolia* Brot. and *Salix atrocinerea* Brot., but also of Hawthorn Crataegus monogyna Jacq., tree heath *Erica arborea* L., alder buckthorn *Frangula alnus* L. and wild blackberry *Rubus ulmifolius* Schott. Oleander *Nerium oleander* L. and African tamarisk *Tamarix africana* L. also occur but are less frequent. In more disturbed areas, two invasive species may occur, the giant reed *Arundo donax* L. and the parrot feather *Myriophyllum aquaticum* Verdc. The dominant land uses in the study area are cork oak woodlands (42%), agricultural crops (27%) and plantations of blue gum *Eucalyptus globulus* Labill (9%). Grazing by cattle and sheep is common throughout the study area.

DATA COLLECTION

We used the Stream Visual Assessment Protocol (SVAP) version 2 (NRCS 2009) to assess the condition of stream ecosystems. SVAP is a rapid bio-assessment protocol widely used in the United States of America (USA) that was developed by the Natural Resources Conservation Service of the United States Department of Agriculture and field-tested in a wide variety of regions including Mediterranean California (Bjorkland, Pringle & Newton 2001; NRCS 2009). It evaluates the overall condition of wadeable streams, their riparian zones and in-stream habitats (NRCS 2009)

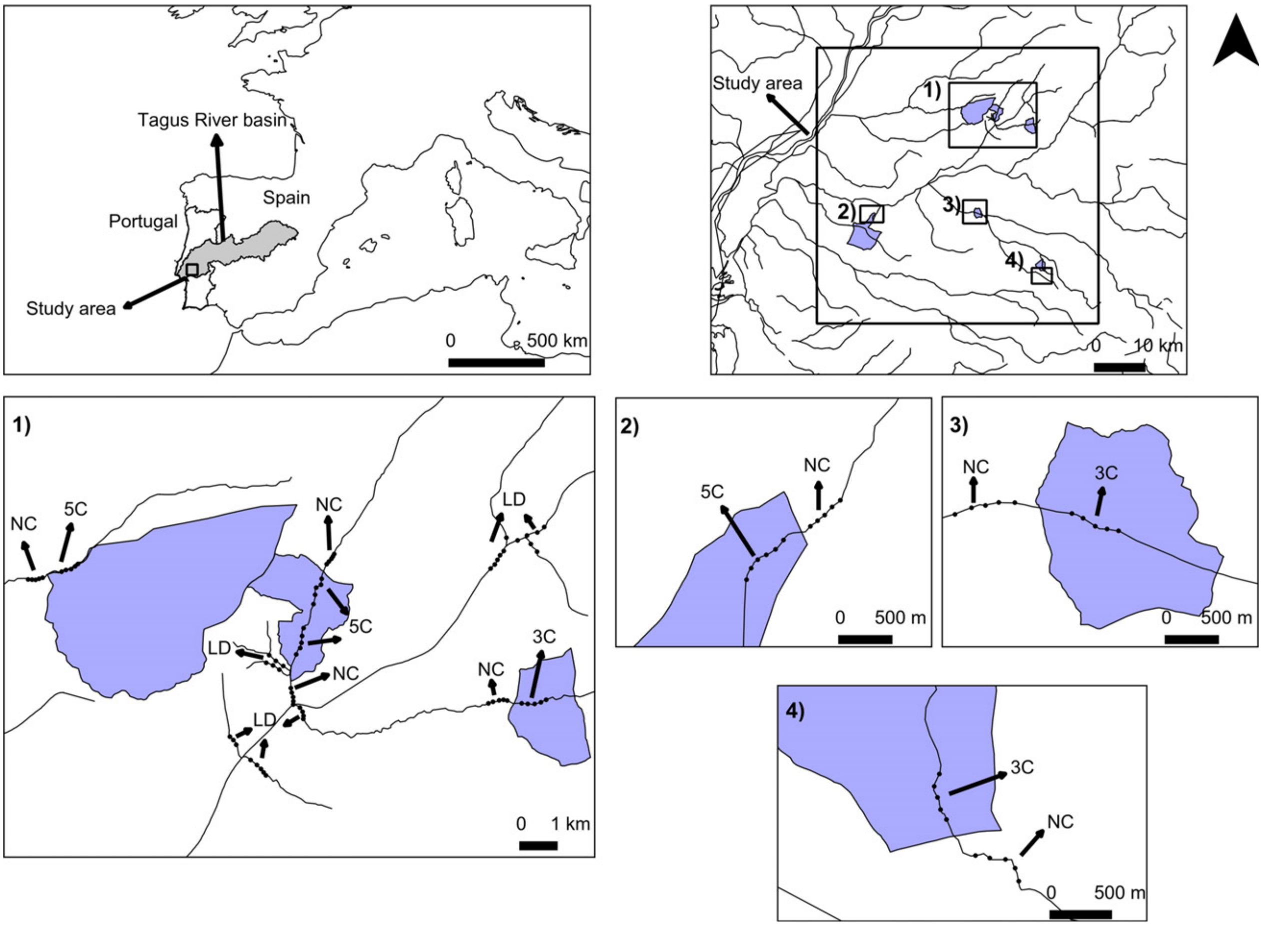

Fig. 1. Location of the study area and of surveyed properties, including the streams crossing those estates. The dots along the streams represent the centre of each 100-metre stream reach where Stream Visual Assessment Protocol (SVAP) was applied. The purple polygons represent the properties. NC – non-certified reach, 3C – stream reaches with 3 years of certification, 5C – stream reaches with 5 years of certification and LD – least disturbed stream reaches.

and is based on the visual inspection and evaluation of up to 16 physical and biological parameters (hereafter 'elements') of in-stream and riparian environments. Scoring varies between one and ten according to the provided guidelines (see Appendix S1 in Supporting information). The final SVAP index is the arithmetic average of the scores of each element. Since SVAP requires a low level of expertise in stream ecology, it can be readily used by landowners or forest managers. Alternative rapid bio-assessment protocols, such as the Riparian Quality Index (González del Tánago & de Jalón 2011) or the 'Qualitat del Bosc de Ribera' (QBR) index (Munné *et al.* 2003), do not cover parameters such as Water appearance and fish and Aquatic invertebrate habitat. Moreover, SVAP has been successfully used to assess the condition of streams crossing cork oak landscapes (Matos *et al.* 2009). In this assessment, we selected 13 elements and excluded the salinity and riffle embeddedness parameters because there was no evidence of salinity in any surveyed streams and because riffles are not a common feature of these streams (personal observation). The element of Aquatic invertebrate community was not assessed because the features assessed by Aquatic invertebrate habitat, Nutrient enrichment and Water appearance are a known proxies for the distribution patterns of aquatic macroinvertebrates and of the availability of microhabitats and water quality (Hughes *et al.* 2009; Jähnig *et al.* 2010). To determine whether the remaining SVAP elements were highly correlated with each other, we calculated variance inflation factors (vif) for each element and used a cut-off value of five (Fox & Weisberg 2010). Aquatic invertebrate habitat had a vif score higher than five, resulting from its correlation with the element Fish habitat complexity. Although both metrics quantify habitat diversity types, they were assessed at different habitat scales (NRCS 2009, Appendix S1, Supporting information), so their scores do not necessarily match in other types of streams. For this reason, we decided to keep both in order to facilitate comparisons with other studies.

We surveyed six low-order streams crossing six FSC-certified areas with 3 and 5 years of certification and applied SVAP to 101 stream reaches. At the time of the study, these were the only estates with three or more years of certification. Thirty-six reaches were located in certified areas and 35 reaches on non-certified areas (Fig. 1). Of the certified reaches, 15 had 3 years of certification and 21 had 5 years of certification (Table 1). Thirty least disturbed stream reaches were surveyed in an area classified as a 'reference site with high ecological status' during the pre-assessment surveys conducted for the implementation of the Water Framework Directive in Portugal (CIS-WFD 2003; Agência Portuguesa do Ambiente 2012) (Fig. 1). Each surveyed stream reach was 100 m long, which corresponds to 50 times the average width of the stream channels. To minimize edge effects, the surveyed reaches were located at least 300 m away from local disturbances (e.g. bridges, weirs) and 150 m away from the point where streams crossed the property boundary (Fig. 1). Field work was conducted in a period of low flow, as suggested in SVAP (NRCS 2009), during three consecutive weeks between June and July 2012. During the sampling period, weather conditions were stable (mean temperature of 22 °C) and there were no precipitation, water discharges or water withdrawals. The surveys were conducted by a single observer (F.S.D) to maximize consistency. Since we were mainly interested in comparing the relative ecological condition of reaches, observer bias will not have a significant impact on the results. The observer travelled across the entire length of each reach for approximately 45 min and scored each SVAP element according to the guidelines (Table 2 and Appendix S1, Supporting information). Data collected during the surveys were stored and processed in Geographic Information System (GIS) using Quantum GIS 1.8 (Quantum GIS Development Team 2012).

STATISTICAL ANALYSIS

We used linear mixed-effects modelling to assess the effects of forest certification on the ecological condition of streams to account for the fact the condition of adjacent stream reaches is not independent (Pinheiro & Bates 2009). All calculations were made in R 2.15.2 (R Core Team 2012) using the package 'NLME' (Pinheiro & Bates 2009). We compared the overall SVAP index and the index for each SVAP element of (i) non-certified reaches, (ii) reaches with 3 years of certification, (iii) reaches with 5 years of certification and (iv) least disturbed streams by modelling these variables against a four-level categorical variable, hereafter referred as 'reaches group', using the lme() function. The location of the surveyed properties was used as a random effect (Fig. 1). To compare the SVAP indexes of each group of reaches, we performed multiple comparisons with the Tukey's test (0·05 significance) using the glht() function of the R package 'multcomp' (Bretz, Hothorn & Westfall 2010). The final models were validated by checking the normalized residuals for violations of normality and homogeneity and for spatial autocorrelation (Zuur *et al.* 2009). Normality of the distribution of the residuals was visually assessed through analysis of the residuals' histogram.

Table 1. Number and length (metres) of the surveyed stream reaches in each surveyed estate and the number of years of certification in non-certified, certified and least disturbed areas

	Certified areas			Non-certified areas		Total	
Estates	Reaches	Length	Years of certification	Reaches	Length	Reaches	Length
Estate 1	5	500	5	5	500	10	1000
Estate 2	10	1000	5	10	1000	20	2000
Estate 3	5	500	3	5	500	10	1000
Estate 4	6	600	5	5	500	11	1100
Estate 5	5	500	3	5	500	10	1000
Estate 6	5	500	3	5	500	10	1000
Least disturbed 1	–	–	–	–	–	12	1200
Least disturbed 2	–	–	–	–	–	18	1800
Total	36	3600	–	35	3500	101	10 100

Table 2. Description of the elements of Stream Visual Assessment Protocol (SVAP)

SVAP element	Description
Channel condition	The geomorphic stage of the channel, according to the Schumm channel evolution model (Schumm, Harvey & Watson 1984)
Hydrologic alteration	The frequency of bankfull or higher flows and the presence of development areas in the floodplain, water withdrawals, flow augmentation or water control structures
Bank condition	The degree of stability of stream banks, the degree of protection by natural vegetation, evidence of erosion and damage by recreational use or livestock grazing. Each margin is scored separately
Riparian area quantity	The extent of the riparian area (length x width in relation to the bankfull width) and its degree of continuity. Each margin is scored separately
Riparian area quality	The composition, diversity and age structure of the riparian community and the percentage of cover by invasive species. Each margin is scored separately
Canopy cover	The percentage of the stream reach surface that is shaded. In this case, we used the scoring matrix for warm-water streams (see Appendix S1)
Water appearance	The degree of turbidity of the water and the presence of oil or metal precipitates
Nutrient enrichment	The nutrient load of the water based on its colour and the amount of algal growth
Manure or human waste presence	The existence of sewage or human waste discharges and whether livestock has access to the riparian area
Pools	The number of shallow and deep pools
Barriers to aquatic species movement	The presence of artificial physical barriers such as dam, dikes, culverts or livestock crossings
Fish habitat complexity	The number of different habitat features for fish. For example logs/large wood, deep pools, other pools (scour, plunge, shallow, pocket), overhanging vegetation, boulders, cobble, riffles, undercut banks, thick root mats, dense macrophyte beds, backwater pools and other off-channel habitats
Aquatic invertebrate habitat	The number of different habitat features for aquatic invertebrates, logs/large wood, leaf packs, fine woody debris, overhanging vegetation, aquatic vegetation, undercut banks, pools and root mats

Homogeneity was checked by visually analysing (i) the spread (the pattern of distribution) of the residuals vs. fitted values in scatter plot and (ii) the spread of the boxplots of the residuals grouped by each of the 'reaches group' categories (Zuur *et al.* 2009). Homogeneity was only violated in a few cases for condition 2. In these cases, a 'VarIdent' variance structure was added to the model (Zuur *et al.* 2009). To check for spatial autocorrelation, a semi-variogram was built using the function Variogram(). When spatial autocorrelation was detected, we added a linear, Gaussian, rational quadratic or exponential correlation structure to the model (Zuur *et al.* 2009). Finally, we checked whether the random effects of all models, obtained with the function ranef(), were normally distributed by visually analysing the corresponding histogram (Pinheiro & Bates 2009; Zuur *et al.* 2009).

Results

The SVAP index of reaches located in areas with 5 years of certification was significantly higher than that of reaches located in non-certified areas or in areas with 3 years of certification. There were no significant differences between the index of streams located in sites with 5 years of certification and the index of least disturbed streams. There were also no significant differences between reaches located in non-certified areas and in areas with 3 years of certification (Fig. 2, Tables S1 and S2 in Appendix S2, Supporting information).

As for individual SVAP elements, the scores of the elements of Bank condition, Riparian quantity, Riparian quality, Canopy cover, Fish habitat complexity and Aquatic invertebrate habitat were significantly higher in reaches with 5 years of certification when compared with reaches without certification and with 3 years of certification. The scores of these elements on reaches with 5 years of certification were not significantly different from the ones located in least disturbed sites (except for Canopy cover) (Fig. 2; Tables S1 and S2 in Appendix S2).

No significant differences were found for the remaining scores, Channel condition, Water appearance, Nutrient enrichment, Manure and human waste, Pools and Barriers to fish movement across the surveyed streams when comparing certified, non-certified and least disturbed sites (Fig. 2; Tables S1 and S2 in Appendix S2, Supporting information).

Discussion

Our results suggest that Forest Stewardship Council (FSC) certification management standards had a positive effect on the ecological condition of the riparian vegetation of stream reaches located in cork oak woodlands. These effects, however, were only measurable after 5 years of certification. After this period, the condition of reaches located in certified areas is similar to that of those located in least disturbed, well-conserved sites.

The high scores of reaches with 5 years of certification for Riparian quantity and Riparian quality, which measure the continuity of the riparian vegetation relative to the bankfull width and the diversity and structure of the

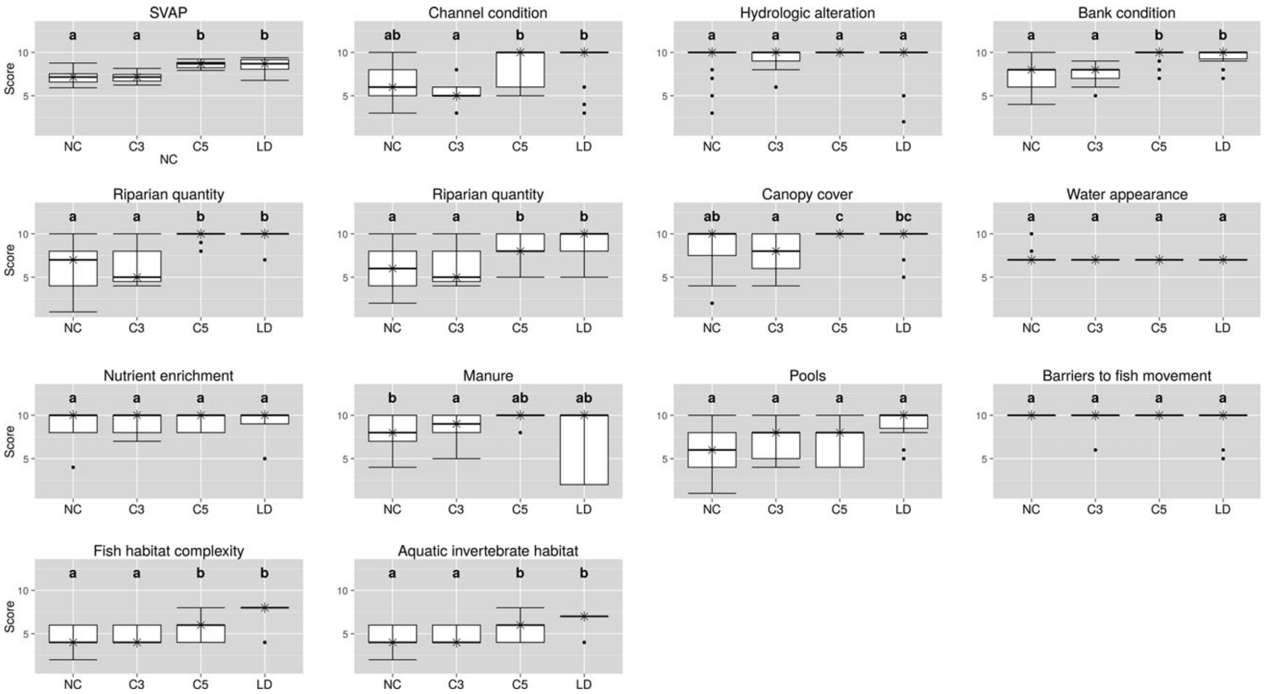

Fig. 2. Boxplots showing the distribution of the Stream Visual Assessment Protocol (SVAP) index and SVAP elements scores on non-certified stream reaches (NC) (n = 35), reaches with 3 years of certification (3C) (n = 15), reaches with 5 years of certification (5C) (n = 21) and least disturbed reaches (LD) (n = 30). The results of the multiple comparisons performed with Tukey's test are presented with a compact letter display ('a', 'b' and 'c'). Groups of reaches with significantly different scores ($P < 0{\cdot}05$) were assigned different letters and vice versa. The boxplots are defined by the 25th and 75th percentiles (lower and upper quartile), and the vertical lines (whiskers) have a length of 1·5 times the interquartile range. The median value for each group of reaches is shown with a thick horizontal line and an asterisk. The isolated points represent outliers.

riparian vegetation, respectively, suggest that forest certification is favouring the development of the riparian vegetation. The vegetation on these reaches is composed of a dominant layer of fast-growing willows and smaller shrub formations of hawthorn and alder buckthorn, which are adapted to poor soils and summer-dry streams and are very resilient to vegetation cutting and livestock disturbance (Ferreira, Aguiar & Nogueira 2005). In non-certified reaches, possibly because of livestock grazing and vegetation clearing, riparian vegetation is scarcer and more patchily distributed and usually composed of shrubs <2 m high (F.S.D, personal observation). The lower score of Riparian quality in non-certified areas also reflects the higher cover by the invasive giant reed, which is a species well adapted to riparian environments that undergo frequent physical disturbances (Bell 1997; Sabbatini, Murphy & Irigoyen 1998). On reaches with 5 years of certification, the condition of the riparian vegetation is similar to that found on reaches located in least disturbed areas.

The better ecological condition of the riparian vegetation explains the higher scores of Bank condition, Fish habitat complexity, Aquatic invertebrate habitat and Canopy cover in reaches with 5 years of certification. Roots, branches and leaves from riparian trees and shrubs help maintain the stability of banks by protecting them against water and wind erosion (Thorne 1990; Corenblit *et al.* 2009). Species such as willows usually develop large root systems that can quickly stabilize river banks (<12 months) (Shields, Cooper & Knight 1995). Higher scores of Canopy cover, Fish habitat complexity and Aquatic invertebrate habitat in areas with 5 years of certification may result from the development of more structurally complex plant communities. Dense and continuous riparian vegetation provides more shaded areas, logs, wood, litter accumulation and thick root mats, which form microhabitats for aquatic macroinvertebrates (Vannote *et al.* 1980; Aguiar, Ferreira & Pinto 2002; Ode, Rehn & May 2005). These habitat features are also used by fish for hiding, resting and feeding (Allan & Flecker 1993; Fausch *et al.* 2002).

There were elements, such as Channel condition or Pools, for which the scores of reaches with 5 years of certification were only marginally higher ($P = 0{\cdot}08$) than the scores of reaches in non-certified areas and similar to the scores of least disturbed sites. These results suggest that more than 5 years of certification are required to ameliorate these elements. Channel condition, which evaluates geomorphic characteristics, is influenced by the occurrence of incision and aggradation. Both these processes affect streams at different rates and across the entire channel and tend to respond slowly to management changes (Poesen & Hooke 1997; Gordon *et al.* 2004). Similarly, the element of Pools seems to be responding slower to forest certification, possibly because pools are usually formed by the accumulation of woody debris from older shrubs and trees that obstruct the stream flow (Naiman 2005; Allan & Castillo 2007). On reaches with 5 years of certification, the riparian vegetation is probably still too young to provide sufficient quantities of woody debris generating a significantly higher number of pools, as compared to non-certified reaches.

The scores of the elements of Hydrologic alteration and Barriers to fish movement did not differ among certified, non-certified areas and least disturbed sites. These elements evaluate the presence of artificial structures or management practices that affect the hydrological regime of streams and restrict fish movements. The surveyed streams have a typical Mediterranean hydrological regime, drying out during most of the summer, which makes the streams unsuitable for agriculture irrigation and also explains the lack of artificial structures.

Elements related to water quality, such as Water appearance, Manure and human waste and Nutrient enrichment, had similar high scores among all surveyed reaches. Water appearance depends on the quantity of suspended particles that enter the stream through bank erosion, whilst Nutrient enrichment depends on the amount of phosphorus and nitrogen resulting from agricultural run-off (Busse, Simpson & Cooper 2006; García-Ruiz *et al.* 2008). Both these processes are strongly influenced by management practices occurring in other parts of the river network and have effects downstream (Poesen & Hooke 1997; Ode, Rehn & May 2005). This, coupled with the fact that cork oak woodlands are rain-fed systems with low artificial nutrient input (Pinto-Correia 1993), explains why no significant differences were observed among the surveyed streams. The lack of differences in the score of Manure and human waste among the surveyed streams is related to the presence of livestock grazing in cork woodlands, which is a prevalent activity in these systems (Bugalho *et al.* 2009), that also occurs in certified areas, albeit at lower stocking rates when compared with non-certified areas.

FSC CERTIFICATION AS A PASSIVE RESTORATION METHOD

Our results suggest that FSC certification is improving the ecological condition of the surveyed streams, possibly through passive ecological restoration, which occurs when ecological disturbances are removed or reduced, relying on natural regenerative processes without additional remedial actions (Suding 2011). Compliance with FSC, management standards require removing or reducing the main causes for stream degradation and this allows the ecological succession to proceed. Our results confirm the findings of two recent studies conducted in Europe and North America. For example, Hough-Snee *et al.* (2013) found in northern Utah (USA) that after 4 years of passive restoration, the vegetation composition had changed from grazing-tolerant graminoids and forbs to hydrophytic graminoid and shrub species. In France, Forget *et al.* (2013) found that 6 years of passive restoration increased the tree cover on river banks and contributed to improve the physical integrity of the banks.

The positive effects of forest certification that we found at the reach scale may spread across the hydrographic network in the medium to long term because of a large and increasing area under forest certification. For example, in the Portuguese part of the Tagus River basin, where this study took place, there are over 348 787 ha of cork oak woodlands, out of which 73 330 ha are FSC-certified and this number is projected to grow (Dias *et al.* 2013). As FSC certification promotes the re-establishment of the riparian vegetation, reduces bank erosion and improves the availability of microhabitats, it would be important to determine which part of the stream network in this area is under FSC certification and then analyse the landscape effects that forest certification may be having in this region. The results of this study would allow us to better understand how FSC certification is affecting the streams crossing the 186 million hectares of certified forests world-wide.

SVAP AS A MONITORING TOOL FOR FSC CERTIFICATION

FSC certificates are issued for periods of 5 years during which certificate holders are audited annually to determine compliance with the management standards (www.fsc.org). We suggest that rapid bio-assessment protocols such as SVAP can be used by forest managers, landowners or forest certification auditors to evaluate the impacts of forest management on the condition of streams. This would validate the effectiveness of FSC management standards and help managers to demonstrate that they are contributing to the conservation of streams and riparian habitats.

FSC certification requires forest managers and auditors to make auditing and monitoring reports publicly available (www.fsc.org). By integrating a standardized and straightforward monitoring tool such as SVAP in forest certification, it would be possible to create a global data base with data on the ecological condition of the streams crossing the 186 million hectares of FSC-certified forests world-wide. This would allow forest managers and the scientific community to improve their understanding of the effects of forest management practices on the conservation of stream habitats.

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Data accessibility

The data set and the R code required for reproducing the analysis presented in this paper are available at: Dryad entry: doi:10.5061/dryad.ps6k0 (Dias *et al.* 2014).

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Stream Visual Assesment Protcol (SVAP) Elements with their narrative descriptions and scoring matrix.

Appendix S2. Tables with model results.