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RESTORING STREAM CHANNEL COMPLEXITY WITH LARGE WOOD. EFFECTS ON ECOSYSTEM STRUCTURE AND FUNCTIONING

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ABSTRACT

Aiako Harria is a 7000 ha Natural Park and Natura 2000 site located in the eastern tip of Guipuscoa (Basque Country, Spain), in a very rainy (> 2000 mm/y) and rugged area. The park includes the Añarbe reservoir, the most important drinking water supply in Guipuscoa. Streams draining to the reservoir have excellent water quality and are habitat of threatened species like European mink and Pyrenean desman. Nevertheless, large inputs of leaf litter and sediments into the reservoir create some concern, and show that stream channels, historically devoid of large wood, have reduced retention capacity and perhaps poor habitat quality. Thus, a LIFE-Nature project was designed to increase in-channel retention, reduce litter inputs, and enhance stream habitat complexity. Following a BACI design, large wood has been added to reach natural abundance (40-80 m^3/ha) in 4 stream reaches ranging in width from 3 to 15 m, which are compared to 4 upstream controls. The hypotheses are that large wood will result in: a) higher in-channel retention of dissolved nutrients and particulate organic matter, that will lead to enhanced metabolism, more detritivores, and more efficient use of inputs; and b) higher channel complexity, that will lead to enhanced diversity and resistance of aquatic communities. All reaches, control and experimental, have been monitored for one year prior to wood addition, and are being followed for two years after. Variables measured include channel form, sediment storage, hydraulic retention, retention of dissolved nutrients and particulate organic matter, decomposition of leaf litter, whole-stream metabolism, periphyton, invertebrate abundance and diversity, fish abundance and size structure, and presence of the Pyrenean desman. Results so far obtained point to a key role of large wood on stream ecosystem structure and functioning. Therefore, actions should be taken to restore the natural abundance of large wood in stream channels, at least where this will not increase flood hazard or damage properties.

Key words: Channel complexity, large wood, restoration, biodiversity, sediment retention

1. INTRODUCTION

Stream and river ecosystems across the world are subject to many impacts, like pollution, regulation, water abstraction and changes in channel form (Allan, 1995). Human activities in stream channels include snagging, canalization, gravel mining, and bank reinforcement, which can all have profound impacts on channel form. As a result, many streams have been transformed from dynamically active and spatially complex ecosystems to more static and homogenous systems. Heavy channel modifications, like conversion to concrete canals, have obviously detrimental effects on stream ecosystem biodiversity and functioning (FISRWG, 1998). Less is known on the effects of more subtle activities, like snagging. Nevertheless, as these practices have been widespread for centuries, at least in Europe, their cumulated impact could be relevant, and the environmental benefits of restoration efforts significant (Gregory *et al.*, 2003). Here we report the preliminary results of a restoration project where logs were reintroduced into mountain streams to increase instream retention of sediments and nutrients, and to enhance habitat diversity.

2. STUDY AREA

Aiako Harria is a 7000 ha Natural Park and Natura 2000 site located in the eastern tip of Guipuscoa (Basque Country, Spain), in a very rainy (precipitation > 2000 mm/y) and rugged area over granites and schists. Extensive oak and beech deciduous forests and conifer plantations cover most of the catchment, where management goals are switching from timber production to conservation. The park includes the Añarbe reservoir, the most important drinking water supply in Guipuscoa, with a capacity to store up to 44 hm^3 of water. Streams draining to the reservoir have excellent water quality and are the habitat of threatened species like the European mink and the Pyrenean desman. Nevertheless, there is some concern, due to the large inputs of leaf litter and sediments into the reservoir, their total volume being estimated at 123,000 m^3/y, and to the decline of the populations of endangered species. Such large inputs suggest that stream channels, historically devoid of large wood, have today a reduced retention capacity, and this could be associated to a decrease in habitat quality. Thus, a project was designed to increase in-channel retention, reduce litter and sediment inputs, and enhance stream habitat complexity.

3. PROJECT DESIGN

The Life-Nature project NAT/E/000067 included many actions to improve the conservation status of species and habitats in the Aiako Harria Natural Park. One of the main work packages focused on increasing the amount of dead wood in stream channels to enhance habitat diversity and in-channel retention, thus reducing sediment and nutrient inputs into the reservoir. It was a pilot project of limited extent, not designed to solve the reservoir problem by itself, but rather to test whether restoring channel complexity might benefit both the reservoir and the streams.

Therefore, it was decided to restore the load of dead wood in 4 streams of contrasting size (Tab. 1). As it is usual in Europe, there were no clear ideas of the natural amount of wood to be found in "reference" conditions, and consequently, of the amount of wood that should be introduced to each stream. The highest amount of large wood (LW) found in the catchment, about 330 m^3/ha streambed, occurred in the first-order Olin stream, and thus it was not directly applicable to larger stream orders. Therefore, a relationship between channel width and wood loading for New Zealand mountain streams under beech forest (Bailey *et al.*, 2008) was used as a rough guideline for the amount of wood to be expected in larger streams, and thus, to the amount to be restored (Tab. 1). Because it was thought that passive restoration methods should be used whenever possible, it was decided to introduce large wood mimicking the kinds of structure usually found in nearby streams, instead of specifically designing each structure to optimize sediment retention, stability or whatever (Fig. 1). Similarly, the added logs were not cabled or fixed in any way, as there was not risk of damaging any structure or property located downstream.

Table 1 - Characteristics of studied streams and amount of wood added to experimental reaches.

	Atseginsoro	Malbazar	Latxe	Añarbe
Channel width (m)	3	4	5	15
Reach length (m)	100	100	100	400
# logs added	81	74	53	72
LWD added (m^3/ha)	216	239	144	33

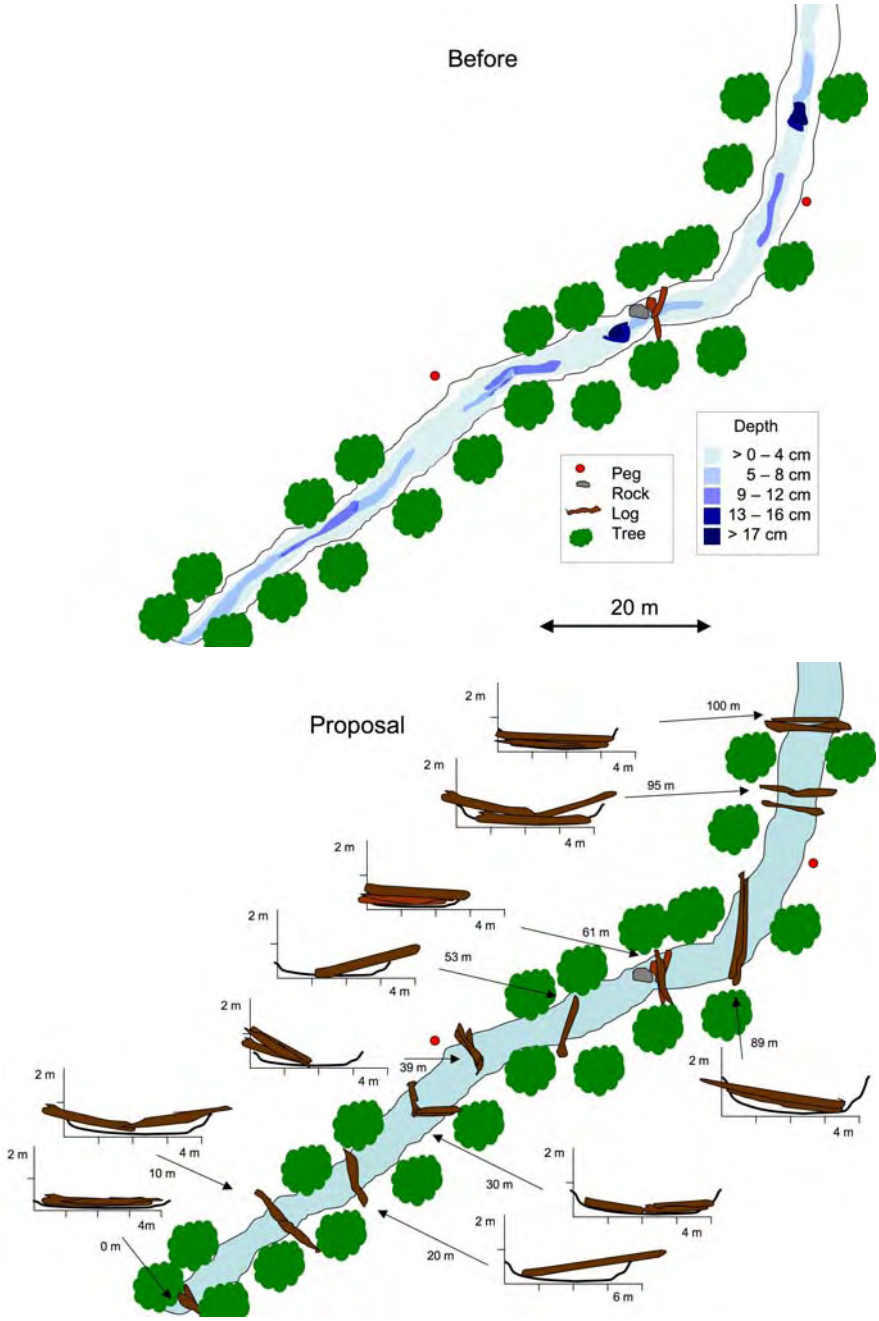

Figure 1 – An example of the project design. Characteristics of Latxe stream prior to restoration (top) and proposed structures (bottom).

The hypotheses are that addition of large wood will result in: a) higher in-channel retention of dissolved nutrients and particulate organic matter, that will in turn lead to more detritivore organims, more fish, and more efficient use of inputs; and b) higher channel complexity, that will lead to enhanced diversity and resistance of the aquatic communities.

4. METHODS

The experiment followed a BACI design, with 4 reaches ranging in width from 3 to 15 m to be restored, and one control reach upstream from each restoration reach. Reaches were 100 m long at the three smallest streams, 400 m long at the largest one. All reaches, control and experimental, were monitored for one year prior to wood addition, and are presently being monitored; monitoring will continue for a total of two years after wood addition.

Channel complexity was restored on January 2008 by adding large wood. Because the area is protected and streams are remote, local wood, collected from the forest floor, or cut from trees far away from the channels, was added by means of hand-held motor winches. The restoration works took three weeks to complete by a crew of 5 people, at a cost of about 96000 €.

The effects of wood addition on stream ecosystem structure and functioning are being assessed with the following methods. Channel form, type and storage of sediment is measured each summer from fixed transects with the help of topographic material (Díez *et al*., 2001). Storage of organic matter is measured each summer and late autumn by gravimetry from Surber samples taken at random at all reaches. Hydraulic retention, and retention of ammonia and phosphate are measured periodically from constant rate or slug (in the large stream) additions of a solution containing common salt, ammonium chloride and potassium phosphate (Stream Solute Workshop, 1990). Retention of leaf litter is measured periodically by releasing *Ginkgo biloba* leaves and measuring the distance travelled in one hour and the retaining structure (Elosegi, 2005). Breakdown of alder (*Alnus glutinosa*) leaf litter is measured in autumn by the mesh bag technique (Bärlocher, 2005). Periphyton is sampled periodically taking 10 cobbles at random per reach, abundance is measured gravimetrically, and chlorophyll *a* content spectrophotometrically (Izagirre and Elosegi, 2005). Surber samples are taken at random in the dominant habitats in summer and late autumn to sample macroinvertebrate communities. Fish communities are also sampled in summer and late autumn by electrofishing, and presence of Pyrenean desman is being checked in late summer with net traps.

5. PRELIMINARY RESULTS AND DISCUSSION

Less than a year has passed after the restoration works took place, therefore our results are still preliminary. Nevertheless, they point to an

important role of large wood on stream ecosystem structure and functioning, and to a very fast recovery of key ecosystem characteristics after wood addition.

The spring of 2008 was extremely rainy in the Basque Country, with continuous spates from March to May. Nevertheless, most wood structures remained in place in the small streams, whereas in Añarbe, logs were rearranged in more spaced, larger structures. In any case, no logs were lost from the experimental reaches. This suggests that restoring large amounts of dead wood in small stream channels is relatively safe. For larger streams, as is the case of Añarbe, it is essential to identify safe places where the risk of damaging properties or lives is minimal.

As regards the physical habitat, streams responded to wood addition by agrading the channel and storing fine sediments. In this sense, the trajectory followed by experimental reaches is almost the contrary to that described by Díez *et al*. (2000) in an experimental wood removal. Stream response was extremely fast. For example, the uppermost dam of Latxe stream collected over 15 m^3 of leaf litter in the first week, and extensive sand bars (a substrate that was almost absent prior to restoration) formed at all reaches by late spring (Tab. 2). Also, leaf litter became much more abundant after wood addition. Litter packs were fairly abundant in stream channels in autumn-winter, but tended to decay or be scoured downstream, and thus, in summertime their presence was tightly associated to large wood. Similarly, salt addition experiments showed a significant decrease in mean water velocity (Fig. 2), and a faster retention of leaves at the restored reaches (Fig. 3).

Table 2 - Percent of streambed covered by substrate categories at experimental reaches before wood addition and six months after wood addition. Both surveys were carried out in summer.

	Atseginsoro		Malbazar		Latxe		Añarbe	
	Before	After	Before	After	Before	After	Before	After
Silt	0.4	6.5	0.0	1.4	2.1	1.2	0.4	0.0
Sand	0.4	2.5	1.9	4.3	0.4	0.8	3.9	5.0
Gravel	52.7	60.0	49.6	39.7	16.6	37.6	22.9	40.4
Cobbles	37.5	18.9	28.7	11.7	59.2	26.0	44.5	30.1
Boulders	3.0	1.2	5.6	3.9	13.6	14.0	10.9	4.0
Rocks	0.0	0.0	7.8	0.4	0.0	0.4	2.7	2.2
Bedrock	6.1	4.1	6.3	5.3	8.1	5.4	14.7	15.5
Roots	0.8	1.2	0.0	0.7	3.0	1.2	0.0	0.4
Wood	0.0	3.3	0.0	13.5	0.4	3.5	0.6	0.8
Litter	0.0	2.5	0.0	19.2	0.0	10.1	0.0	1.4

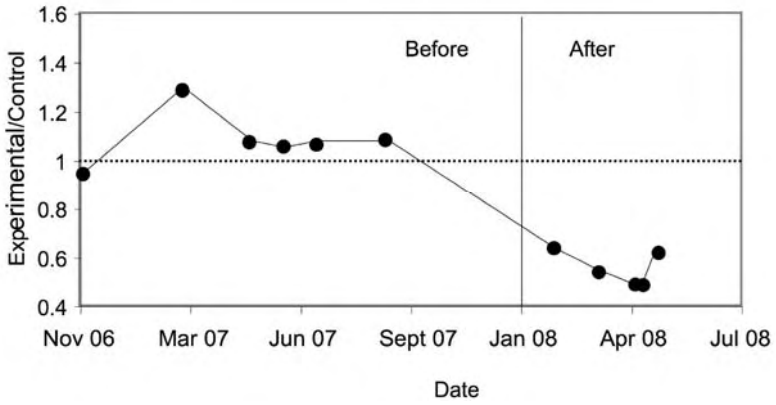

Figure 2 –Effects of restoration on mean water velocity as measured from salt additions. The ratio of water velocity between the experimental and control reaches is shown. Points above the dotted line show water which is faster at the experimental than at the control reach.

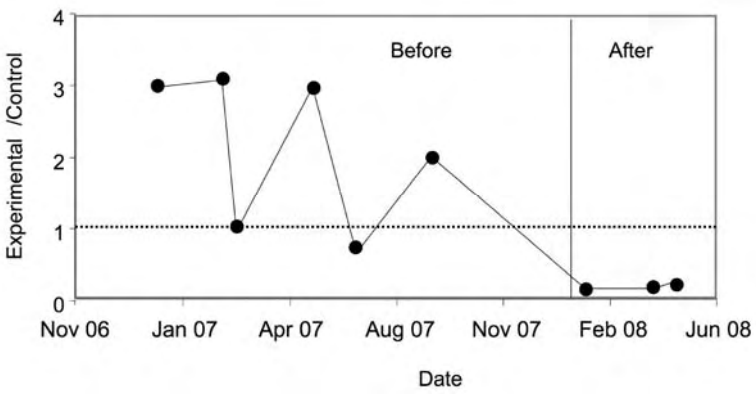

Figure 3 – Effects of restoration into average distance travelled by *Ginkgo biloba* leaves before being retained in the channel. The ratio of distance between the experimental and control reaches is shown. Points above the dotted line show that leaves are less-readily retained at the experimental than at the control reach.

The time spent after restoration is still too short to expect great changes in communities (Darby and Sear, 2008), and indeed, most of the samples are still being processed. In the case of fish, restoration works were carried out after trout spawning, and thus, could have been detrimental to egg survival. Only two fish species occurred in the study area: brown trout (*Salmo trutta*) and common minnow (*Phoxinus phoxinus*). All reaches were dominated by smolt, thus suggesting a poor habitat for adults, probably due to lack of refugia. A general increase in fish densities was detected from summer 2007 (before restoration) to summer 2008 (after, Tab. 3), but it occurred similarly

in control and experimental reaches, and thus, showed no clear effect of wood addition. Nevertheless, it is expected that the effect of wood will be more evident after the first post-project spawning season.

Table 3 - Fish captured (#/m^2) in the study reaches in summer 2007 (before) and summer 2008 (after).

		Atseginsoro		Malbazar		Latxe		Añarbe	
Reach	Species	Before	After	Before	After	Before	After	Before	After
Control	Trout	0.30	0.39	0.15	0.18	0.31	0.56	0.009	0.027
	Minnow	0	0	0	0	0.02	0	0.005	0.006
Experimental	Trout	0.68	0.69	0.42	0.59	0.45	0.74	0.007	0.030
	Minnow	0	0	0.04	0.07	0.05	0.18	0.030	0.030

One of the most dramatic effects produced so far by the project, is a generalised change in attitude towards large wood in stream channels. Initially, most managers in the area, from local authorities to people in the water agencies, saw large wood as a nuisance, as is often the case in most of Europe (Piégay *et al.*, 2005). It took a long time to convince some of them that introducing wood in a safe setting could be an interesting scientific experiment. Nowadays most of them think the project was a good idea, and like the "wild" look of the restored areas.

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