The natural variability approach. Application to five rivers in the Ebro basin, Spain

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ABSTRACT: We use a method described by Richter et al. (1997), where the principal objective is to compare streamflows in two defined time periods, in pre-regulation and post-regulations conditions, in order to subsequently measure the degree of alteration of the streamflow regime. The method identifies the components of a natural flow regime, in terms of magnitude (both high and low flows), timing (indexed by monthly statistics), frequency (number of events) and duration (indexed by moving average minima and maxima). Each index is calculated on an annual basis for each year in the hydrological record, thus concentrating on inter-annual variability in the indices. An acceptable range of variation of the indices is then set, in this approach using + or – 1 standard deviation from the mean. The study considers data corresponding to five sites (rivers Gállego, Aragón, Jalón, Segre and Guadalope) in the Ebro basin, one of the major rivers in Spain. The results show that some parameters fluctuate outside the targeted range. The analysis takes into account the magnitude of the alterations and their frequency. The gravity of the alterations is classified in four categories: slight, moderate, medium and severe, and the analysis considers how many parameters in the post-regulation regime are outside the natural range in more than 50% of years. When the impact is extreme the alteration is classified as unacceptable, either because of the magnitude of the events (value of hydrological indices too far from natural range of variability) or the frequency of cases. Our observations show that the Gallego and the Aragón are the rivers with the highest number of indices outside the range. The Gallego is also the river that is most often classified as unacceptable due to the gravity of its alteration. In contrast, the Jalón is the river with the least modified regime with the fewest and least frequently altered parameters.

1 INTRODUCTION

Streamflow quantity and timing are critical components for water supply and ecological integrity of river systems. The structure and persistence of native biotic communities within river ecosystem is strongly influenced by temporary variation in streamflow (Poff et *al*, 1997). Environmental regimes influence the composition and structure of aquatic communities, with strong effects on movements of organisms between habitats and shaping environmental conditions and the distribution of habitat. Their variation should be maintained in order to protect native biodiversity and the evolutionary potential of aquatic, riparian and wetland ecosystem (Lytle and Poff, 2004). Components of a natural flow regime can be characterised using various time series of daily discharge, and then a statistic analysis we obtain calculated hydrologic parameters from these data.

2 METHODOLOGY

We use a method described by Richter et al. (1996) where the main objective is to compare streamflows in two defined time periods, in pre-regulations conditions, in order to subsequently measure alteration degree of the streamflow regime. The method identifies the components of a natural flow regime, in terms of magnitude (both high and low flows), timing (indexed by monthly statistics), frequency (number of events) and duration (indexed by moving minimum and maximum average) Each index is calculated on an annual basis for each year in the hydrological record, thus concentrated on inter-annual variability in the indexes. An acceptable range of indexes variation is then set, in this approach using more or less a standard deviation from the mean.

The study considers data corresponding to five places (rivers Gallego, Aragón, Jalón, Segre and Guadalupe) in the Ebro basin (Northeast of Spain), one of the mayor rivers in Spain.

The analysis was carried out with the data of daily values of five water gauge stations (CEDEX, 2002) that are under regulation structures which affect the natural regime of these rivers. We have tried to choose rivers with a certain hydrological variability (table 1) There are three rivers of the left margin, pirenaicos mountain rivers and the other two of the right margin, one of them Jalón river with its head in an area of mesozoic limestones that constitutes an excellent aquiferous.

So that the data were comparable and the rank of variation among the years had an equal interval, daily data of 20 years were taken in all the rivers before the intervention and 20 years after the intervention.
Following Richter et *al* (1997) methodology. It was calculated 32 hydrologic parameters that served to characterise the natural regime of flow, and 32 parameters after the intervention once the regime has been modified. In order to determine the rank of natural variability, the average and their standard deviation of each parameter obtained in the 20 previous years to the intervention, we decided that the rank of natural variation will be included between the values that turn out, to add and to reduce to the average the standard deviation.

3 RESULTS

In the first result has been verified that human perturbation appears in the regime in all the rivers. Besides of this we wanted to verify the state of the gravity of the alterations and for it we have made a classification, this classification groups the alterations being based on the difference with respect to the limits of the interval of natural variation.
The results show that some parameters fluctuate out of the targeted range. The gravity of the alterations is classified in four categories: slight, moderate, medium and severe, and the analysis considers how many parameters in the post-regulation regime are out of the natural range in more than 50% of the years. When the impact is extreme the alteration is classified as unacceptable, either because of the magnitude of the events (value of hydrological indexes too far from natural range of variability) or the frequency of cases.
We found that the frequency and the value of the alterations depended much on the river stretch and the type of use of the hydraulic infrastructure. The five analysed rivers present different alterations, the three mountain rivers Gallego, Aragón and Segre have hydroelectric power plant in the affected reach. Those plants manage the regulation and conditions of the hydrologic regime, in the reaches of both rivers of the right margin there are no hydroelectric power stations and the water of their dams is used for irrigations and regulation.
One of analyses was about verifying if the average values of each hydrologic parameter were within the rank of natural variation or out of it in the period in which the river is regulated. With it, we were able to know how many parameters in each river are undergoing a considerable deviation of their natural flow. The following analysis consists of studying the frequency of alterations.
In the following table it is exposed. In the first column is the number of parameters in each river in which the obtained average values in the 20-year post regulation leave out the interval of natural variation. In the following column we found how many studied parameters of the 32 leave out the NRV (Natural Range of Variability) in more than 50% of the years.

Table 1. Rivers with the water gauge number station and the dam that regulates them. Results of the number of parameters that in post regulation regime their average leaves out the NRV and results of parameters that their value is out the natural rank more than half of the studied years.

RIVER	Number of parameters that in post regulation regime its average leaves outside the NRV	Number of parameters that its value is outside the natural rank more than half of the studied years
Guadalope (15) Santolea	3	17
Gállego (12) Bubal	18	25
Segre (104) Oliana	6	19
Aragón (101) Yesa	8	26
Jalón (9) La Tranquera	3	6

When we analysed the gravity of the interventions, measuring them within the four categories described previously, according to the magnitude of alteration. What matters is distance, the value that takes the parameters in relation to the reference intervals. The results are those of the following table.

Table 2. Classification of alteration produced in the studied regimes, every year is classified in a category according to the percentage of parameters that are out the NRV. A regime in a year is considered unacceptable in which more than 68% of the parameters leave out that rank, or some parameter has reached values very far from the interval of natural variation

Río	Slight	Moderate	Medium	Severe
Guadalope (15) Santolea	0	2	14	3
Gállego (12) Bubal	0	3	5	3
Segre (104) Oliana	0	4	15	0
Aragón (101) Yesa	0	3	14	3
Jalón (9) La Tranquera	0	8	12	0

Río	Unacceptable, because of the frecuency	Unacceptable because of the magnitude
Guadalope (15) Santolea	1	17 times
Gállego (12) Bubal	9	109 times
Segre (104) Oliana	1	21 times
Aragón (101) Yesa	0	15 times
Jalón (9) La Tranquera	0	5 times

The regulation imposed by the electrical production causes a very severe disturbance in the regime of the pirenaicos rivers, this alteration can lead to multiple damages to riverine and riparian processes and communities (Baron et al, 2002)

The regulation imposed in the other two studied stretches is less severe since it is not produced by the electrical demand. Although, we also found some years and some indexes with a deviation that gets to be unacceptable.

The use of the water from rivers for human activities produces alterations in these ecosystems that in many cases are not recognized and have not been evaluated in their true value. There is growing recognition that functionally intact and biologically complex aquatic ecosystems provide many economical valuable services and long-term benefits to society (Yount and Niemi, 1990).

The natural range of streamflow variation is critical for maintaining the integrity and dynamic potential of aquatic ecosystem. Therefore, a work like this one seems very useful for a good administration of the river basins and the water that allows to maintain the ecological communities and biological processes that characterize the riverine ecosystem.

Once characterized the natural regime and the effects on means of the altered regime, restoration measures can be established suitably handling a new regimen tax from the interventions that modify it, something that already has been made successfully in some rivers of the world (Rood et al, 2003).

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